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Performance of pour flush toilet

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INTRODUCTION

In search of an appropriate low cost sanitation system for the unsewered areas in Calcutta Metropolitan District (CMD), India, the Pour Flush (PF) toilet was selected from the various sanitation technology options proposed by Kalbermatten, et.al.(ref 1) for a thorough situation specific techno-economic appraisal. This led to the initiation of the present 9-month duration investigation on an experimental PT toilet at Jadavpur, Calcutta, to study the following functional aspects :

subsoil dispersion of effluent,
rate of sludge accumulation,
problem of odour and other nuisance,
subsoil travel of pollutants and potential danger of ground water pollution,
cost of the system.

MATERIALS AND METHODS

The details of the toilet along with the twin ecentric seepage pits as illustrated in Figure 1 were as per the specifications of the National Environmental Engineering Research Institute (NEERI), India.

The subsoil travel of leachate was monitored through analysis of the ground water samples collected from appropriately located monitor wells around the toilet pits. The auger bored monitor wells were 100 mm.dia. and 3m. deep and were left unlined but provided with a top cover. Seven monitor wells were operated as shown below.

monitor well	direction from pit 1	distance from pit 1, m
1	south	2.40
2	south	18.00
3	east	2.35
4	east	12.00
5	north	4.20
6	north	9.60
7	west	2.30

Soil samples were collected from 0.3m, 0.9m, and 1.5m depths from the identified location for the twin seepage pits and were tested for textural classification, permeability with remoulded samples, field density, percent moisture and shear stress. Field percolation tests at three test holes around the seepage pits were also carried out.

The experimental toilet was commissioned in early Aug, 81, and the investigation was carried out till April, 82. At the outset seepage pit 1 was operated and the other was cut off.

Ground water quality monitoring included determination of the virgin ground water quality followed by subsequent monthly testing of water samples collected from these wells during the experimental run. The water quality parameters monitored were pH, EC, COD, Cl, NH_3-N, NO_3-N, total and fecal coliforms, in accordance with the Standard Methods (ref 2).

The quantity and composition of sludge were determined immediately after the close of the present phase of the work. Sludge samples were analysed for moisture, organic matter, N, P_2O_5, and K_2O.

Besides, the number of users each day, average water use per pour-flush, rainfall and water level in the monitor wells were also determined during the study.

RESULTS

The maximum values of quality parameters as observed for the virgin ground water, as well as the maximum observed values in monitor wells at 2.4m, 4.2m, and beyond subsequent to the commissioning of the toilet are shown in Table 1.

Table 1 - Ground water quality

parameter	virgin ground water	monitor wells at 2.4m	at 4.2m	beyond 4.2m
pH	7.25	7.25	7.10	7.25
EC(mmhos/cm)	3.20	4.20	4.30	4.10
COD, mg/l	28	62	61	50*
NH_3-N, do	0.10	1.35	1.25	0.15
NO_3-N, do	1.51	1.76	1.95	2.10*
total coliform MPN/100 ml	11	540	540	70*
Fecol coliform MPN/100 ml	2	70	140	17*

* in well 6

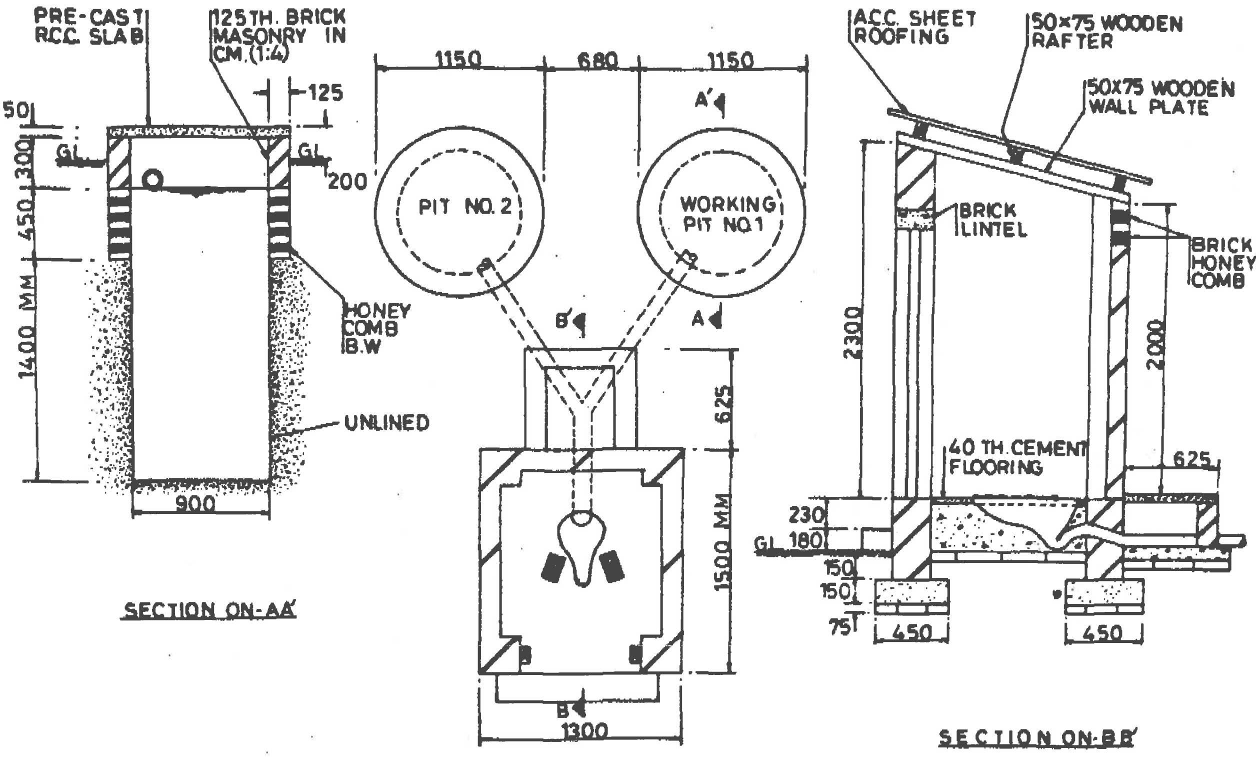

FIG 1 - Experimental PF toilet

The observed data on sludge accumulation and its characteristics appear in Table 2.

Table 2 - Sludge characteristics

parameter		value
wet sludge in 270 days, m^3		0.42
wet sludge, m^3/cap/day		0.00025
% moisture		70
% organic matter, oven dry,		49
% N - - - - - -,	do	1.40
% P_2O_5 - - - - -,	do	0.82
% K_2O - - - - - -,	do	0.46

Rainfall, level of ground water in monitor wells, average water use etc., as observed are shown in Table 3.

Table 3 - Rainfall, ground water level and water use

parameter	range
rainfall, mm/month	nil - 312
ground water level in monitor wells, m	0.40-1.10
liquid level in pit 1,m	0.40-0.80
pour flushes/day	8 - 17
water used for flushing, litres/day	16 - 42
hydraulic loading, litres/day/sqm	35 - 59

The salient characteristics of the soil in the study area are presented in Table 4.

Table 4 - Soil characteristics

parameter	value
texture	clayey-silt
field percolation rate, cm/min	0.23
laboratory permeability, cm/sec	2.3×10^{-5}
field density, kg/m^3	1.96×10^3
shear stress, kg/cm^2	0.29

It is also worthy of mention that the trend of ground water movement was in the northerly direction.

The observed COD, total and fecal coliforms in the seven monitor wells at the commencement and at close of the investigation are shown in Figs.2 and 3.

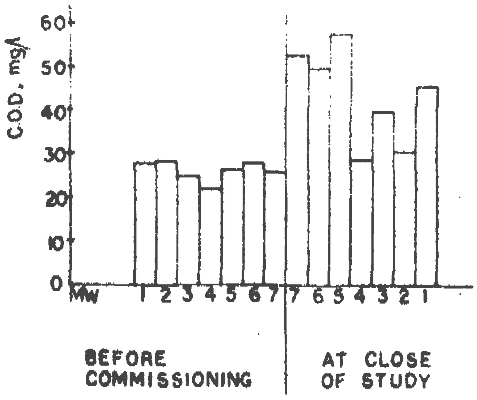

FIG 2 - Change in COD

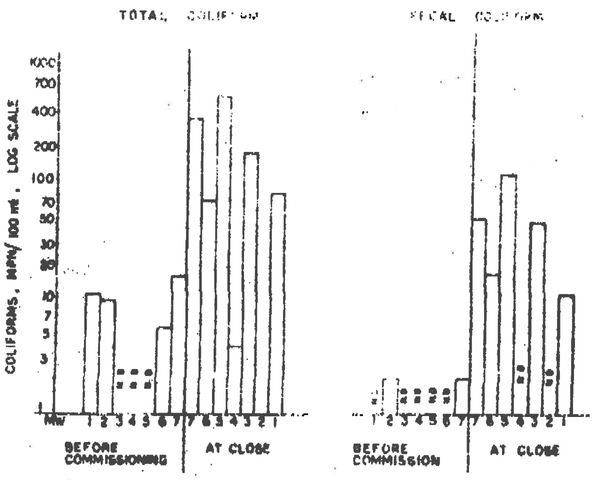

FIG 3 - Change in total and fecal coliforms

DISCUSSIONS

The soil texture in the study area was clayey-silt with an average permeability of 2.3 x 10^{-5}cm/sec and the field percolation rate was 0.23 cm/min. During the reported study, the ground water levels were at 1.10 and 0.40m below the ground surface during summer and rainy seasons respectively, accordingly, the effective leaching surfaces through the working seepage pit under extreme summer and wet conditions were 2.68 and 0.71 sqm.

The average quantity of flushing water was 25 litres/day, however, the upper limit went upto 42 litres/day. Hence, the average and maximum hydraulic loadings during rainy season were respectively 35 and 59 litres/day/sqm of leaching surface. The dispersion of the effluent, however, was always satisfactory.

The experimental toilet could be taken to be equivalent to six users using it twice a day in case of domestic installation. Thus, the minimum leaching surface under worst condition during rainy season should be 0.12 sqm/user for design of domestic installation.

The seepage pit was 2m deep, hence, the lower 0.9m of the pit below the lowest ground water level remained ineffective from the consideration of sub-soil dispersion. However, this under-water space could effectively serve as sludge storage and the constant pool of water would provide some dilution of the concentrated waste from toilet. So reduction of the depth of seepage pit to less than 2m was not considered essential.

As regards leachate movement and pollution of shallow level ground water, it was observed that the leaching fluid (effluent) from the seepage pit had distinct pollutional effect upto a peripheral distance of 4.2m. As shown in Table 1 and Figure 2, the range of COD in monitor wells 1,3,5 and 7 located within the stated distance was 40-62 mg/l at the close of the study as compared to 25-28 mg/l before commissioning of the toilet. Furthermore, the total coliforms in these monitor wells at the beginning were between ND-14 MPN/100 ml and at the close the densities were 79-540 MPN/100 ml. Fecal coliforms also increased and ranged between 11-140 MPN/100 ml at the close.

It was alarming to note that the water quality in monitor well 6,which was located at a distance of 9.6m north of working seepage pit was also affected, and this could be attributed to the northerly movement of the ground water as observed during the study. For example, the COD in this monitor well 6 increased to 50 mg/l from the initial 26 mg/l. The total and fecal coliforms at the close were 70 and 17 MPN/100 ml respectively as compared to the initial densities of 6 for total and ND for fecal coliform. The monitor wells 2 and 4 at distances of 18.00m south and 12.00m east were not affected due to the movement of leachate.

On the basis of the reported observations, it would be reasonable to mention that in clayey silt soil, ideally, the separation distance between seepage pit and unlined shallow wells should be minimum 10m, however, under extreme constraint of space, closer location could be permitted in which case impermeable lining of the shallow well extending to a depth of minimum 8m from the surface should be obligatory.

The rate of wet sludge accumulation was estimated to be 0.00025 m^3/cap/day. The sludge as abstracted at the end of the 270-day study period was fairly digested with good de-waterability and could be applied on land only after sun drying for a couple of days. The sludge possessed modest fertiliser value besides the desired properties as a soil conditioner. It was also felt that the second seepage pit was not essential either for permitting further anaerobic digestion of the accumulated sludge or for maintaining continuity in service.

COST

PF toilet with properly designed seepage pit, and septic tank with subsoil dispersion facilities are the two appropriate on-site sanitation systems in unsewered areas with modest water supply level. Cost estimates as per 1981 price index in India showed the capital cost of construction of the septic tank system (excluding the toilet structure and pan) was nearly US $30 per capita and the cost of single seepage pit of the PF system was US $3 per capita. The cost of toilet structure including pan would be mostly same for the two systems. Again the annual recurring expenditure (repayment of capital plus OM&R) for septic tank system was nearly US $4 per capita against US $0.50 only per capita for the PF toilet system. The economic aspect, therefore, is worthy of consideration in planning sanitation programme for settlements of subdued economic level.

CONCLUSIONS

With good design and operation compatible with local geological and climatological factors, the PF toilet could be a satisfactory on-site sanitation alternative in developing countries.

In sub-soil with field percolation rate around 0.23 cm/min, the minimum leaching surface at worst condition during rainy season should be 0.12 sqm /capita. The hydraulic loading rates in such worst conditions could range between 35-59 litres/sqm/day which could be taken up by clayey silt deposits.

Sub-surface travel of organics and coliforms along with the leaching fluid was significant upto a peripheral distance of 4.2m, and was also noticed upto a distance of 9.6m in the direction of ground water movement. Hence, ideally, unlined wells should not be located within 10m from the seepage pit, however, under extreme constraint of space, closer location may be permitted in which case 8m. deep impervious lining of the shallow water well should be made obligatory by necessary regulation.

The accumulation of wet sludge was 0.00025 m^3/capita/day. The moisture content of 70% and good drainability indicated fairly digested sludge. Organic matter, N, P_2O_5 and K_2O in the sludge were 49, 1.40, 0.82 and 0.46 percent respectively on oven dry basis. The 270-day old sludge could be applied on land without further anaerobic digestion but after sun drying for several days.

Provision of the second seepage pit was not essential either for permitting further anaerobic digestion of the accumulated sludge or for maintaining continuity in service. One seepage pit, 0.9m internal dia. and 2m deep, with annual desludging schedule could serve 6 users continuously as the desludging operation would not take more than a few hours. The depth of the single seepage pit should not be less than 2m. The lower under water volume could be effective for sludge storage.

The capital cost of construction of one seepage pit was US $3 per capita excluding the cost of toilet structure, and the annual recurring expenditure (repayment of capital plus OM&R) was estimated around US $0.50 per capita. Thus the system indicated techno-economic merits.

ACKNOWLEDGEMENT

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