PN-ABQ-834

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مصدر التمويل : الوكالة الامريكية للتنمية الدولية

SULLAGE DISPOSAL IN
RURAL EGYPTIAN VILLAGES
REPORT NUMBER 1

COPY
M. Kaplan

USAID CONTRACT NO. : 263-0182-C-00-6041-00
PROJECT NO. : 263-0182-3-60054

Prepared By:
Environmental Engineering Section

January 1989
ENV-R-1(E)

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٨ شارع الفواكه / مهندسين ، القاهرة / تليفون : ٣٤٨٢٢٤٧ ، ٣٦٠٢٥٤٥ / فاكس : ٧١٨٩٨٦ / تلكس : ٩٣٠٣٧
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Chapter 1

INTRODUCTION

In the past whenever wastewater projects have been considered for rural Egyptian villages the emphasis has been on the more developed villages, where only conventional waterborne sewage followed ultimately by treatment has been contemplated. In many cases in rural Egypt this may be the only solution as many of the villages relate more to small towns. Irrespective of whether this may or may not be the ideal solution, it is the most favorable because it introduces a method of waste disposal akin to that used in the larger towns and cities. Since this type of project is most socially acceptable it is only too easy for it to be viewed as a panacea for all rural wastewater problems by both the indigenous population and local government. It is, therefore, necessary to ensure that alternative solutions are sought for villages of different sizes and economic standing in order that inappropriate systems are not installed which may be more expensive with regard to both capital and operational expenditure. One such solution could be the use of separate sullage and septage disposal systems.

When ever wastewater is discussed it is immediately assumed that foul sewage is being considered. However domestic wastewater has two separate components, namely septage which consists of body wastes and sullage which consists of all other household wastes which do not contain faeces or urine.

The purpose of this report is first of all to give an overview of sanitation in the developing countries and then to look at the particular problem of sullage in rural Egypt and to try and discern whether using a separate sullage and septage disposal system could be a viable option in a rural sanitation project; if this option is affirmative then the immediate and long term course of action will also be discussed.

Chapter 2

BACKGROUND

A convenient supply of safe water and the sanitary disposal of human wastes are essential ingredients for a healthy and productive life. Water that is not safe for human consumption together with inadequate and poor sanitation can spread disease causing an inordinate amount of suffering and debilitation. Such considerations led to the United Nations International Water Sanitation Decade from 1980 to 1990, the aim of which is to provide adequate water supply and sanitation for all people.

However, to date the emphasis has largely focused on "clean water"which can have serious ramifications. Foul water can be the source of great human suffering and misery as inadequate facilities for sewage disposal reduce the potential benefits of a safe water supply by transmitting pathogens from a diseased to a healthy person. Kalbermatten et al (1982). have indicated that under such conditions some fifty diseases can be transferred from a diseased person to a healthy one by various direct or indirect routes. Coupled with malnutrition these excreta related diseases account for a large proportion of deaths in the developing countries, with young children being particularly susceptible. It is invariably the poor who suffer through inadequate sanitation because they lack not only the means to provide for such facilities but also the information on how to minimize the ill effects of the unsanitary conditions in which they live. As a result the debilitating effects of endemic disease lower the productive potential of the very people who can least afford such loss of productivity.

2.1 Sanitation in the Developing Countries

Supplying good clean water to people in developing countries is always well received by the community and is politically very acceptable. In addition it is usually less costly to install and maintain when compared with the associated necessary sanitation. However, without the provision of basic sanitation coupled with a good personal environmental health program the benefits of a safe water supply can never be fully enjoyed. That is to say, large capital investments will have been made with very little general health improvement. The cost of sanitation is undoubtedly of prime importance with conventional methods, as used in developed countries, such as waterborne sewerage and treatment proving beyond the reach of the majority of communities in developing countries. Therefore, there is a continuing requirement for low cost solutions to sanitation problems in the less developed areas of the world. Aside from the cost, conventional solutions demand high per capita water usage which very often cannot be met by supply. For example, data collected by the World Health Organization (WHO) in

preparation for the United Nations Water Conference in 1977 indicated that only one third of the population in the developing countries have adequate sanitation services and Rybczynski et al (1978) have indicated that less than two per cent of the population of these countries is connected to conventional sewerage systems.

Yet the demand for better sanitation is now greater than ever. In the past few years there has been a great emphasis on research into alternative appropriate low-cost technology for improving sanitation in developing countries. Many on-site options have been proffered, such as pit-latrines, septic tanks, aqua privies and composting privies. In addition, off-site solutions have also been sought, such as vault and vacuum truck, bucket latrines and small-bore sewerage together with relevant treatment methods and their derived benefits such as effluent reuse, aquaculture or pisciculture. There is no paucity of information on these topics in the literature and almost all aspects of good sanitation programs have been covered in detail including feasibility studies, financial planning, final design and construction.

2.2 Sanitation in Rural Egypt

The policy with regard to water and sanitation in rural Egypt has followed a similar pattern to that described in section 2.1. The early emphasis was correctly placed on supplying safe potable water and this is still an ongoing goal of both the government of Egypt and the major funding agencies.

However, as with other areas of the developing world the need for good sanitation has also been recognized and projects have recently been undertaken to either study or to implement appropriate wastewater technologies for the rural areas. Some have been innovative whilst others are the more tried and tested technologies described previously. The majority of these projects are in a preliminary stage and it will be some considerable time before a rational evaluation can be undertaken.

2.2.1 Sanitation in an Egyptian Village

Egyptian villages are not as one might think of small rural communities in most developing countries. Indeed a large proportion are more akin to small densely populated towns of between twenty and forty thousand people. In general the sanitary conditions are very poor with the subsequent health problems associated with such situations. Whilst, as previously mentioned, these general conditions and in particular wastewater disposal are slowly receiving attention consideration has not been given to one common source of wastewater in the villages that being sullage disposal. When communities use some form of latrine or vault system for disposal of body wastes there remains a large proportion of household waste which does not contain faeces or urine, this is collectively known as sullage.

Throughout Egyptian villages sullage is disposed of in the streets, invariably close to the home and in some cases immediately outside the front door of the house, or in an adjacent watercourse. The proximity of disposal to the home can be seasonal in that during the summer months the women are prepared to walk a few meters to dispose of their waste in an attempt to keep the street in front of the house dry. In the winter when the streets may be wet from precipitation then disposal tends to be at the front door. Such practises, irrespective of any potential health hazards, often lead to domestic feuds between neighbors resulting in a lack of harmony in the community.

The sullage very often contains animal remains in addition to the normal organic kitchen waste and so very quickly it becomes odorous and unsightly. In some cases large proportions of the street become saturated with sullage which means that everyone, including the predominately bare footed pre-school children, are forced to walk through the soil and sullage mixture. Any areas which allow ponding of this liquid only encourage children to use it as a play medium. In locations where the groundwater is high and already causing standing water then the sullage simply adds to the problem.

Chapter 3

CHARACTERISTICS OF SULLAGE

Sullage or greywater as it is sometimes called consists of all domestic wastewater with the exception of toilet wastes (known as septage) - the water discarded from baths, sinks, laundry and the kitchen which one would expect to have considerably fewer pathogenic microorganisms than conventional sewage.

In countries which predominately use conventional waterborne sewerage, sullage is simply discharged to the sewers and conveyed to the treatment plant with the septage. Only in very isolated rural areas did the disposal of sullage ever present any real concern and consequently very little attention was paid in the past to its disposal in these countries. This has remained the case until recent years when more activity has been noted in research regarding sullage disposal and reuse.

This has come about as a result of interest in the use of sewerless chemical toilets and separate sullage disposal as a way of overcoming environmental problems associated with the disposal of large volumes of heavily contaminated sewage from urban areas. There has also been interest in chemical toilets and on site sullage disposal for use in nature parks, where environmental considerations are paramount (Winneberger 1974). In contrast virtually no research has been carried out in this area in the developing countries.

3.1 Volume of Sullage

Sullage volumes depend upon domestic water use. This of course varies tremendously from the developed countries, where most of the data has been collected, to the developing countries where there is a paucity of information. However, some information has been collated by Feachem et al (1983) who compare it with that for developed countries and this is discussed below:

Where people use public taps, daily domestic water use may be as low as 10 litres per capita (White 1977). In affluent households with full plumbing, daily water use may be 200 or more litres per capita, and all water not used for flushing toilets may be classified as sullage. Bennet, Linstedt and Felton (1974), studying homes in the United States, found that the toilet was used 3.6 times daily per capita, that the average flush used 15 litres, and that toilet flushing accounted for 33 percent of domestic water use. Witt, Siegrist and Boyle (1974) also studying homes in the United States found corresponding figures of 2.3 times daily per capita, 15 litres for flush, and 22 percent of water use allocated to flushing. Reviewing data from several studies, Witt and his colleagues found that water from toilet flushing was between 22 and 45 percent of the total domestic water useage. Laak (1974) reviewed data from Canada, Sweeden and the United States that show the following percentage allocations of water use in houses with full plumbing:

Table 3.1
Percentage Allocation of Sullage Water in Developed Countries

	MEAN	RANGE
BATHROOM	26	12-40
KITCHEN	9	5-16
LAUNDRY	18	4-22
TOILET FLUSHING	47	41-65

Comparable figures are unavailable for urban households either with or without sewer connections in developing countries. However, in rural Egypt Gaber (1986) found that in sewered areas toilet flushing increased water consumption by 50 percent. Data is also available for rural households without sewers and examples of water use allocations in Lesotho, Papua New Guinea, and Uganda are given in table 3.2. These figures highlight the immense differences in water use practice and thus in the kind of sullage produced, in areas varying in culture, environment, wealth, and other factors. The health implications of sullage disposal will depend on the technologies used which in turn must consider such variables as the household volume of sullage, density of housing, local climate, soil type, and groundwater conditions.

TABLE 3.2
Allocation of Water Use in Sewerless Rural Households
in Developing Countries

Water Use	Country			
	Lesotho	Papua New Guinea (Enga Province)	Uganda	
			Lango	Kigezi
Average total daily use per capita (liters)	18	0.68	18	8
Bathroom (personal hygiene) (percent)	15	0	)	
Laundry (percent)	22	0	) 66	20
Drinking				
Animals (percent)	2	8	0	0
Humans (percent)	)	79a	19	6a
Kitchen (cooking and utensil hygiene) (percent)	)45	11	13	74
Vegetable gardens (percent)	6	0	0	0
Other (percent)	10	2	2	0

Sources: Lesotho (Feachem and others 1978); Papua New Guinea (Feachem 1977); Uganda (White, Bradley and White 1972)

a These are very small volumes of drinking water. In Papua New Guinea they may be due to low salt intake and consequent low low demand and to water intake from food, especially sugar cane. In Kigezi Uganda, the practice of eating gruels and other high liquid foods might account for the low drinking water consumption.

3.2 Composition of Sullage

With regard to sullage composition then the literature available is confined almost entirely to the developed countries. It is, however, worth considering some of these results as an initial insight of what can be expected from communities with high standards of sanitation.

The results of surveys of five households in the United States are shown in table 3.3 (from Laak 1974). The sullage contributed 53 percent of the sewage flow, 52 percent of the BOD_5, 43 percent of the chemical oxygen demand, about 15 percent of the nitrogen, and 45 percent of the phosphates. The data in table 3.3 further indicate that, if the ratio of chemical oxygen demand to BOD_5 is used as the criterion, toilet wastes are more resistant to biodegredation than sullage. Hypes (1974) points out the effect of sink-installed garbage units on the quality of sullage. In his test, sullage had a BOD_5 of 328 milligrams per litre when without garbage solids and 480 milligrams per litre when with garbage. Another report found that in Taipei, sullage contributed 40 percent of BOD_5 in sewage (World Health Organization 1970).

Witt, Siegrist and Boyle (1974) examined the bacterial content of sullage in the United States. Their results summarized in table 3.4, show that water used for bathing and showering became less contaminated with faecal bacteria than water used in washing clothes. Furthermore, 38 percent of the total faecal streptococcal isolates were enterococci (Streptococcus faecalis, S. faecium, and S.durans); the majority of the bath water enterococci were S.faecalis var. liquefaciens (in contrast, only a few enterococci isolated from the clothing waters were of this species, now widely regarded as being non faecal in origin). S. bovis, a primarily nonhuman species, accounted for 22 percent of all streptococcal isolates.

TABLE 3.3
Pollution Loads of Wastewater Sampled from Various Plumbing Fixtures in the USA (milligrams per capita day)

Wastewater source	Biochemical oxygen demand (BOD)		Chemical oxygen demand		NO_3-N		NH_3-N		PO_4	
	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent	Mean	Percent
Bathroom sink	1,860	4	3,250	2	2	3	9	0.3	386	3
Bathtub	6,180	13	9,080	8	12	16	43	1	30	0.3
Kitchen sink	9,200	19	18,800	16	8	10	74	2	173	2
Laundry machine	7,900	16	20,300	17	35	49	316	10	4790	40
Toilet	23,540	48	67,780	57	16	22	2782	87	6473	55
Total	48,670	100	119,410	100	73	100	3224	100a	11862	100

Source: Adapted from Laak (1974)
a.Total percentage rounded to 100

These findings suggest that under half of the streptococci isolated were from human feces, and that the bath water was even less contaminated relative to the clothing water than the total counts suggested. Hypes (1974) found that coliform counts in sullage were about 1.9 x 10^7 per 100 milliliters irrespective of garbage content. After 24 hours of storage, this count had increased to 5.4 x 10^8, indicating that sullage is a favourable medium for coliform growth.

Available information on the microbiological quality of sullage is very limited and neither of these two data sets (Hypes 1974 and Witt, Siegrist and Boyle 1974) may be representative. A more recent study in the USA reports lower bacterial counts in clothing wash water (215 total coliforms, 10^7 fecal coliforms and 77 fecal streptococci per 100 milliliters), and higher counts in bath water (1,810 total coliforms, 1,210 fecal coliforms and 326 fecal streptococci per 100 milliliters), than those given in table 3.4 (Small Scale Waste Management Project 1978).

Feachem et al (1983) conclude that although data are lacking, it may be assumed that sullage from bathrooms and laundries will contain small numbers of any pathogenic viruses, bacteria, protozoa, or helminth eggs being excreted by the people who use them. The washing of babies and their soiled clothing may substantially raise the pathogen content of sullage. It is also possible that some bacteria find warm sullage a suitable medium for multiplication. They further suggest that data on the microbiological quality of sullage from the tropics might verify this possibility, and its collection should be a priority of sanitation research.

TABLE 3.4
Bacterial Content of Sullage in the USA (per 100 milliliters)

Sullage source	Total coliforms		Fecal coliforms		Fecal Steptococci	
	Geometric Mean	Range	Geometric Mean	Range	Geometric Mean	Range
Bath and shower water	1,100	70-(8.2 x 10^3)	220	1-(2.5 x 10^3)	44	1-(7 x 10^4)
Clothing washwater	13,000	85-(8.9 x 10^5)	1,400	9-(1.6 x 10^4)	210	1-(1.3 x 10^6)
Clothing rinsewater	5,300	140-(1.5 x 10^6)	320	35-(7.1 x 10^3)	75	1-(2.3 x 10^6)

Source: Adapted from Witt, Siegrist and Boyle (1974)

3.3 Sullage Disposal and Health

There are five kinds of sullage disposal: casual disposal by tipping wastewater receptacles in the yard; garden watering; on-site disposal by soakaway; drainage into open drains; and drainage into covered drains or sewers. Feachem et al (1983) have indicated that each of these has different health implications:

(i) Tipping in the yard may create breeding sites for insects such as Culex pipiens as well as muddy and unsanitary conditions close to the dwellings. Because it does not offer concealment, a clean, dry yard is less likely to be used by children for defecation, and any worm eggs their feces might contain will be less likely to mature (nematode eggs require a moist environment to develop). Sullage containing pathogens from babies' bath water or adults' ablution water may also infect children playing in the yard. In well-draining soils, where sullage production or housing density is low, tipping of sullage outside the home is unlikely to be a major health hazard. Where soils are less permeable and where water use or housing density is high, however, an adequate method of sullage disposal is essential.

(ii) Sullage disposal by watering vegetable gardens near the house is likely to create few if any health hazards, provided that prolonged ponding of wastewater is prevented (to discourage mosquito breeding) and that children are discouraged from defacating in or near the gardens.

(iii) Sullage disposal by soakaway provides a low risk of groundwater contamination; the risk of microbiological groundwater pollution is much lower with sullage than it is with sewage. The same is true of high nitrate pollution (as indicated in table 3.3, sullage contains little nitrogen compared with sewage).

(iv) Drainage of wastewater into open drains, perhaps into storm drains, provides the most readily identifiable health risk, namely that of promoting the breeding of C. pipiens and other mosquitoes. In areas of year-round rainfall, storm drains will contain water continuously. If they are kept free of garbage and are well designed, the drains will flow freely and provide few sites for mosquito breeding, and the presence or absence of sullage will not affect community health. But in areas of seasonal rainfall, and where the drains are liable to blockage and ponding, the addition of sullage will create year-round standing water and thus year-round Culex breeding, but the continuous addition of sullage to storm drains subject to ponding that converts wet season breeding into year-round breeding. In this case the rise in Culex populations may lead to increased filariasis transmission and thus to more and heavier infections and so more disease.

An example of this effect can be found in the fairly recent resurgence of Bancroftian filariasis as a major public health problem in Egypt (Southgate 1979). Since approximately 1965 a complex of factors - including major changes in irrigation practice, a proliferation of

poorly maintained water supplies, and inadequate excreta disposal facilities contaminating surface water - has increased C. pipiens breeding in parts of the Nile Delta. Consequently, the prevalence, intensity, and geographic spread of Bancroftain filariasis have increased. It has also contributed to explosive epidemics of Rift Valley fever in Egypt during 1977 and 1978 (Hoogstraal, Meegan and Khalil 1979).

Similar health risks can occur when large-scale sullage disposal is into open drains with a tendency to blockage. Too often sullage makes its way to streams by natural gullies, and no formally defined drainage system exists. The solution to these problems is either to use an alternative method of sullage disposal or to prevent drains from blocking by covering them or by vigorous efforts to keep them clear. The latter approach is the more realistic and labor intensive and can be implemented by the employment of municipal workers, by subcontracting the job to the private sector, or by organizing and motivating community effort on a neighborhood basis.

(v) Finally, sullage may be disposed of into a sewerage system, as is sewage, except that smaller-bore pipes are used. This means of disposal raises no special health problems, and conventional treatment before discharge or reuse should be highly effective. The load of pathogenic microorganisms in sullage will be small, so that discharge or reuse can take place without tertiary treatment.

However, it must be noted that the above observations and comments are those of Feachem et al. (1983) and are not supplemented or supported by experimental or field data. In particular it is difficult to know what degree of pollution really exists, as in section (iii) when there are no data available on the microbiological quality of sullage.

Chapter 4

SULLAGE COLLECTION, CONVEYANCE, TREATMENT AND REUSE

It is evident that the financial constraints associated with the implementation of conventional waterborne sewerage together with large mechanical treatment plants are in the majority of cases prohibitive for developing countries. Furthermore there is a new awareness that the use of up to fifty percent of the households precious high quality drinking water to convey excreta along sewers is extravagant. Whilst it is recognized that many Egyptian villages, especially those of a more developed nature, do not resemble the typical villages of developing countries, there are many where conventional sewage disposal and treatment will be economically prohibitive for the foreseeable future. For these villages where environmental pollution is equally as much a problem as it is for those which can afford more conventional solutions, then alternative less expensive methods of solving their wastewater problem would seem to be a priority.

This need for more inexpensive treatment and disposal methods has in turn led to the development of new and existing dry and wet on site disposal systems as described in chapter one. The adoption of any one of these sanitation technologies, with the exception of septic tanks and sewerage networks, requires that separate facilities be considered for sullage disposal. It would, therefore, seem that the need for sullage disposal systems is paramount for any community not using toilets flushed with water. However, merely the disposal or collection of sullage will not eliminate the effects of pollution but will simply covey that pollution from one site to another. It is, therefore, necessary that some form of treatment be considered for sullage prior to its ultimate disposal; subsequently there would seem to be no reason why the effluent from a properly designed treatment plant, could not meet the required standards for reuse in irrigation. In the remainder of this chapter the four components of collection, conveyance, treatment and reuse will be considered.

4.1 Sullage Collection

In a large proportion of villages sullage may be collected from the various points within the house and stored in some container before being discharged or alternatively it is discharged in smaller volumes as it is produced. This more traditional pattern has been altered in some villages where a central, or several localized, collection tanks have been constructed. The women can then take their sullage to these points and discharge into the tanks as frequently as they wish. The tanks are emptied by truck on a daily basis and discharged to a local drain.

The idea of a collection tank is a great improvement over indiscriminate discharge onto the streets but it does only remove the pollution to another location. Either the tankers would have to discharge directly to a treatment plant or the collection points could be connected to some form of conveyance system which would ultimately be treated. A variation of the latter is discussed in section 4.2.2

4.2 Sullage Conveyance

In order to obviate any further health hazard from sullage collection and disposal it is necessary to consider only piped conveyance. However, the system must differ from conventional sewerage otherwise the capital costs will not be reduced.

4.2.1 Small Bore Sewerage

The use of small bore sewerage, designed to carry only settled effluent from domestic sewage has been used on a limited basis in some developing countries. The system has several advantages over conventional sewerage, inter alia, the pipes are of a much smaller diameter, they can be laid at shallower gradients and fewer manholes are required; all of these factors contribute to reducing the cost of the system.

In order to use such a system for sullage the large solids normally contained in the waste would have to be removed prior to discharge to the network. Indeed the settlement of solids prior to discharge would also be preferable. Kalbermatten et al (1982) have suggested that where sullage is discharged separately to small bore sewers that a sand and grease trap should be provided. They further suggest without citing specific examples that small bore sewerage systems would be ideal for areas where the on site disposal of sullage is no longer possible. Such situations certainly exist in Egypt where the ground is fully saturated or in lesser cases where the water table is inordinately high.

4.2.2 Piped Network

In a village in the governorate of Fayoum the people have decided to try and alleviate the pollution in their streets caused by sullage. In this instance the system is cognate to a conventional arrangement in that it consists of a main interceptor sewer, though in this case still of fairly small diameter (300mm).

Through a portion of the village a single pipeline has been laid in the middle of the street with manholes spaced at larger than normal intervals. Along the length of the pipeline short piped connections have been made at approximately 100m intervals. The upstream ends of these branches are connected to a "MEKAB", located at the edge of the street. This consists of an above surface structure

with a square or rectangular opening covered by a wire screen through which the women discharge their receptacles full of sullage. The system finally discharges to an irrigation drain. The screens are periodically removed and the screenings dumped at the side of the mekab, unfortunately this also constitutes a health hazard as the screenings are highly putrescible.

The system works well and although probably more expensive and less convenient, in that it is not connected to every household, than small bore sewerage it does not require settlement of the waste prior to discharge and the system does not suffer from blockages.

4.2.3 Small Diameter Plastic Hoses

In some cases the people of rural Egypt have been very innovative, probably due to necessity which has often been described as the "mother of invention". In one particular village in Damietta governorate the people have introduced a system of plastic hoses which have been laid above ground in order to form a reticulation system for the disposal of vault effluent.

Faced with increasing costs for vault evacuation and more importantly difficulty in obtaining regular service from evacuation trucks, the villagers have established their own system. Pumps are used to remove the effluent from the vaults after a period of settlement. The suction hoses of the pumps are put into the top layer of liquid in each vault and the pump then discharges the waste via the plastic hoses to an adjacent drain.

Once again the pollution has only been transferred and not eliminated however, it is the method of conveyance together with its development which is of interest not to mention the communities desire to remove the pollution from their streets. Perhaps some adaptation of this method could be utilized for the disposal of sullage to a treatment plant. Even if this were proved to be impractical for sullage disposal it does emphasize the fact that given a problem of this nature the people can react to find a solution provided that the motivation exists.

4.3 Sullage Treatment

Due to the paucity of information which exists with respect to the chemical characteristics of sullage it is difficult to state with any confidence the degree of pollution which it contains. Nevertheless the information which has been gathered indicates that, by its very nature, it tends to be high in organic content and consequently will exert a significant BOD on any receiving watercourse. Therefore, once the sullage has been collected and conveyed from the houses and streets it must be treated if any further pollution is to be avoided.

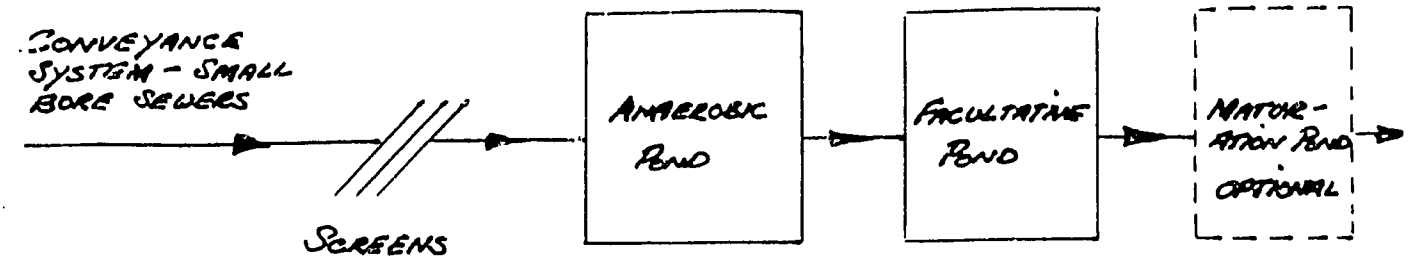
Kalbermatten et al (1982) have suggested that the domestic biochemical oxygen demand (BOD) contribution of sullage will be around 20 - 30 grams per capita per day. For high daily water consumption figures such as 100 litres per capita per day the BOD of the sullage will be in the range of 200 - 300 mg/l whereas in areas of low water consumption, say 20 litres per capita per day the BOD will be in the range of 1000 - 1500 mg/l. Although such figures seem inordinately high Gaber et al (1987) whilst carrying out field work in Egyptian villages in the Nile delta not only found the sullage to be in this range but in several cases found it to be higher. It can, therefore, be seen that a wide range of BOD values can be expected which will have a considerable impact on the type of treatment employed.

To date there is no record in the literature of sullage being treated separately in a wastewater treatment plant. The world bank have proffered alternatives which may be suitable for treatment (Kalbermatten et al 1982 and 1982+) such as stabilization ponds, aerated lagoons, evaporation beds, rapid infiltration and anaerobic filtration. Obviously other treatment methods could be considered eg. oxidation ditches, extended aeration and trickling filters to name but a few. However, these are all mechanical plants and whilst they will have their use in certain cases the emphasis in developing countries, such as Egypt, is to avoid such plants where alternative less expensive and easier to operate substitutes can be employed. We shall, therefore, consider some of these less sophisticated methods of treatment which may be suitable for sullage. Typical flow diagrams for these processes are given in figure 1.

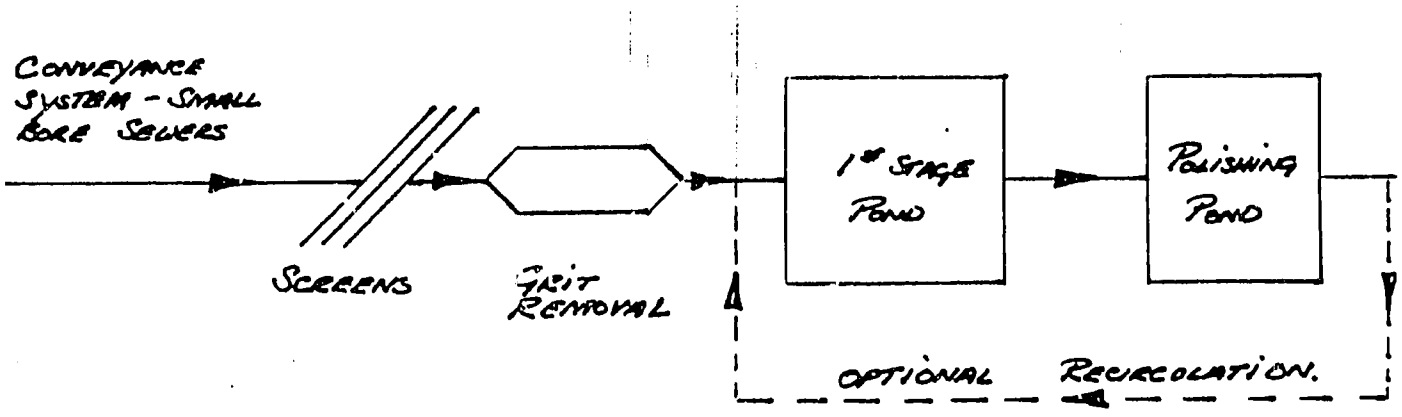
4.3.1 Waste Stabilization Ponds

There is no need to discuss, in this report, the theory of design as it is well documented in several reputable texts. If any one of the conveyance methods described in section 4.1 are adopted then screening of the sullage will already have taken place prior to the discharge of the sullage to the network. In this case the sullage can enter the stabilization ponds without preliminary treatment.

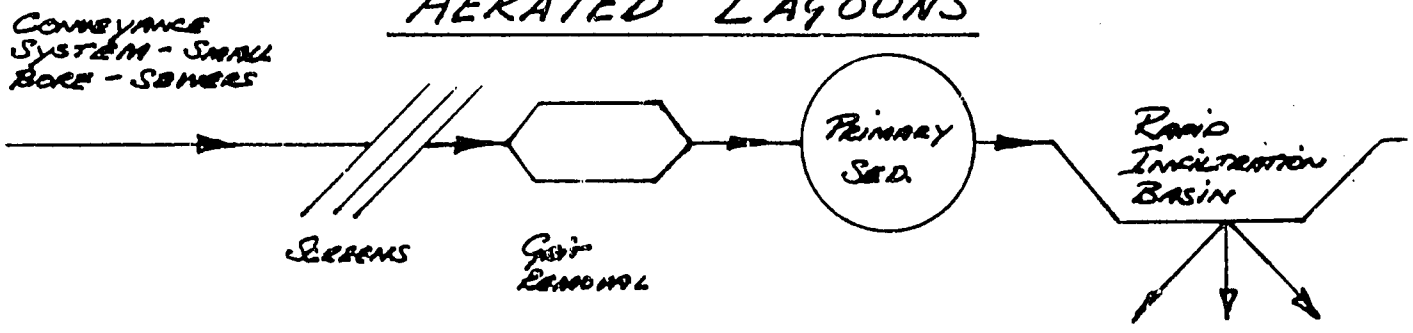
The use of first stage anaerobic ponds is recommended in the treatment of domestic sewage, as a significant proportion of the BOD can be removed in this stage. Consequently there is no reason why the same logic should not apply to the treatment of sullage, indeed in the instances where the BOD values are much higher than normal domestic waste the use of anaerobic ponds should be obligatory. These would be followed by conventional facultative ponds where the BOD would be further reduced. It has been suggested that the use of maturation ponds in sullage treatment would be redundant (Kalbermatten et al 1982) as the pathogenic concentration will be insignificant compared to that of conventional domestic sewage. Whilst this may be the case, there is some conjecture in this as figures are not available for sullage in developing countries.



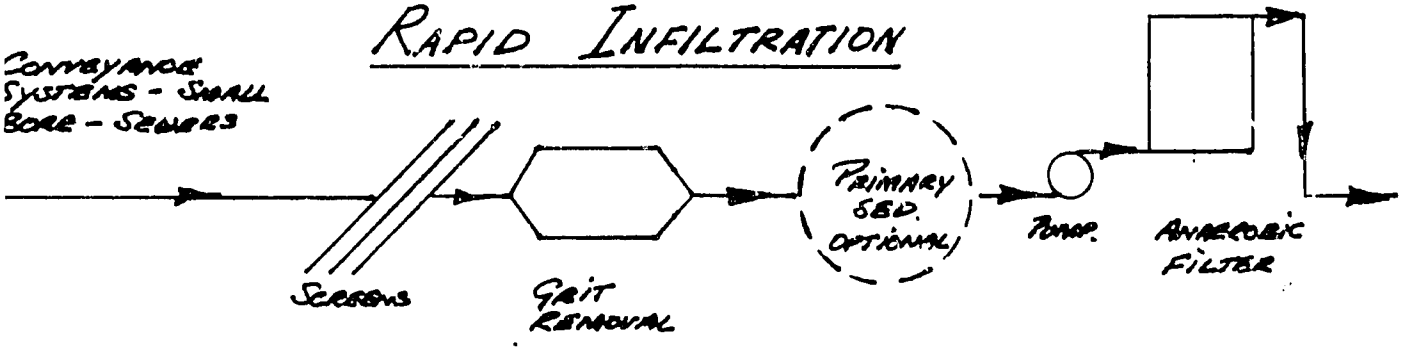
STABILIZATION PONDS



AERATED LAGOONS



RAPID INFILTRATION



ANAEROBIC FILTRATION

BEST AVAILABLE COPY

FIGURE 1

4.3.2 Aerated Lagoons

Once more there is little need to discuss the details of this type of treatment or provide any treatise of design methods as this is well documented in the literature. Aerated lagoons are more sophisticated than stabilization ponds but are still a good deal simpler and easier to operate than a fully fledged mechanical plant. They have the advantage of a reduced land usage but obviously greatly increased operating costs due to the power supply for aeration.

Aerated lagoons have successfully been used throughout the world for both domestic and industrial waste and so can adequately treat liquid waste of varying strengths, which of course would be the likely case of sullage in rural Egypt. The degree of treatment from such a plant would be higher than that obtained from stabilization ponds and if recirculation is employed the plant can be operated as a basic activated sludge unit.

4.3.3 Land Treatment

Land treatment of wastewater has been used for some years now and involves the use of the soil and vegetation for the purpose of treatment. A sound knowledge of the soil mechanics, geology and vegetation of the area together with details of the wastewater characteristics and the public health requirements are essential to the successful operation of such treatment systems. There are several types of land treatment such as irrigation, rapid infiltration, and overland flow. It is important to realize that when these are discussed as treatment methods they are principally for the application and treatment of effluent from some upstream process which has previously removed a significant proportion of the BOD. That is to say none of the treatment systems mentioned can accept raw wastewater.

The majority of recorded experience with land treatment systems as with the previous methods has been with domestic wastewater and nothing to date has been documented using sullage as the sole source of waste. Whilst it is difficult to predict if any of these treatment systems may be useful in rural Egypt for the treatment of sullage, without knowing the exact characteristics of the waste, it is fair to say that in the case of irrigation and overland flow even with a fairly weak waste a reasonable degree of treatment would be required prior to the land application. Indeed these two methods may well be more appropriately discussed under section 4.3 reuse of sullage.

With regard to rapid infiltration then this could be of some use in the governorates which border the desert but not for areas such as the delta with a high ground water table. In rapid infiltration raw waste has occasionally been used (i.e. domestic sewage) but in general at least primary treatment is required in order to reduce the suspended solids to prevent ground clogging. The waste is then fed to basins where it is literally allowed to infiltrate the soil. Treatment of the

waste and removal of the bacteria takes place within the upper layers of soil which should preferably be of a sandy nature, gravel layers with large pores are of no use as they allow the waste to pass too quickly. The purified waste eventually reaches the aquifer where it can be used to recharge the groundwater or it can be collected by a drainage system and pumped to the surface and used for irrigation. It would seem that this might be most usefully applied to sullage treatment when reuse of the effluent was also a consideration.

4.3.4 Anaerobic Filters

An anaerobic filter consists of a vertical column which is packed with a solid media used for the treatment of the organic matter in wastewater. The waste flows upwards through the media on which anaerobic bacteria grow and are retained. Due to the fact that the bacteria are not washed off in the effluent and are retained the organisims can achieve very long mean cell residence times (mcrt) in the order of 100 days. Large values of the mcrt can thus be achieved with relatively short hydraulic retention times.

Once again this process has not been used with sullage although one would envisage that with a low to medium strength sullage their would be no real difference over treating domestic sewage. However, the use of sullage with high BOD's would require further investigation. This type of treatment would obviously require pumps in order to transfer the waste upwards through the tower and consequently would involve operational costs similar to those associated with aerated lagoons. Nevertheless the land usage of such a system would obviously be greatly reduced

4.3.5 Summary

In all of the treatment processes described above a degree of speculation has been employed, due to the lack of information to hand, as to how each might cope with the treatment of sullage. In the case of weak sullage then the BOD will possibly not be a great deal different from that of domestic sewage and so providing the chemical characteristics are not too dissimilar then the treatment provided might well be satisfactory. Although it is difficult to predict the composition of the sullage as a whole it would not be presumptious to expect that the detergent content was fairly high in all strengths of the waste and this could cause certain problems with the treatment process.

In the majority of the rural villages in Egypt where the separate collection and treatment of sullage may be appropriate then it is highly likely that the per capita water consumption will be low resulting in sullage with a high BOD. Whilst it is important when attempting to treat waste of any nature for the first time, including weak sullage, to perform pilot testing it would seem to be even more prudent to do so for sullage with a high degree of pollution.

4.4 Sullage Reuse

The topic of reuse of wastewater is very much one which is to the fore in developing countries especially those with arid climates such as Egypt. Unlike its neighbours Egypt has the tremendous resource of the River Nile, which providing their is sufficient precipitation within its upper catchment area caters for a large percentage of the current needs with respect to domestic industrial and agricultural demands. However, this precious supply is dependent on not only the climatic conditions but international agreements with Egypts neighbours and should never be taken too much for granted. In addition Egypts population continues to rise at an alarming rate and so the water demand will also continue to rise in every sector. With this increase in population the government and the people of Egypt have come to realize that the reclamation of desert land is of the utmost importance and imperative to the economy of the country. Obviously such reclamation programs require water and consequently further demand is placed on supply, be it surface or groundwater. This demand could be met in part by the reuse of treated wastewater and in particular treated sullage.

Sullage could have several advantages with regard to reuse in that it may be more psychological acceptable when compared with sewage. It may also have considerably fewer pathogenic organisims than sewage and so be easier to treat to certain irrigation standards, perhaps even for use with edible crops such a root vegetables. This is an extensive subject and one which requires much work in research, testing and evaluating present standards for sewage effluent reuse as well as establishing new standards for sullage reuse.

Chapter 5

QUANTIFICATION

In section 4. many options have been proffered for collection treatment and the reuse of sullage. Whilst these are all viable solutions on paper nothing has yet been quantified. That is to say the real advantages of using a separate sullage and septage system have and indeed cannot be accurately quantified. In order to do this the raw data pertaining to the characteristics of sullage would have to collected and from that point pilot schemes would be developed to try and accurately quantify the advantages and disadvantages of the systems. Obviously this would take a great deal of time and effort and results would not be forthcoming in a short period.

Nevertheless it would be of some value at this point in time to try and establish any obvious advantages to such systems with a view to confirming the general hypothesis and to reinforce that further work on the topic would be fruitful to the environmental improvement in rural development. To do this some assumptions must be made and these shall be emphasized in the following short example:

5.1 Assumptions

If we assume a typical rural Egyptian village in the delta region which is not highly developed, i.e. there is still a paucity of multi storey buildings, at least fifty percent of the houses are of adobe construction and no more than fifty percent of the population is connected to a potable water supply, and try and estimate the volume of sullage from that village.

village population.....10,000
population per household.....5
number of households.....2000
water consumption.....50l/c/d
sullage BOD.....1000mg/l
total organic waste production.....55g BOD/c/d

Before proceeding with any calculations it is worth noting that the figures given above for the per capita water consumption and organic waste production are not based on conjecture but infact are taken from the results of Gaber et al (1986 & 1987) who obtained the data from rural Egyptian villages of the "developing category".

5.2 Conveyance and Treatment Quantities

From Feachem et al (1983) we find that the estimated BOD of faeces in rural areas of developing countries is 20.3g/capita/d which means that we can assume the BOD of the sullage to be approximately 35g/capita/d.

since the concentration (c) = mass (m) / volume (v)
then $v = m / c$

$$= \frac{35 \text{ gBOD/d (sullage)}}{1.0 \text{ g/l (BOD sullage)}}$$

= 35 l/d of sullage

therefore sullage produced / household = 35x5 = 175l/d
" " " / village = 175x2000 = $350m^3/d$

then the total organic loading = $350x10^3$l/d x 1.0g/l(BOD sull.)
= 350 Kg/d

5.3 Sizing of One Treatment Option

From these figures it is now possible to calculate the basic size of stabilization ponds required to treat the sullage.

Assume the configuration of the ponds to be Anaerobic followed by Facultative followed by Maturation.

Then for an organic loading rate of 0.25Kg BOD/m^3/d the volume of the anaerobic ponds = total BOD kg/d / organic loading
= 350 /0.25
= $1400 \ m^3$

check the detention time = 1400 /350
= 4 days - this is high so increase the organic loading to 0.35

then volume of the pond = 350 /0.35
= $1000 \ m^3$

check the detention time = 1000 /350
= 2.9 days - this is satisfactory

assume two ponds of $750m^3$ which allows for additional capacity should one pond be down then if we take the depth of each pond to be 4.0m the total mid depth area of the ponds
= 1500/4
= $375m^2$

assume 60 % BOD removal from the anaerobic ponds then organic loading passing to the facultative stage
= 0.4 x 350
= 140 Kg/d - this gives an influent

BOD using $350m^3$/d of = $140x10^6/350x10^3$
= 400mg/l

assume 70 % removal in the facultative ponds then the effluent BOD would be
= 0.3x400
= 120mg/l

however according to Mara (1976) in order to keep the facultative pond aerobic the effluent BOD must be kept in the range of 50-70 mg/l, therefore use 50mg/l

then using information from Mara (1976) the mid depth area of the ponds can be calculated from the formula given below

$$A = \frac{Q(L_i - L_e)}{18\ D\ (1.05)^{t-20}}$$

where L_i = influent BOD mg/l
L_e = effluent BOD mg/l
Q = influent flow m^3/d
D = depth of pond in m
t = mean temp of the coldest month degrees Celcius

then using a pond depth of 1.75m and a temperature of 20 degrees Celcius we have

$$A = \frac{350(400 - 50)}{18\ 1.75\ (1.05)^{20-20}}$$

$$= \underline{3890m^2}$$

check the surface loading rate (Y_s Kg/ha/d) from the following equation (Mara 1976):

$$Y_s = (10L_iQ)/A$$
$$= (10.400.350)/3890$$
$$= \underline{360\ kg/ha/d}$$

check the permissible surface loading from the following equation: Arthur (1983)

$$Y_s = 20t-60$$
$$= \underline{380\ kg/ha/d}$$

therefore, this is satisfactory as the actual organic surface loading is less than the permissible.

check the retention time of the pond $t = v/q$
$= (3890.1.75)/350$
$= \underline{20\ days}$ (approx)

The decision to use or not to use maturation ponds is very difficult. As previously mentioned Kalbermatten et al (1983) suggested that because of the likelihood that sullage will have a low pathogenic content then maturation ponds could be dispersed with. Since the level of pathogens has not yet been established beyond doubt then it would be prudent to provide some degree of maturation. In addition the effluent from the facultative ponds is predicted to have a BOD of at least 50mg/l (which would be a high reduction rate for this type of pond) and this should be reduced in value before discharge.

The determination of the influent bacterial concentration is very difficult as what little work has been done on this relates to sullage in the USA. Feachem et al (1983) presented data from the USA where the faecal coliform from sullage were of the order of magnitude of 10^4, whilst Kalbermatten et al (1980+) suggested that the order of magnitude might be 10^6. It would be expected that sullage from a rural Egyptian village would be higher in faecal content than that from an average house in the USA and so the former figure is probably low for this example. Since data is not available let us consider a figure somewhere between the two and say that the influent contains $2x10^5$/100ml.

Then using the equations given by Mara (1976) we can first of all calculate the rate reaction constant from the following:

$$K_b = 2.6(1.3)^{t-20}$$

$$= 2.6 \text{ at 20 degrees Celcius}$$

then the reduction in faecal coliform can be found from

$$N_e = \frac{N_i}{(1+K_b t_1)(1+K_b t_2)\ldots(1+K_b t_n)}$$

where N_i = number of faecal coliform /100ml of influent
N_e = number of faecal coliform /100ml of effluent

then try using one maturation pond with a retention time of 5 days

$$N_e = \frac{2x10^5}{(1+2.6.2)(1+2.6.20)(1+2.6.5)}$$

$$= \underline{45 \text{ FC/100ml}}$$

this is more than acceptable and would also serve the purpose of reducing the BOD of the effluent to give 96 % reduction which would give a value of 40mg/l.

The volume of the maturation pond would be = 5x350 = 1750 m^3 assume a deptn of 1.5m then mid depth area = 1750/1.5 = $\underline{1170m^2}$

Therefore the total mid depth area of the system = $5500m^2$
Approximate surface area of ponds = $7150m^2$

Approximate area required for system = $9000m^2$

= <u>2.1 Feddans</u>

5.4 Comparison with the Sewage Treatment Option

In the World Bank report (Arthur 1983) an example is given for a waste stabilization pond treating the domestic sewage for a population of 10000 people; the total land required is 5.1 feddans. The example differs from the above in that it has a lower per capita BOD contribution, 40 g/c/d, than is used in the above example for sewage as a whole, 55 g/c/d. The flow however is greater at 80 l/c/d.

If the necessary adjustments are made for the differences in flow and organic loading then it will be possible to estimate, on a pro rata basis, the size of ponds required for the same village to treat the entire volume of sewage stead of the sullage alone.

Then the total area required = $\frac{5.1 \times 50 \times 55}{80 \times 40}$

= 4.4 Feddans

therefore, difference in land requirements = 4.4 - 2.1 = 2.3Feddans

Land area saving = 52%

It can, therefore, be seen from the foregoing example which due to the lack of data available does include assumption and estimates, that the difference in land requirements between the same village treating sullage compared with that treating sewage is in the order of fifty percent. This would of course increase if the maturation pond could be eliminated. In recent experience in the delta area of Egypt stabilization ponds have been designed for smaller populations, however again if the figures are adjusted to accommodate the different flows and loadings the area required for treating sewage would be 3.75 feddans.

It must also be pointed out that this exercise was for the purpose of providing some quantification to the subject and that any economic consideration must not only take the above into account together with the possible savings on the collection system but more importantly must consider the cost of an improved septage collection and disposal system. Furthermore when comparing the two systems economically the operational as well as the capital costs must be considered.

Chapter 6

CONCLUSIONS

From the foregoing it is evident that in the past little attention has been paid to this topic, yet, what information exists indicates that sullage may be a formidable source of pollution. Consequently it has been suggested in the literature that there is an urgent need for research to be undertaken in various areas of sullage disposal. Rybczynski et al (1983) stated that although sullage could be disposed of by surface drains this could ultimately be done by underground pipes whilst maintaining a dry on-site system for excreta disposal. They further added that the now developing countries have an opportunity that was not available to the industrial countries in the mid-nineteenth century, that is, to choose a dual system; dry treatment of excreta and underground drainage of sullage, indicating that such a crucial decision could avoid many of the difficulties that only now are becoming evident in Europe and North America. Likewise, Kalbermatten et al (1982) stated that whilst most of the alternative low-cost technologies have been successfully applied at various sites there is a specific requirement for research into various areas, one of which is to determine the effects of sullage disposal and develop methods of sullage disposal for various population densities together with on and off-site sullage treatment methods. Finally Feachem et al (1983) suggested that there is an urgent need for information pertaining to the microbiology of sullage in developing countries.

At present there is a paucity of information and data available to the environmental engineer. This makes it impossible for a rational decision to be undertaken regarding first of all the necessity of such sullage disposal projects with respect to any health benefits for the community and secondly the engineering and financial benefits when compared to other solutions. From the design example given in chapter 5. it appeared that a considerable saving could be made with regard to treatment if only sullage is considered. Nevertheless to reiterate what was said previously, this is only part of the consideration and the entire scenario of using separate systems must be considered when analyzing the financial pros and cons.

It is, therefore, evident that before any conclusions can be reached with respect to the viability of using a separate sullage and excreta disposal system in rural Egyptian villages, much work is needed regarding the investigation of collection, treatment, disposal and reuse of sullage. Before such work can commence the raw data must be analyzed and it is towards this goal that initial efforts will be directed over the coming months in order to begin to determine the characteristics of sullage.

Following completion of this first stage of the work the second phase can be engaged which would be to consider in more detail the possibilities for conveyance of the sullage together with appropriate treatment methods. At this time the possibilities of effluent reuse must also be considered as this would have an effect on the standard of the treated effluent. An early start could be made on this second phase by utilizing the existing sullage collection system in Fayoum. It is not envisaged that the studies would be of a desktop nature but infact would be carried out in pilot situations where meaningful costs and results could be obtained.

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