SOIL INFILTRATION CAPACITY AS AFFECTED BY SEPTIC TANK EFFLUENT APPLICATION STRATEGIES

(Small Scale Waste Management Publication #8.10)

by

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Presented at the
Onsite Sewage Treatment Symposium
Chicago, Illinois. December, 1981.

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Home Sewage Treatment, Proceedings of the Third National Home Sewage Treatment Sumposium, ASAE Publication _____, St. Joseph, Michigan, 1981 (in press).

SOIL INFILTRATION CAPACITY AS AFFECTED BY SEPTIC TANK EFFLUENT APPLICATION STRATEGIES

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On-site wastewater systems utilizing soil absorption depend upon the ability of the soil to absorb and purify all of the wastewater applied. Soils used for absorption of effluents may have high initial infiltration rates and more than adequate capacities to absorb the hydraulic load of wastewater. However, with continued application of effluent, a clogging layer usually develops at the infiltrative surface. This clogged zone creates a barrier to flow, restricting the rate of infiltration. Clogging is not synonymous with soil absorption failure because flow, albeit reduced, continues through the clogged zone. Some clogging may, in fact, be regarded as an enhancement to purification.

Management of soil absorption systems with mature clogged layers infers management of this zone of reduced hydraulic conductivity. Controlling the intensity of clogging is essential to maintaining a desirable infiltration rate. Because the clogged zone controls the infiltration rate of the wastewater absorption medium, proper design requires that effluent loading not exceed the infiltration rate of the clogged system.

Major factors influencing the development and intensity of soil clogging are the pattern of the wastewater application, the loading rate, and the wastewater quality. This paper reports results of a 21-month study that examined rate and frequency of application under a controlled, replicated loading regime, yet in natural undisturbed soil conditions.

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FACTORS AFFECTING SOIL ABSORPTION

Hydraulic Conductivity and Loading Rate

After a soil absorption system matures, the clogging zone at the infiltrative surface controls the rate of wastewater absorption. Thus the initial saturated hydraulic conductivity or percolation rate is of little direct value in developing a loading rate for a mature system, except through use of some empirical design constraints. Because of the hydraulic barrier effect of the clogged layer, flow in the soil beneath is unsaturated. Total flow through the clogged soil system is dependent upon the thickness of the clogged zone, the hydraulic head above, the moisture tension below, and the hydraulic conductivity of the restrictive layer.

Bouma (1975) studied the unsaturated hydraulic conductivity under clogged systems in order to understand the dynamics of the mature soil absorption system. This work recognized the significance of a hydraulically restrictive clogged layer in reducing soil infiltration rate. Because the clogging zone affects different soils in dissimilar ways, Bouma recommended specific loading rates for distinctive soil textural groups. These recommended rates were based on the interrelationship of each soil's unsaturated hydraulic conductivity, as influenced by texture, structure, and porosity and the conductivity of the clogged layer (1975).

Bouma's technique for determining an appropriate loading rate produced results which compare favorably with those recommended by more casual techniques (Federick, 1948; Bendixen, 1950; USPHS, 1967). Bouma's method is, however, more direct than those using percolation rate values empirically related to a loading rate by comparative analysis of previous system performance. The latter approach customarily incorporates some gross factor of safety to allow for its imprecision and non-recognition of important soil properties (Otis et. al., 1977). Nevertheless, the percolation test procedure, in various forms, has been widely adopted by most states, and continues to the the most popular technique for sizing soil absorption systems.

Application Pattern and Frequency

Soil clogging is a complex phenomenon that results from many mechanisms that act simultaneously. They can usually be grouped into physical, chemical and biological processes. Many investigators (Allison, 1947; McCalla, 1946, 1950; McGauhey and Krone, 1967) have concluded that biological agents and their activities and by-products are the most important cause of soil clogging.

Several researchers (Bendixen et. al., 1950; Winneberger et. al., 1960; Jones and Taylor, 1965; Thomas et. al., 1966) have suggested that biological clogging cannot predominate, provided the soil absorption system remained at least intermittently aerobic. Lysimeter studies showed that the infiltrative capacity of the soil was reduced more slowly when periods of ponding were interrupted with periods of aeration (Thomas et. al., 1966).

These findings have influenced the development of working concepts in septic tank/soil absorption system practice that are meant to confer greater system longevity. Resultant innovations have included use of aerobic treatment units, installation of vent pipes to facilitate reaeration of the soil after a wetting front has passed, use of dosing systems for controlled effluent application, uniform application over the entire absorption area, and periodic resting by the use of alternating soil absorption systems. Most of these strategies attempt to enhance aeration of the infiltrative surface and thus reduce clogging. Obviously, these approaches are not equally effective, nor are they equally well adapted for all management situations.

Much of the information on soil clogging has been obtained from column studies designed to simulate a natural field clogging regime. Generally, these studies use lysimeters with air-tight walls, which create anaerobic conditions within the soil below the clogging mat. Unfortunately, most column studies have neglected the effect of redox conditions in soil clogging dynamics.

Walker et. al. (1973) showed that aerobic conditions exist under soil absorption systems in sands. Magdoff and Bouma (1974) and Magdoff et. al. (1974) showed that sand columns aerated beneath the infiltrative surface displayed clogging zones with hydraulic resistances very similar to actual field systems in sands. Perry and Harris (1975) showed variable clogging behavior in aerated versus nonaerated sand columns. Nonaerated treatments clogged more slowly than aerated columns but infiltration rate recovery during resting was more rapid in the aerated columns. These results suggest that data from laboratory column studies must be carefully interpreted before extrapolation to field applications.

These aerated column studies, all of which were conducted only in sands, indicate that application regimes characterized by anaerobic conditions alternated with aerobic conditions on a short-term basis, may reduce infiltration as an intense crust forms directly below the surface during the aerobic (resting)phase (Perry and Harris, 1975). These conditions are analogous to dosing or short-cycle alternation of field soil absorption systems.

These results imply that dosing and resting frequencies must be selected with care to prevent excessive clogging. It has not yet been established what these frequencies should be for the variety of soil conditions encountered in the field. Likewise, it is not well understood how application frequency interacts under field conditions with other management factors, particularly application rate and wastewater quality. Although dosing and alternating system designs have been frequently used in the field, their operation and dynamics has not been quantitatively evaluated. This study sought to further validate the effects of wastewater application strategies under well-defined field soil conditions.

MATERIALS AND METHODS

Experimental Design

The experimental design for this study employed a total of eighteen specially designed soil absorption "mini"-systems or cells. Septic tank effluent (STE) was applied at three rates and by two methods, with three replicates for each experimental condition, thus 18 total systems. To provide a constant soil infiltrative surface area for each of the cells, impermeable barrier rings impressed into the soil infiltrative surface were used. Based upon consideration of the volume of wastewater available from a trial household and that required for the application rates selected, a single outer barrier, circular in shape, with a diameter of 0.9 m (3 ft.) was chosen. Galvanized iron culvert pipe, 20 guage (0.036 in.), was fabricated into the required 0.9 m diameter cylindrical sections 0.3 m (1 ft.) long with a single watertight seam. Note that by using this controlled surface area for effluent application, no sidewall absorption was available; however, the infiltrative surface area was exactly known for effluent absorption and infiltration rate calculation.

The basic design STE loading rate for the soils at the site, based on soil morphology, hydraulic conductivity characteristics, and percolation rates, was approximately 2 cm/day (0.5 gal/ft^2/day). This application rate was used as the lowest loading rate, with higher loading rates stepped progressively to 2X (4 cm/day) and 4X (8 cm/day). The wastewater application methods included conventional (semi-continuous trickle flow) and once-daily-uniform (dosed) application. The experimental layout of this study is presented in Figure 1; this layout was based on plumbing convenience and efficiency. The application rate and application method shall be referred to throughout this paper as a "treatment", and shall be coded by numerical loading rate and letter designation, respectively. For example, 2C denotes 2 cm/day conventionally applied and 8D denotes 8 cm/day dosed.

To simulate conventional gravity trickle application, the conventional application cells received an average of eight small intermittent applications of septic tank effluent per day, trickled onto the gravel. The once-daily-uniform application cells received an average of only one dose of septic tank effluent per day distributed over the cell infiltrative surface via a mini-distribution network. The time of application and the actual daily loading to the cells depended upon the residence wastewater generation patterns.

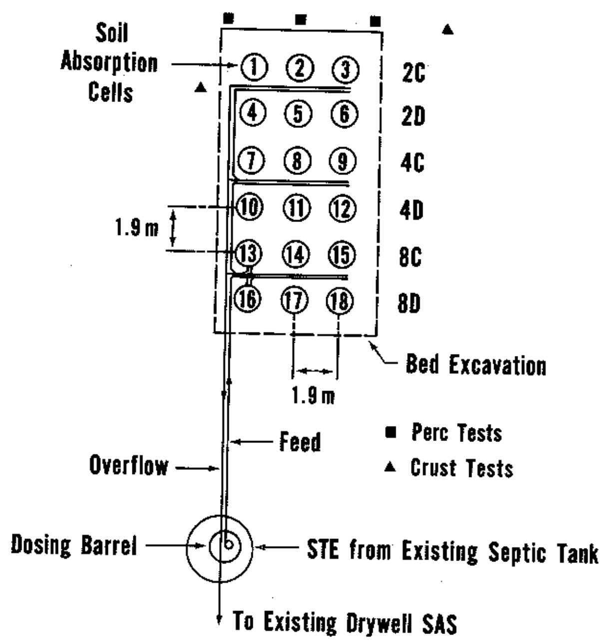

Figure 1. Experimental Layout

Site Characterization

Wastewater Generation: The study residence, a typical rural wastewater source, housed two adults and two children (ages 2 and 9). The residents produced an average of 795 L/d (210 gpd) of wastewater. The plumbing features of interest were one toilet, an automatic clotheswasher, but no automatic dishwasher or garbage disposal; the water source was a well and the previous wastewater disposal method was a drywell.

Soil Morphology and Hydraulic Porperties: The soils at the site were identified initially using detailed soil maps and verified from soil bore holes. The soil profile was sampled and examined morphologically according to the Soil Survey Manual (Soil Survey Staff, 1951) and Soil Taxonomy (Soil Survey Staff, 1975).

Percolation tests were conducted in three separate test holes at the site according to the procedure described in the Wisconsin Administrative Code (CH H63.09). These tests were performed at the depth at which wastewater would be applied to the soil infiltrative surface, 70 cm (28 in). At this same depth, *in situ* hydraulic conductivity was determined at two locations using the crust test method (Bouma and Denning, 1972: Bouma et. al. 1974a). Particle size analysis was also conducted on representative bulk samples (Day, 1965).

Site Design, Installation, and Operation

A backhoe was used to excavate an area approximately 6.4 m (21 ft) wide and 11.9 m (39 ft.) long to a depth of 0.70 m (2.3 ft). The eighteen soil absorption cells were then placed in the excavated area as depicted in Figure 1. The interior soil surface of each cell was then leveled off and hand-picked to expose the natural soil structure; loose soil was carefully removed. An observation port, PVC pipe 7.5 cm (3 in) e.d., was then carefully placed near the center of each cell, with its base flush with the infiltrative surface. This pipe was perforated in its lower portion for hydraulic continuity with the cell. Next, approximately 20 cm. (8 in) of washed gravel was carefully placed within the cell. A distribution network appropriate to each cell's method of STE application was installed and 10 cm (4 in) of additional gravel was added. Filter fabric (Dupont Typar) was placed over the gravel in each cell to prevent soil illuviation into the gravel from the backfill.

An application vessel controlled STE loading volume for each cell. Wastewater was delivered to each of the 18 soil absorption cell vessels; overflow was directed through an outlet pipe to the existing household drywell. The effluent load was discharged to the soil infiltrative surface via an outlet at the bottom of the vessel, controlled by an electrically-operated solenoid valve. The application vessel was situated immediately on top of the drainage fabric covering the gravel and connected to the cell's distribution network. To facilitate access to the application apparatus and the observation port, an access cylinder was placed vertically, extending from the top of the gravel to 5 cm (2 in) above final surface grade. Each cylinder was fitted with an insulated, removable cover.

To obtain STE for this experiment, the drain line connecting the existing household septic tank (4 m^3 or 1000 gal) and drywell was intercepted by an in-ground pumping chamber. Inside the chamber a 340 L (90 gal) basin received the septic tank effluent. A 1/2-hp effluent pump (Peabody Barnes, Model SE51) and a high- and low-level float switch were situated in the basin to activate STE pumping to each soil absorption cell via a distribution network as shown in Figure 1.

Distribution of wastewater to the 18 soil absorption cells and application to the soil was controlled by an electrically operated system as follows. After 110 L (30 gal) of STE flowed into the receiving basin in the pumping chamber, the high-level float switch was activated which in turn initiated a ten-minute cam-timer sequence. After 18 seconds, the effluent pump was activated and discharged wastewater to the 18 cells. The pump continued to operate until a low-level switch was triggered. At this point, the application vessels for the nine conventional application cells had been filled to the invert of the overflow outlet. The application vessels for the nine dosed cells had been filled to approximately 1/8 of the level of the overflow outlet. Approximately 210 seconds into the cam-timer cycle, the discharge valves in the conventional cells were opened to allow the wastewater to drain onto the gravel and the soil infiltrative surface. The discharge valves serving the dosed cells were not opened each cycle, but rather only every eighth cycle, or an average of once daily. After pumping, the system was automatically reset and ready for another cycle pending the accumulation of another 110 L of STE in the pumping chamber. Application of wastewater to the 18 systems was begun in December 1978, and continued for 21 months until September 1980.

Monitoring

Wastewater: The wastewater application to the soil cells was monitored using a continuous chart event-recorder (Cole-Palmer, Model No. 8364-30) to record the time of day of each wastewater application. Electrical event-counters tabulated the number of wastewater applications as well. These data, coupled with the known volume of wastewater per application to a given cell, were used to determine the average daily loading rates and representative hourly and daily loading patterns. Flow-composited samples (24 hours) of septic tank effluent were periodically collected and analyzed according to procedures outlined in Standard Methods (1976).

Soil Absorption System Ponding: Effluent ponding above the infiltrative surface of each cell was monitored via the observation port. Each observation port was inspected to determine the depth of STE ponding, if any.

Soil Infiltration Rate: Bottom area infiltration rates for each cell were measured prior to the experiment and approximately bi-monthly thereafter. A constant-head, permeameter-type device was developed for this purpose. Hydraulic access to the infiltrative surface of each cell was gained through the observation port. The infiltrometer device maintained a constant one cm head at the infiltrative surface during measurement. After an equilibration period, the volume of water infiltrating per unit time was measured. This procedure was repeated until a constant rate was determined. Effluent application was withheld during this measurement. After many months of operation, natural, persistent ponding conditions developed in some cells. In this case, that same equilibrium level of inundation was measured and the permeameter device was adjusted to make the infiltration rate measurement using a hydraulic head equal to the ponding depth. This approach was felt to express the true operational infiltration conditions at that time in the study.

RESULTS AND DISCUSSION

Soil Conditions

Field investigations of soil morphology confirmed that the soil is Plano silt loam. This soil is a well-drained member of the fine-silty, mixed, mesic, Typic Argiudolls (Soil Survey Staff, 1975). The Plano soils are derived from deep loess deposits over glacial till. They typically have very dark brown friable silt loam A horizons, brown silty clay loam B2 horizons to a depth of about 45 inches, and IIB3 horizons of stratified sandy loam till.

Particle size analysis of samples collected from the B22t horizon at 70 cm depth yielded mean values of 8 percent sand, 53 percent silt, and 39 percent clay. This clay content barely falls in the silty clay loam USDA textural class (more than 40 percent clay constitutes a silty clay). Because of this heavy silty clay loam character, water movement characteristics may be significantly different from Plano soils with as little as 27 percent clay in the same morphologic horizon, such as those reported by SCS (1967).

Results of three percolation tests ranged from 6.3 to 10.6 min/cm (16 to 27 min/in), with a mean value of 9.2 min/cm (23.3 min/in). These percolation rates are all lower (faster) than expected for this soil, considering the high clay content previously described. Percolation rates for Plano silt loam soils are reported as ranging from 17.7 to 23.6 min/cm (45 to 60 min/in) by Glocker and Patzer (1978). These variations from predicted behavior may be at least partially explained by many large biopores (worm channels) present in these strongly structured soils.

In situ crust test determinations of hydraulic conductivity (K) showed that K decreased very rapidly from relatively high values at and near saturation to low values as the soil dried and soil moisture tension increased up to 20 mbar. Saturated K values of approximately 200 cm/day were determined, whereas the unsaturated K at 50 mbar of tension was approximately 0.02 cm/day, a K change of four orders of magnitude. Such conductivity relationships are expected, since the larger pores, both structural and biotic, with the greatest conductivities, do not transmit fluids at these tensions. Soil moisture tension under mature soil absorption systems is often in the range of 50 ± 25 mbars such that these low conductivities prevail (Bouma, 1975).

Wastewater Characterization

Typical quantitative and qualitative characteristics of the septic tank effluent used in the study are summarized in Tables 1 and 2, respectively. As shown in Table 1, actual loading rates and frequencies differed only slightly by design. The pattern of application of wastewater depended entirely upon the residential STE generation pattern. The qualitative characteristics of the wastewater (Table 2) were well within the usual reported ranges for all parameters (Otis et. al., 1980).

Table 1. Summary of wastewater loadings[a].

Design loading (cm/day)	Actual loading (cm/day)	Applications (no./day) Conventional cells	Dosed cells
2	2.2	8.18	1.02
4	4.2	8.18	1.02
8	8.2	8.18	1.02

[a]Average over first 398 days of operation, 364 full operation days.

Table 2. Summary of applied wastewater characteristics[a].

Parameter	Mean	Range	No. Samples
BOD_5, mg/L	153	92-225	10
COD, mg/L	265	157-388	9
Suspended solids, mg/L	44	22-75	10
Volatile suspended solids, mg/L	37	12-67	10
Ammonia nitrogen, mg/L	41	32.8-64.8	9
Total phosphorus, mg/L	18.4	8.5-27.0	11
pH	-	7.5-8.0	-
Total bacteria, Log_{10}#/L	-	8.08-9.76	9
Total coliforms, Log_{10}#/L	-	7.65-8.52	9
Fecal coliforms, Log_{10}#/L	-	7.60-7.66	9

[a]24-hour flow-composited samples.

Soil Absorption Systems

System Ponding: Persistent ponding was first noted in the experimental cells in September 1979, after nine months of operation. Of particular interest is the pattern with which this ponding appeared and became more strongly expressed with regard to application rate and method. Figure 2 summarizes ponding depths for the period from 12 to 20 months of operation. The application treatments began displaying ponding in the order 8C (8 cm/day conventional), 8D, 4C, 4D, and 2C, at 9. 11, 12, 13, and 15 months of operation, respectively. The depth and persistence of ponding varied slightly in individual cells and within treatments, but the between-treatment trends and their magnitude were very consistent. Only the 2 cm/day dosed treatment (2D) never displayed inundation during the entire 21 months the study was conducted. The general trend of Figure 2 demonstrates increasing ponding depth during the period for all treatments except 2D. This corresponds with a relative increase in hydraulic resistance and continually deteriorating infiltrative capacity. Bouma (1975) used field observations of ponding depth in soil absorption systems to aid in estimating the flux across the clogged barrier, and thus the hydraulic resistance of the barrier.

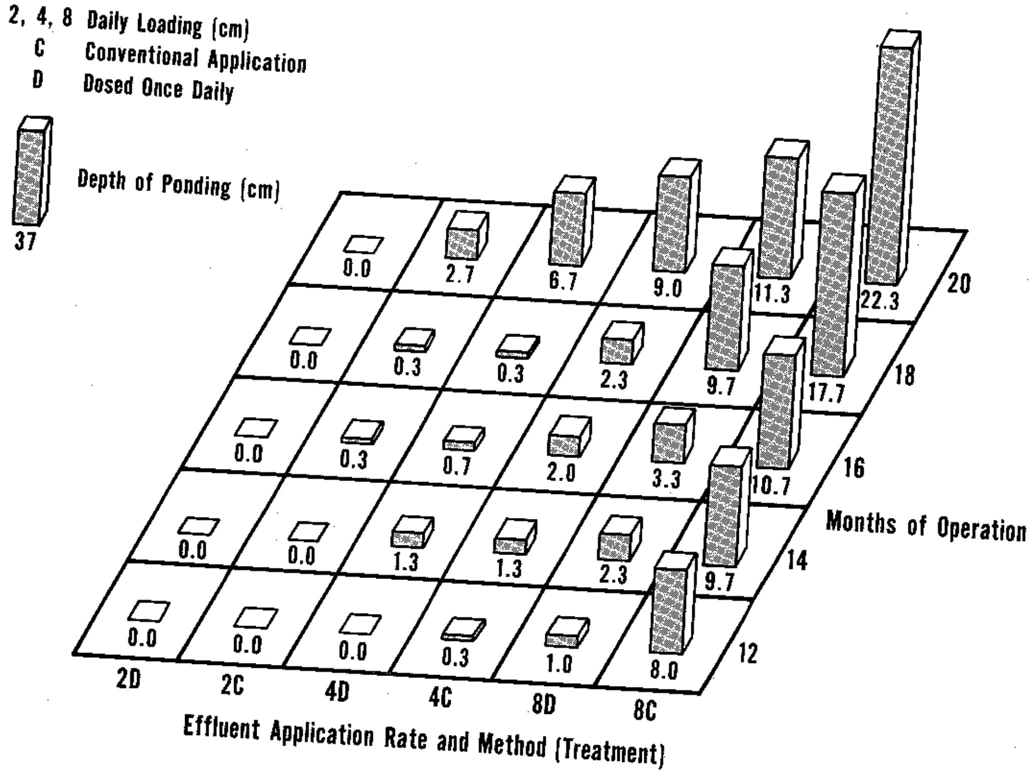

Figure 2. Relative Hydraulic Resistance, as Depth of Ponding, vs. Time, by Treatment

The hydraulic resistance of the clogged infiltrative surface, as indicated by the magnitude of ponding depth in Figure 2, strongly suggests that higher STE loading rates result in more rapid hydraulic decay of the soil absorption system. This trend is most strongly evidenced for conventional application, but is also quite obvious for the dosed method. The ponding depth became unacceptably high in some 8C cells at 21 months, one factor which precipitated termination of STE application. Whether the ponding rates would have continued to increase for all treatments or may have come to some dynamic equilibrium can only be speculated.

Because ponding occurred first in conventional treatments for all loading rates, and never in the 2D (2 cm/day dosed) treatment, it appears that dosing uniformly once-daily may have a beneficial effect in retarding clogging, although this effect is very much dampened at the higher loading regimes. As an example, the 8C treatment first showed ponding at 9 months, but was soon followed by the 8D treatment at 11 months of operation. Nevertheless, the positive effect of dosing appeared to be great enough at the basic design loading rate of 2 cm/day to maintain an aerobic, or daily-rested soil infiltrative surface. Recall that the 2C treatment ponded at 16 months. This follows the favorable effect of dosing espoused by Bouma et. al. (1974). In very similar soil conditions less than 3 km from this study site, Bouma et. al. (1974) demonstrated very rapid infiltration of effluent applied at 3.2 cm/day (p.8 g/ft^2/d) for a period of 10 months. This system continues to function at this application rate, and has never experienced persistent ponding in over nine years of operation (Converse, 1981).

Note that once ponding occurs as a persistent phenomenon in the dosed treatments, that they no longer receive effluent in a truly dosed sense. Therefore if the loading rate is so great as to result in the inundated condition of the infiltrative surface, then dosing can have little if any functional effect on the system after ponding occurs. However, as indicated by the 2 cm/day dosed treatment of this study, and the experience of Bouma et.al. (1974), once-daily dosing of effluent does appear to have significant advantages over conventional gravity-trickle application in terms of maintaining infiltrative capacity.

Infiltration Rate: The 18 soil absorption cells had a mean initial infiltration rate (IIR) of 202 cm/day and a standard deviation of 42 cm/day. Bouma (1971) reported an infiltration rate of 200 cm/day for Plano subsoils. Figure 3 presents the relative infiltration values for each treatment, for selected months throughout the 21-month study, and also nine months after wastewater application was stopped (30 months).

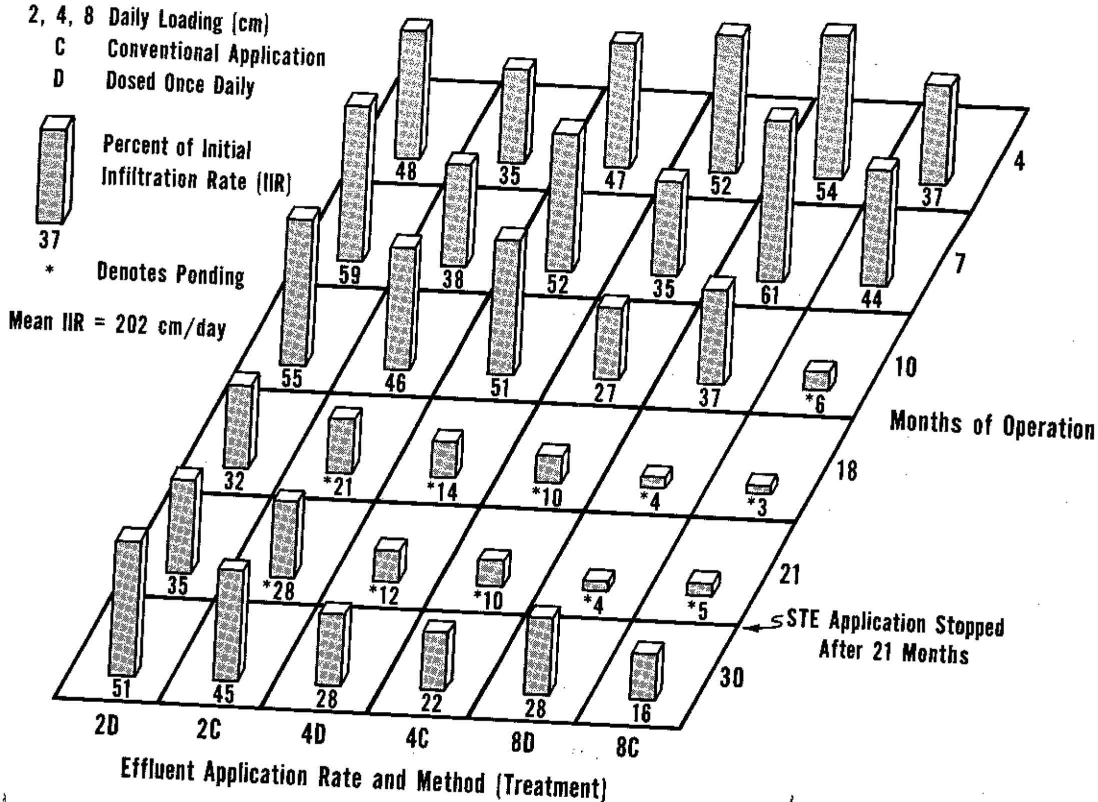

Figure 3. Operating Infiltration Rate, as Percent of Initial Infiltration Rate (%IIR), vs. time, by treatment.

The values depicted in Figure 3 have been normalized to a percent of the initial infiltration rate (%IIR) for each treatment. This proved useful in dampening the variability in the IIRs of the 18 cells, an expression of soil variability at the site. The %IIR values of Figure 3 represent the operational infiltration rate, that is, a rate measured to correspond to the operating conditions of ponding, if present, at that time in the study. With proper assumptions, an infiltration rate based on a common hydraulic head could be calculated. Such corrected %IIR values would reduce the apparent infiltrative capacity in proportion to the depth of ponding. It is more appropriate to express infiltrative capacity in terms of operational conditions. In reality, the amount of equilibrium ponding present on a given day expresses the hydraulic head required by that system to drive the daily wastewater load through the barrier.

Examining Figure 3, we see that early in the study (4 months) there was no apparent trend in infiltrative capacity as influenced by either application method or rate. It is important to note, however, that an average of only 46 %IIR was retained after only four months of wastewater application. After seven months of operation an effect associated with method of application had developed. For each application rate, the %IIR was considerably higher for the dosed cells than for the conventionally loaded cells. However, there was no clear trend at this time based on application rate. The effect of application method was even more strongly expressed at ten months and by this time a strong rate effect had become evident, especially for the conventionally loaded cells. At this time the %IIR values ranked by treatment as 2D > 4D 2C > 8D > 4C > 8C. Between 4 and 10 months of operation the 8C, 8D, and 4C treatments continued to decline whereas the other treatments had been generally stable or variable.

Between 10 and 18 months of operation the infiltration conditions of all treatments declined, but especially those which became ponded during this period. At this time all of the treatments except 2D had become ponded and their %IIR values, all <15 percent, ranked as 2C > 4D > 4C > 8D > 8C. The correlation between the presence and magnitude of ponding and the relative %IIR values is highly evident for the 18 month data. Lower application rates and dosed treatments continued to display the highest %IIR values. However, since all 4 and 8 cm/day treatments were ponded at this time, the effect of dosing at these rates had become very small. Nevertheless, at 2 cm/day dosing continued to have an apparent advantage over conventional application in terms of maintaining intermittently aerobic conditions and higher infiltration rates.

The %IIR values at 21 months were very similar to those at 18 months, suggesting perhaps that some stabilization of the systems had occurred. However, the dynamics of flow had actually deteriorated somewhat as indicated by the increased ponding depths between 18 and 20 months for all ponded cells (Figure 2). Although the variable %IIR remained relatively constant curing this period, the forces required to drive the daily effluent load through the clogged system had increased significantly. Thus, the hydraulic resistance of each of these treatments had continued to increase.

Wastewater application to the systems was stopped after 21 months of operation, in September 1980. By late September, some 8C (8 cm/day conventional) cells experienced ponding depths-approaching the height (30 cm) of the corrugated steel sleeve confining the gravel. Overflow into the surrounding soil body would have resulted in loss of experimental control for those cells. Because of these and other factors, the wastewater application study was unfortunately ceased.

After nine months of system rest infiltrative capacity was again measured (at 30 months or May 1981) to determine the degree of natural rejuvenation. Figure 3 shows that the %IIR values increased for all treatments during this period. As indicated, all treatments improved in permeability. The average increase in permeability was 16 percent of IIR, or about 1.8 percent increase per month. Dosed treatments displayed a mean of 18.7% increase, whereas conventional treaments showed 13.3% increase. These improvements in infiltrative capacity are probably significant but appear to be rather sluggish. In any case, at least for the 4 and 8 cm/day loaded cells, natural rejuvenation was not great enough during this nine months to recommend that the systems begin receiving effluent again. These cells ranged foom 16 to 28 %IIR after the rest period. After May 1981 other strategies for rejuvenating the cells were pursued; these results constitute another experiment and will be presented elsewhere.

SUMMARY AND CONCLUSIONS

The effects of method and rate of application of septic tank effluent to replicated soil absorption systems in an undisturbed silty clay loam subsoil were studied. Soil and wastewater properties were thoroughly characterized and each experimental factor was carefully controlled. Methods of wastewater application included conventional (simulated) and dosed (uniformly once-daily). Wastewater application rates were 2, 4, and 8 cm/day, with 2 cm/day as the normal design loading rate based on soil properties. The primary variables measured were depth of effluent ponding and infiltration rate; both are direct indicators of the absorption capacity of the systems.

Interpretations of this study's results should be tempered by a degree of caution because of the specific conditions and limited duration of the experiment. Wastewater was applied for only 21 months; therefore, no absolute statements regarding long-term effects should be related. Also, because soil conditions were specific, it would be unwise to make general inferences to distinctively different soil conditions. With these qualifications, the following conclusions are developed from the results of this study.

1. The loss of infiltrative capacity is related to the amount and frequency of wastewater applied over time.

2. The initial loss in system permeability is very rapid regardless of application rate or method.

3. Loading rates higher than those appropriate for soil conditions cause the most rapid and continuous long-term declines in infiltrative capacity. Generally, the higher the loading rate the more rapid and severe the loss in permeability.

4. Conventional application, even at conservative rates, is likely to result in some degree of system ponding.

5. Dosing results in higher infiltration rates as long as the application rate is not so high as to induce persistent ponding, thereby negating the effect of dosing. At reasonable application rates, dosing can be useful in maintaining higher infiltrative capacity than conventional loading.

6. Dosing has little, if any, long-term advantage over conventional application for high loading rates. The short-term advantage is to delay ponding for one or two months.

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