THE DESIGN AND TESTING OF A SANITATION AND SEWAGE TREATMENT UNIT FOR DISASTERS AND LONG TERM USE

J. HOWARD, B. LLOYD AND D. WEBBER

(Abstract)

Following three years research and development work including microbiological studies a prototype sanitation unit designed and developed by Oxfam was tested during the months of November and December 1974 at the Cholera Research Laboratories (CRL), Dacca, Bangladesh. The annual autumn epidemic of cholera produced the highest number of cholera cases treated by the CRL hospital in their recent history, and the wards thus provided an extremely potent effluent for testing the efficiency of the prototype in destroying or removing various microbial pathogens, particularly V. cholerae.

The sanitation unit, which is assembled from the contents of a wooden crate measuring 2m x 2m x 1m and weighing approximately 500 kg, can be installed in a day to provide sanitation for 500 persons. Each unit at the time of writing costs £1,350 i.e. £2.60 per head with an estimated working life of 5-10 years. The unit consists of 20 glass fibre squatting plates connected in series to two 21,000 litres flexible reinforced butyl rubber sedimentation tanks which provide an 8 to 10 day retention time under strictly anaerobic conditions. These tanks may in turn be connected to an optional percolating filter, to further improve the effluent, and this would be constructed of locally available stone. Tests demonstrated that during the retention period cholera vibrio counts were reduced by as much as 100 fold, to a level far below the infective dose. In addition salmonellae counts were reduced by 10 to 100 fold, parallelling the reduction of the coliform count. Simple toxicity tests showed that the reductions in numbers of bacteria were not attributable to disinfectant or antibiotics released with the hospital sewage. Ascaris and Trichuris eggs were efficiently removed by sedimentation to the order of 1,000 to 10,000 fold and were rarely detectable in 100 ml of effluent from the second tank.

Introduction

In disaster situations with high population density and especially refugee camps, there is a very high incidence of gastro intestinal disease and often human degradation resulting from the non-containment of human excreta. Oxfam and similar relief organisations have long realised the desperate need for efficient sanitation systems which would reduce the level of infection and attack these diseases at the heart of their endemic foci by breaking the closed cycles of infection, excretion and reinfection. Traditional human waste treatment and containment systems such as septic tanks, trench and bore-hole latrines have been found unsatisfactory in these circumstances. Septic tanks take weeks to construct, need skilled labour and costly materials such as cement, steel and bricks. Latrine trenches and boreholes are easily flooded and result in contamination of the typically unprotected water supply. Furthermore the latter cannot cope with large numbers of people. The exceptional circumstances prevalent in disaster situations require a new approach, but one which must satisfy the following criteria:

1) The provision of an acceptable place for excretion.
2) Retention of the excreta in a protected water tight location for adequate time to render it harmless.
3) Ultimate safe disposal of the liquid effluent and of the solids.

In addition, disaster sanitation units should satisfy the following requirements:

cont'd.....

4) The unit must be of light weight and low bulk to facilitate transportation, and inexpensive. It should be packaged complete with assembly instructions and tools required for installation and maintenance.

5) Rapid installation of the unit should be possible, within hours of arrival at the intended site, by a small semi-skilled work force, of say 4 persons.

6) The unit should be able to be installed in or on the ground, regardless of waterlogged or other adverse soil conditions.

7) The unit should function by gravity flow and be independent of a power source.

8) No chemical dosing procedures should be required.

9) The maintenance requirements are to keep the latrine area clean and flushed, and periodic desludging of the first tank.

10) It should be possible to drain, dismantle and relocate the unit without difficulty.

The senior author of this paper organised the installation of a sanitation unit serving approximately 2,000 people daily in a Bengali refugee camp in 1971. That unit consisted of glass fibre squatting plates, plastic pipework and polythene sheeting for lining an open containment lagoon. The unit has been redesigned and an effort has been made to meet all of those requirements listed above in the new unit described here and illustrated diagramatically in Figure 1.

This sanitation unit, designed and patented by Oxfam, includes the following 3 stages of which the first two are packed in a single wooden crate.

Stage 1 - Latrine area

This comprises two parallel rows of 10 glass fibre squatting plates. These plates are designed to stack one inside the other for transportation. The connecting plastic pipework is of the push-fit type requiring no jointing techniques or special tools, and is prefabricated for immediate assembly. Where required the main walls of the latrine area are assembled from the wooden crate which can be used to divide the unit into male and female sections. A 20 litre flushing tank is located at the head of the drain.

Stage 2 - Sewage containment or treatment

Specially designed flexible pillow tanks made of butyl rubber reinforced with nylon comprise the main component of the sanitation unit. Each tank weighs 80 kg when empty and folds down to less that $1m^3$. When rolled out flat and filled with water or sewage each tank has a maximum capacity of 21,000 litres and measures 9m long by 2.8m wide and 0.9m high. The tanks are of standard design, each is provided with a 100mm inlet and outlet pipe connection, a desludging point at a low point on the tank, and a 50mm vent pipe at the highest point of the tank.

Each tank may be used singly as a containment unit for short term use, or several may be connected together in series or parallel to treat sewage flowing through the unit anaerobically. With an input of 4,600 litres per day, two tanks in series will give an 8 day retention period whereas three tanks will give a 12 day retention; at the same time a minimum settleable solids retention time of three months is provided, depending on desludging procedure.

cont'd.....

Stage 3 - Percolating filter

The liquid effluent leaving the second or third tank may be passed over an aerobic percolating filter medium of area 1m x 1m and a minimum of 1.5m depth. This filter medium would be locally obtained broken brick or stone recommended sizes of between 50-75 mm. The percolating filter is fed by a simple distributor; or mechanical tipping device. The filtrate (or effluent if no filter is to be used) is allowed to drain to the soil in a narrow trench or ground drain.

The Cholera Research Laboratories (CRL) Dacca was chosen as the site for the first trials of the Stage 2 tanks because a strong sewage was available here which was known to contain a variety of pathogens and parasites, including high numbers of cholera vibrios. Furthermore on site workshop and microbiological laboratory facilities were also available. The work undertaken at the CRL, and described here, was to monitor and evaluate the effectiveness of the sewage treatment provided by two flexible tanks which were charged daily with the total sewage output of the cholera wards and associated laboratories; this amounted to 4,600 litres of crude sewage per day and included the rice water stools from cholera patients. Testing was carried out over a period of 6 weeks during which time samples were taken on a daily basis to determine the ability of the unit to remove pathogens. Routine physical and chemical tests were carried out alongside the quantitative microbiological ones in order to elucidate what mechanisms might be responsible for the changes observed in the populations of pathogens, and a record of patient numbers which would be expected to control the numbers of pathogens entering the tanks.

METHODS

Location and installation of Stage 2 at CRL

Two flexible pillow tanks were positioned end to end, on a flat open grass area 50m from the cholera wards and laboratories and adjacent to the main 30cm diameter hospital sewer. The sewer was plugged below the nearest manhole chamber and sewage allowed to surcharge the drain and manhole chamber in order to provide an adequate volume for pumping. As the sewer was 2m below ground level it was necessary to raise the sewage up to the flexible tanks by means of a 5cm centrifugal pump. To measure the quantity of sewage entering the flexible tanks a 1,800 litre metering tank was installed between the sewer and first flexible tank. This metering tank was charged daily with a total of 4,600 litres of sewage over a six hour period, but the first 1,800 litres of each day was passed into the treatment tanks between the hours of 08.30 and 09.30 to simulate severe overloading conditions. The total quantity of sewage pumped during the period of the trials was 160,000 litres. The final effluent from the second flexible tank was passed by gravity to a convenient sewer connection below the point of pumping.

Sampling procedures

500ml samples were collected daily after pumping had commenced, (at 09.00). Sampling points included the raw sewage inlet, the outlet of the first flexible tank and the effluent from the second flexible tank. Sample analysis commenced immediately following collection.

Microbiological Methods

Preliminary toxicity tests

These were undertaken to investigate whether the hospital sewage entering the tanks contained sufficient levels of antibiotics, disinfectant or any other

cont'd.....

dissolved substances which might adversely affect the survival of bacteria and thus artificially enhance the efficiency of the treatment process.

Four hundred millilitres of fresh sewage was pre-filtered using a Whatman GFC grade filter pad and the filtrate filter sterilised using the membrane filtration technique. The filtrate was used to prepare batches of 50, 25, 5, and 1% final strengths of filtrate in molten double strength nutrient agar. Two freshly isolated pathogenic strains of bacteria, one of Vibrio cholerae the other of Shigella dysenteriae, neither of which had been exposed to antibiotics, were cultured for testing the toxicity of the sewage filtrate. Pour plate colony counts were prepared from a 10,000 fold dilution of visibly turbid suspensions of each culture in separate experiments. The counts of five replicates of each sewage filtrate concentration were compared with the same number of replicates in filtrate-free nutrient agar after incubation at 37°C for 24 hours. It was not possible to test full strength filtrate by this technique since the heat treatment involved in media preparation might result in the destruction of any toxic substances present. Nonetheless the results of these tests show that the sewage filtrate had no detectable toxic effect on V. cholerae (Table 1), although there was a marginal effect on S. dysenteriae (Table 2) where the means of colony counts of all filtrate strengths tested were below that of the control. None of these data suggests that the filtrate could depress the counts to a significant degree, say to the order of a 10-fold reduction. It may therefore be concluded that unabsorbed toxic substances present in this sewage were not present at sufficient levels to have a significant effect on the survival of the pathogens tested.

Sample analysis

Cholera counts were assayed by taking a 1 ml sample of sewage and preparing a 10-fold dilution series in alkaline peptone water to 10^{-7}. Dilutions were incubated at 37°C and subcultured onto Monsur's medium (Monsur, 1961) and TCBS (Kobayashi et al. 1963) after six and twenty-four hours. Suspicious colonies from each plate were tested against cholera antiserum by slide agglutination. The terminal dilution at which V. cholerae was confirmed represents a count of 1-9 organisms times that dilution factor. In tabulating these results an arbitrary most probable number of 5 has been listed in front of the log 10 of the terminal positive dilution. More accurate counts, using say 2-fold dilutions towards the end of the dilution series, were not carried out since a 10-fold difference between sampling points was considered to be the minimum change worth monitoring and significantly greater differences were anticipated.

Salmonella counts were assayed using a technique similar to that used for cholera except that in addition the Hyflosupercel concentration technique of Hammarstrom and Ljutov (1954) was used because much lower numbers of salmonellae were found to be present in the raw sewage. Following dilution or concentration in the enrichment broth of Rappaport et al., (1956) at 37°C for twenty-four and thirty-six hours, these cultures were plated onto Salmonella-Shigella agar and suspicious colonies tested by standard biochemical techniques and confirmatory agglutination against polyvalent 'O' and 'H' salmonella antiserum.

Coliform counts were carried out by the standard membrane filtration technique described in the U.K. Ministry of Housing and Local Government report number 71 (1969).

Enteroparasitic egg counts were limited to two species of nematodes. Ova of Ascaris lumbricoides and Trichuris trichuria were found to be the most abundant and they were counted by filtering measured volumes of sewage containing a little

cont'd.....

Lugol's iodine through a membrane filter. Filters were dried in air, cleared in immersion oil and mounted on glass slides for microscopic examination of the whole filter at a magnification of x 100. Thus an accurate count of stained ova per unit volume of sewage was obtained. When excessive organic solids impeded filtration or interfered with examination of the sample these were hydrolised and extracted with 50% hydrochloric acid and ether.

Physical and Chemical Test methods

Temperatures of the samples were taken at the time of sampling.

Dissolved oxygen was measured in the metering tank and in both flexible tanks by means of a portable oxygen meter, model 1520 (Electroniv Instruments Limited, U.K.). The probe was lowered into the tanks via the metering tank lid and gas vents respectively.

The pH of samples was measured using a Corning model 7 pH meter (Scientific Instruments, U.S.A.).

Suspended solids, ammonia and biochemical oxygen demand were measured using the standard methods described in Analysis of Raw, Potable and Waste Waters (London, 1972).

RESULTS

Microbiological data showing the effect of treatment on particular organisms have been tabulated so that the horizontal rows include the three samples taken on the same occasion, but it is important to note that the fate of a given unit volume of sewage entering the system can only be found by reading the appropriate result four days later in the outlet of the first tank and a further four days on in the effluent of the second tank. Therefore to simplify evaluating the efficiency of the unit an overall mean and percentage reduction at each stage of treatment has been calculated for each micro-organism studied and presented at the foot of all the tables of results. Thus for cholera (Table 3) the first tank approaches a 100 fold reduction (98% efficiency) whilst the second tank achieves a 100 fold reduction (99% efficiency). In the case of salmonellae (Table 4) the first tank achieves less than a 10 fold reduction (83.3%) and the two tanks together barely a 100 fold reduction (98.8%), but if allowance is made for the much lower inlet innoculum, by comparison with cholera, then the salmonellae data are more impressive since in all biological unit treatment processes the last fraction of a percent becomes exponentially more difficult to achieve. There is good evidence from other sources that the members of the Enterobacteriaceae are generally more resistant to this type of treatment process than bacteria such as the cholera vibrio. The coliform population recorded in Table 5 agree with this observation. At each treatment stage they exhibit a percentage reduction similar to that of the salmonellae despite their one million times greater initial populations. These results are in accord with the repeatedly made observation that the coliform group and the pathogenic enterobacteria have survival rates in the same order of magnitude under similar environmental conditions.

Although the temperature of the sewage fell by $10^{o}C$, from 32 to 22, during the period of the study this had no measurable effect upon the survival of the bacteria monitored, neither was there a significant fall in the raw sewage inoculum of any of the microorganisms despite the decline in both cholera and total admissions during the same period (Figure 2). Other parameters monitored which would be expected to affect the survival of the bacteria included oxygen,

cont'd.....

B.O.D., pH and solids concentration. Redox potential measurements which, in retrospect, may have been one of the most significant factors, were excluded. A small amount of oxygen, 0.8 to 1.2 mg per litre was detectable in the metering tank immediately following pumping but this was rapidly consumed. In the treatment tanks no oxygen was detected in the sewage on any occasion and no aeration was possible since, apart from the sampling points and gas vents, air could not enter the tanks. Anaerobic conditions were thus achieved and maintained in the treatment tanks within a few hours of their being charged with sewage. The rapid fall in pH usually occurring in the first week during conventional anaerobic digestion was not detected at the treatment tank sampling points since there were supernatant liquor samples containing typically high levels of ammonia (40-90 mg/l) of human origin. All samples were in the pH range 6.25 to 6.7 throughout the study, and liquor pH was therefore likely to be a major factor affecting the survival of bacteria in this instance. The first tank was observed to gas via the appropriate vent from the end of the first week onwards and thus indicated that the sludge accumulating here was undergoing the normal digestion processes, including primary acidification. Furthermore, continual gasification showed that any toxic substances, derived from the hospital sewage, which may have absorbed onto the sludge were not present at adequate levels to inhibit this process. That the highest proportion of solids was settling in the first tank is shown unambiguously by the suspended solids results in Table 8. This has the practical implication that arrangements have to be made for desludging the first tank after about 3 months. There is also the hazard that since large numbers of pathogenic bacteria have been removed from the liquid effluent they may have been retained and even concentrated by absorption onto the sludge solids. Separate sludge samples were analysed and did not show counts of bacterial pathogens significantly higher than those leaving the tanks, nonetheless the longevity of ova of parasites has been extensively documented and since these are clearly concentrated in the sludge the supervision of sludge disposal into slit trenches and immediate back filling is strongly advised. The effect of treatment on the removal of Ascaris ova is shown in Table 6 and on Trichuris ova in Table 7. The efficiency of removal is again impressive but attributable simply to sedimentation rather than to complex and ill-defined biological processes as is more likely the case for bacteria.

DISCUSSION

The design of the system described here was primarily controlled by public health considerations and dependent partly on earlier studies of the survival of microorganisms under anaerobic conditions. Laboratory studies carried out by Webber (1974) and Adams (1973) showed that sewage artificially contaminated with cholera vibrio populations of more than 1×10^8 per ml could be reduced to very low numbers within 7-14 days depending on the temperature, pH and solids concentration of anaerobic domestic sewage sludge. The cholera data obtained under field conditions and presented in this paper confirm that the retention time is adequate and hence justify the design specifications of the stage 2 tanks. Up to 1×10^6 cholera vibrios per ml were entering the tanks whereas approximately 5×10^2 per ml were present in the effluent. According to Cash et al., (1974) the 50 per cent infective dose able to produce at least one cholera positive stool together with diarrhoea was 1×10^8 vibrios when gastric acidity was not neutralised: no cholera positive stools or diarrhoea was observed with a dose of 1×10^7 vibrios per volunteer. Extrapolating from this information, 100 litres of the effluent from the second tank would be required theoretically to provoke choleraic symptoms and therefore an effective measure for the prevention of the spread of this infection is obtained.

cont'd.....

A less dramatic reduction of species of the Enterobacteriaceae had been anticipated due to the resistance which members of this group have been shown to exhibit during conventional anaerobic digestion. McKinney, Langley and Tomlinson (1958) reported 84 and 92.4 per cent reductions of S. typhi after six and twenty days respectively. This represents a 10-fold reduction approximately and is of the same order as the data presented here for salmonellae, excluding S. typhi. The numbers of salmonellae recovered from the raw CRL sewage were low, reflecting the low numbers of patients admitted to the hospital with infections due to the genus Salmonella. For example, there was not one typhoid case admitted to the CRL during the period of this study. By contrast there were significant numbers of infections due to the Shigella group, but these were regretfully excluded from the monitoring programme as no effective quantitative isolation procedure is currently available. Although a regular 10 to 100-fold reduction of salmonellae was observed these results are more difficult to interpret in terms of their public health value because published data on the infective dose of salmonellae are highly variable. The coliform count may be considered as a general index of the efficiency of the tanks in reducing the populations of most members of the Enterobacteriaceae including the enteropathogenic species and again a 10 to 100-fold reduction was observed between the inlet and effluent from the second tank. Although it cannot be claimed that the unit will reduce pathogenic populations of this taxonomic group to a safe level, nonetheless a significant reduction of their numbers entering the environment should make a positive contribution to lowering the probability of infection.

The data showing the removal of enteroparasitic ova by sedimentation were as encouraging as those for the removal of cholera vibrios. However the extremely high incidence of infections with Ascaris lumbricoides and Trichuris trichiura throughout Bangladesh make it pointless to suggest that the further spread of these parasites may be prevented in disaster situations in that country since a high percentage of human population there is already infected. Nonetheless in many other areas the containment provided by this sanitation unit offers a valuable public health measure for the prevention of spread of enteroparasitic eggs and cysts. The removal of ova of Ascaris sp. and Trichuris sp. may be taken as an index of the efficiency of the unit in removing the dispersal phase of many other parasites such as the much larger Fasciolopsis buski and even the small cysts of Entamoeba hystolytica for example.

Additional advantages observed with this unit were the absence of flies and noxious odours. The unit was originally conceived as a short-term solution to sewage containment problems in disaster situations but the progress achieved within the research and development show clearly that the unit is a major advantage in sanitation and sewage treatment systems for long-term use - particularly in poorer parts of the world. It could for example be used to advantage in crowded slum communities, providing the flexible tanks were protected from damage by adequate fencing and supervision. It is intended to test the long-term durability of the principal components and the various uses and acceptability of the unit commencing in the Spring of 1975 by installing complete units in selected refugee camps and possibly at the CRL hospital in Matlab Bazaar in Bangladesh.

ACKNOWLEDGMENTS

This project was made possible by the generous financial support of the Leverhulme Trust Fund and by the Overseas Development Ministry of the U.K. government which funded the equipment. The authors are also grateful for facilities provided at the Cholera Research Laboratories, Dacca, Bangladesh, and at the Loughborough and Surrey Universities, U.K. Particular thanks are due to Dr. W. Verwey, Director, and Mr. Mark Tucker, Engineer, and the engineering and laboratory staff of CRL, Dacca, for their encouragement, advice and practical assistance; and to Mr. J. Pickford, Senior Lecturer, Civil Engineering Dept., University of Technology, Loughborough, and Mr. J. Mc. L. Fraser, WHO, Consultant Chartered Engineer, for their significant contributions to the design of the unit.

REFERENCES

Adams, J. (1973) University of Surrey, Oxfam Project Report.

Cash, R.A., Music, S.I., Libonati, J.P., Snyder, M.J., Wenzel, R.P. and Hornick, R.B. (1974) J.Inf.Dis. 129, (1), 45.

Hammarstrom, E. and Ljutov, V. (1954) Acta.path. microbiol. scand., 35, 365.

Kobayashi, T., Enomoto, S., Sakazaki, R. and Kuwahara, S. (1963) Jap.J.Bact., 18 387.

McKinney, R.E., Langley, H.E. and Tomlinson, H.P. (1958) Sewage Ind.Wastes, 30 12, 1469.

Monsur, K.A. (1961) Trans. Royal Soc.Trop.Med.Hyg., 55 440.

Rappaport, F., Konforti, N. and Navon, B. (1956) J.clin.Path. 9, 261.

Webber, D. (1974) University of Surrey, Oxfam Project Report.

Analysis of Raw, Potable and Waste Waters (1972) H.M.S.O. London.

Report No. 71 (1969) Reports on Public Health and Medical Subjects, H.M.S.O. London.

Table 1. The effect of CRL sewage filtrate on the viability of a standard inoculum of V. cholerae measured by pour plate colony counts in a nutrient agar.

Replicate number	Final strength of sewage filtrate in nutrient agar				
	50%	25%	5%	1%	Control
1	60	42	47	41	65
2	64	43	65	45	55
3	60	62	63	45	56
4	35	56	54	53	53
5	63	55	43	54	51
Mean	56.4	51.6	54.4	47.6	56.0

Table 2. The effect of CRL sewage filtrate on the viability of a standard inoculum of S. dysenteriae measured by pour plate colony counts in nutrient agar.

Replicate number	Final strength of sewage filtrate in nutrient agar				
	50%	25%	5%	1%	Control
1	381	339	354	392	349
2	416	328	359	350	484
3	342	422	327	463	476
4	468	336	364	415	458
5	413	390	365	349	467
Mean	404.0	363.0	353.4	393.8	446.8

Table 3. Effect of treatment on the count of cholera vibrios per 1 ml sample.

Sampling date	Raw Sewage - inlet	Outlet - first tank	Effluent - second tank
Nov. 14	5×10^4	5×10^2	5×10^2
18	5×10^5	5×10^3	5×10^2
20	5×10^5	5×10^3	5×10^1
22	5×10^4	5×10^2	
27	5×10^4	5×10^3	5×10^2
28	5×10^4		5×10^2
30	5×10^3		5×10^1
Dec. 2	5×10^4	5×10^2	5×10^1
3	5×10^4	5×10^2	5×10^1
7	5×10^4	5×10^2	5×10^1
8	5×10^5	5×10^2	5×10^1
9	5×10^5	5×10^1	5×10^0
11	5×10^4	5×10^4	5×10^3
12	5×10^3	5×10^4	5×10^1
13	5×10^3	5×10^3	5×10^1
Mean	5×10^4	9.5×10^3	5.3×10^2
Number of results	15	13	14
Percentage of vibrios removed		98	99

Table 4. Effect of treatment on the count of salmonellae per 100 ml sample

Sampling date	Raw Sewage - inlet	Outlet - first tank	Effluent - second tank
Nov. 14	5×10^3	5×10^2	5×10^1
18	5×10^3	5×10^2	5×10^1
20	5×10^2	5×10^2	5×10^1
25	5×10^2	5×10^2	5×10^1
Dec. 1	5×10^1	5×10^0	5×10^0
3	5×10^1	5×10^0	0
8	5×10^3	5×10^2	5×10^1
11	5×10^3	5×10^2	5×10^1
13	5×10^3	5×10^1	5×10^0
Mean	2.9×10^3	3.4×10^2	3.4×10^1
Number of results	9	9	9
Percentage of bacteria removed		88.3	98.8

Table 5. Effect of treatment on the count of coliforms per 1 ml sample

Sampling date	Raw Sewage - inlet	Outlet - first tank	Effluent - second tank
Nov. 14	500×10^4	50×10^4	20×10^4
20	400×10^4	50×10^4	3×10^4
22	350×10^4	80×10^4	0.5×10^4
28	400×10^4	40×10^4	8×10^4
30	190×10^4	30×10^4	5×10^4
Dec. 2	30×10^4	6×10^4	0.3×10^4
4	40×10^4	10×10^4	3×10^4
8	400×10^4	30×10^4	4×10^4
10	110×10^4	50×10^4	10×10^4
11	200×10^4	30×10^4	30×10^4
13	300×10^4	20×10^4	7×10^4
Mean	265×10^4	36×10^4	8.3×10^4
Number of results	11	11	11
Percentage of bacteria removed		86.4	96.5

Table 6. Effect of treatment on the count of ascaris ova per 100 ml sample

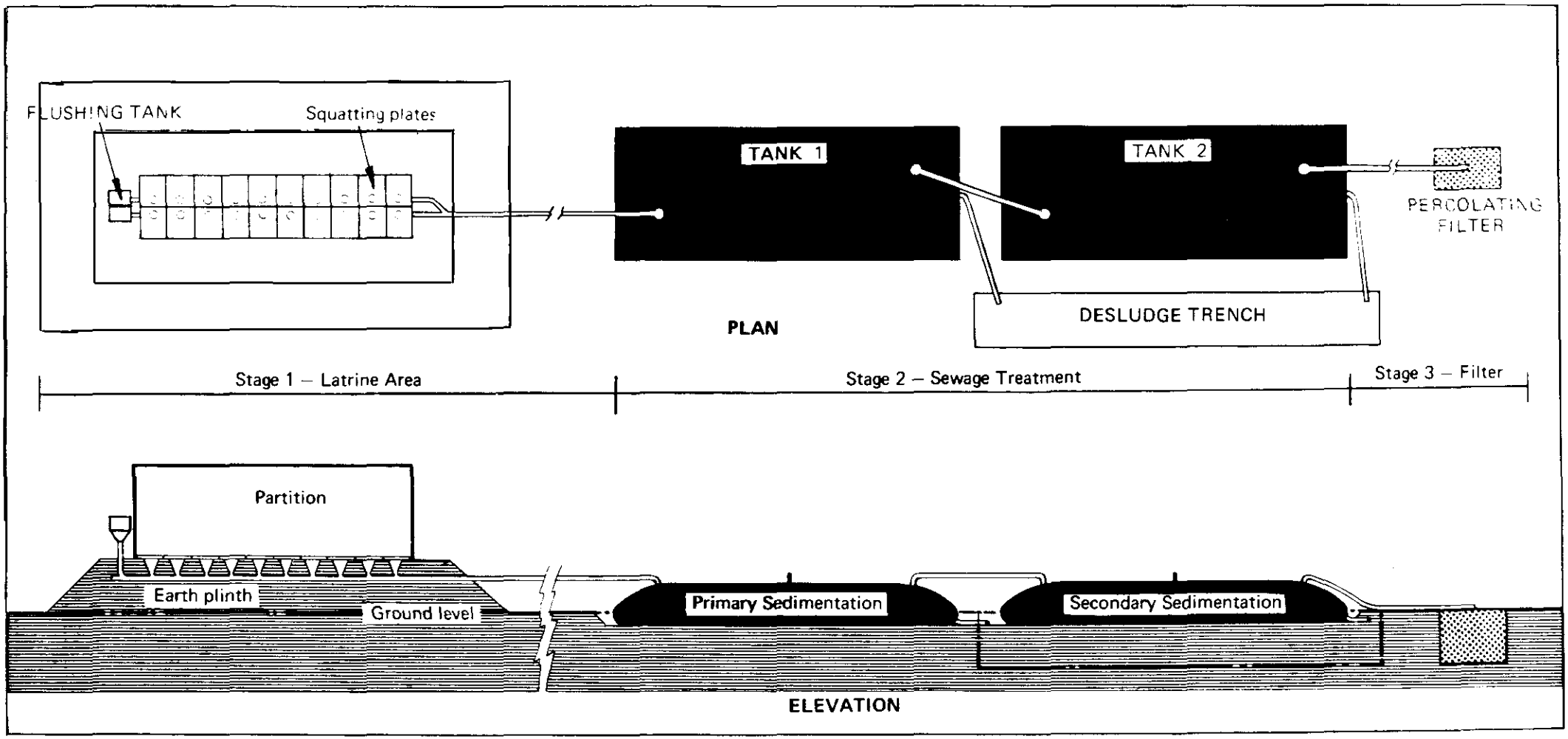
Sampling date	Raw Sewage - inlet	Outlet - first tank	Effluent second tank
Nov. 17	6,000	0	0
18	3,560	60	0
20	2,340	0	0
22	3,200	10	0
25	2,760	20	0
28	5,460	300	0
30		63	0
Dec. 2	9,750	100	9
5	11,500	45	0
7	12,700	140	12
8	6,100	172	0
10	13,200	410	4
11	9,000	190	20
12	8,000	370	4
13	8,000	720	4
Mean	7,612	173	3.5
Number of results	14	15	15
Percentage of ova removed		97.7	99.95

Table 7. Effect of treatment on the count of trichuris ova per 100 ml sample

Sampling date	Raw Sewage - inlet	Outlet - first tank	Effluent - second tank
Nov. 18	560	0	0
20	200	0	0
22	760	10	0
25	320	20	0
28	1,160	0	0
Dec. 2	1,050	0	0
5	700	0	0
7	1,800	0	0
8	100	12	0
10	800	10	0
11	200	0	0
12	400	0	0
13	350	0	0
Mean	646	4	0
Number of results	13	13	13
Percentage of ova removed		99.38	100

Table 8. Effect of treatment on the suspended solids in MG per litre of sample

Sampling date	Raw Sewage - inlet	Outlet - first tank	Effluent - second tank
Nov. 14	240	71	39
18	452	61	50
20	332	50	44
22	950	68	32
25	612	52	30
27	352	54	33
28	1,604	58	38
29	1,810	43	36
30	2,020	52	30
Dec. 1	1,400	52	24
2	1,325	49	36
3	2,010	46	24
4	1,940	38	19
5	1,900	41	28
7	1,620	54	28
8	2,020	57	28
9	1,900	40	26
10	1,750	53	26
11	1,790	47	27
12	2,380	74	27
Mean	1,420	53	31
Number of results	20	20	20
Percentage of solids removed		96.27	97.82



GENERAL LAYOUT OF SANITATION UNIT

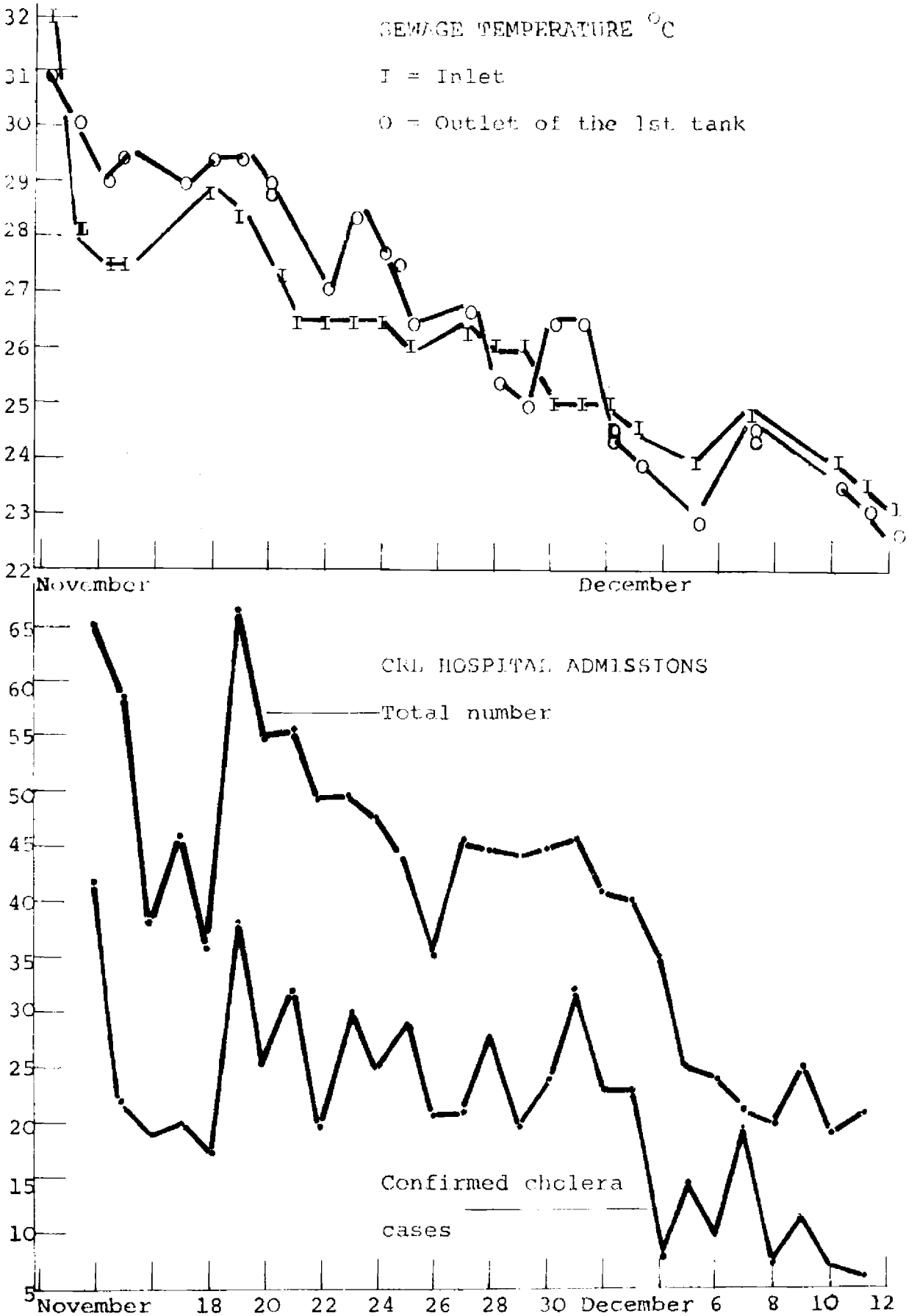


Figure 2. Some of the factors expected to affect the inoculum of microorganisms in the treatment tanks