THE SOIL AS A TREATMENT SYSTEM

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Approximately 25% of all housing units in the United States dispose of their waste through a septic tank - soil absorption system (Cooper and Rezek 1977) and more systems using soil to perform a major portion of sewage treatment are being installed each year. Small communities such as Westboro, Wisconsin are even utilizing the soil for purification of centrally collected waste (Otis 1977). The effectiveness and acceptability of these disposal systems depend on the soil for absorbing and purifying the wastewaters.

Failure of the soil absorption area may result in a health or environmental hazard or a public nuisance. Inability of the soil to accept the septic tank effluent results in surfacing or "backing-up" into the house, a commonly recognized failure. However, often unnoticed rapid transport through large cracks in the underlying materials such as creviced bedrock, or for short distances to high ground water because of poor siting also constitute failure. In evaluating the effectiveness of the soil as a treatment medium it is necessary to consider the fate of bacteria, viruses, organic substances and the nutrients N and P. The purpose of this paper is to review what is known about the soil as a treatment medium for on-site disposal of wastewaters.

THE SEPTIC TANK SYSTEM

On-site disposal systems most frequently employ a septic tank to remove settlable and floatable solids and to store the sludges and scums. Because of the active bacterial populations in the tank, approximately 40% of the solids passing from the waste source to the septic tank are altered and passed on to the soil absorption area. The soil absorption area may be in the form of a bed, pit, or trench or some combination of man-placed materials and the natural soil, as used in mound or fill systems. Regardless of the source of the earthy materials the principles of function in the bed should be similar. A diagram of a typical septic tank - soil absorption system is shown in Fig. 1.

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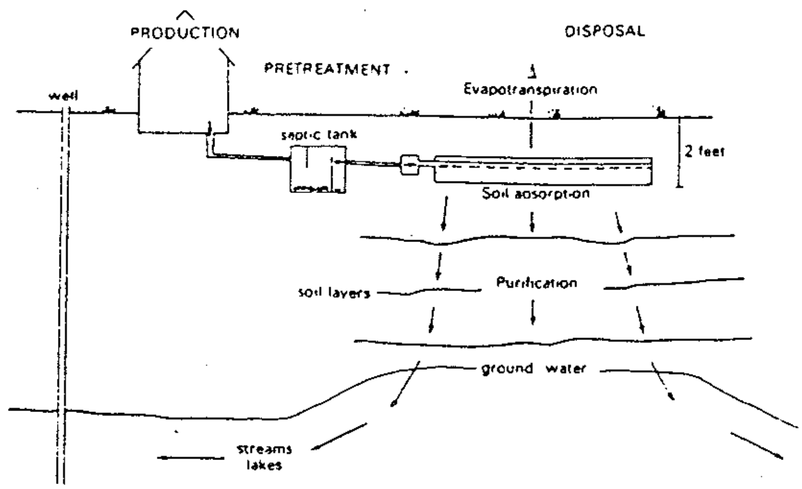

Fig. 1. Schematic Diagram of Typical Septic Tank Soil Absorption System.

Septic tank effluent still needs considerable treatment before being returned to the hydrocycle. Activity in the tank does reduce the biochemical oxygen demand (BOD), total suspended solids (TSS), and N from the levels in raw household waste. As illustrated in Table 1. the composition of these effluents is variable.

Table 1. Mean and Range of Constituents in Septic Tank Effluents (Otis et al. 1975).

	Mean	Interval
BOD_5 (mg/L)	158	142-174
TSS (mg/L)	54	47-62
Fecal Coliforms (No./mL)	4210	2879-6158
Fecal Streptococci (No./mL)	38.2	20.1-72.4
Total Nitrogen (mg-N/L)	55.3	48.9-61.6
Ammonium-N (mg/N/L)	38.7	34.3-43.0
Nitrate-N, Nitrite-N (mg-N/L)	0.56	0.39-0.82
Total Phosphorus (mg-P/L)	14.6	11.4-17.7
Orthophosphate (mg-P/L)	11.5	10.2-12.8

Although usually called the absorption bed of the septic system, the soil does more than receive and dispose of the wastewater. It also purifies that water as the final step of treatment. The septic tank effluent contains partially digested sewage, partly soluble and partly solid matter. The septic tank is anaerobic and the BOD of its effluent is high, as indicated in Table 1. (BOD_5 158 mg/L mean). As this effluent enters the soil it often encounters aerobic conditions, where biodegradation can continue oxidatively and further reduce the BOD. The bacteria carrying out this purification are a complex of those in the sewage (using their aerobic oxidative metabolism) plus the highly efficient aerobic bacteria of the soil. If growth conditions permit, the sewage-soil bacteria can biodegrade the whole complex of sewage organics--proteins, fats, carbohydrates including cellulose of kitchen and toilet tissues, pectin and lignin of vegetable wastes, even hydrocarbons and many more.

The bacteria growing under conditions of excess carbonaceous nutrients, store polysaccharides as slime capsules, and thus slimy films of bacteria cover the soil particles in the region of the trench. These slimes, along with the fine pore system of the soil, trap additional bacteria and some suspended solids, thus creating the so-called crust or clogging zone. The clogging in this zone may be enhanced under some conditions by swelling of clay sized soil particles and alteration of the soil fabric. The conditions created in the soil because of the clogging layer and previously existing natural conditions will be those where most treatment must occur and will be discussed briefly.

In naturally well drained soils, the soil horizons under the absorption bed will be unsaturated because of impeded flow through the crust. Therefore the rate of flow through the soil is much lower than from an uncrusted bed. In fact, the flow under a clogging layer in a sand may be more than 100 times less than the saturated flow for that sand. This allows the effluent to be in contact with the soil a considerable length of time. The flow into the soil is a function of the head of effluent above the crust, the resistance of the crust and the moisture potential of the underlying soil. At some point the crust-soil system may not accept all the added effluent and some will "back-up" spilling over the surface of the ground or into the lower level of the house. Only the effluent accepted by the soil will be considered in this paper. A good discussion of flow in crusted soil is given by Bouma (1975).

Because different crust-soil, loading and ground water combinations result in different degrees of soil saturation it would be expected that the degree of aeration would be different for each case. Based on knowledge of measured soil moisture conditions under absorption beds in different textured soils Sikora and Corey (1975) estimated that soils with sandy, sandy loam, and loamy textures, would generally be aerobic and in clay soils conditions would be "nearly" saturated and anaerobic. In silt loam and silty clay loam textured soils an intermediate aerobic-anaerobic condition would likely occur. Undoubtedly, because of the variations in soil materials there could be pockets or zones of contrasting aeration conditions around any system. This has also been suggested by Winneberger (1971).

The soil constituents themselves can react with the applied effluent. Soil particles are negatively charged and act as cation exchangers. In general, the finer the soil particles the greater the cation exchange capacity of the soil; however, some minerals have greater charges than others and can contribute greatly to the variations in exchange capacity. Soil organic matter is also highly charged and an important cation exchanger. Ca, Al and Fe compounds are found in the soil solution and associated with soil particle surfaces. The form and amount of these substances depends greatly on the pH of the soil. These substances are particularly important when considering reactions of P.

Septic tank effluent passing the crust layer and going slowly through a soil will have time for many reactions to occur at the surfaces of particles and in the soil solution which is in contact with air-filled voids. If, however, flow is very rapid as in a gravelly soil or through large cracks in bedrock very little time is available for purification to occur. This situation has long been recognized and has been related to severe groundwater pollution. It is also possible to have channels or cracks in fine textured soils. These features may be a result of worm activity in some soils (producing large continuous channels as much as several millimeters in diameter) or the natural breaks between the peds or structural units. As illustrated in Fig. 2 these large pores adjacent to a region of saturation will result in continuous saturated flow through that pore before there is time to enter the finer pores in the soil. This type of flow is referred to as "short circuiting". If the loading rate is low or a clogging mat is present this type of flow will not occur (Fig. 2).

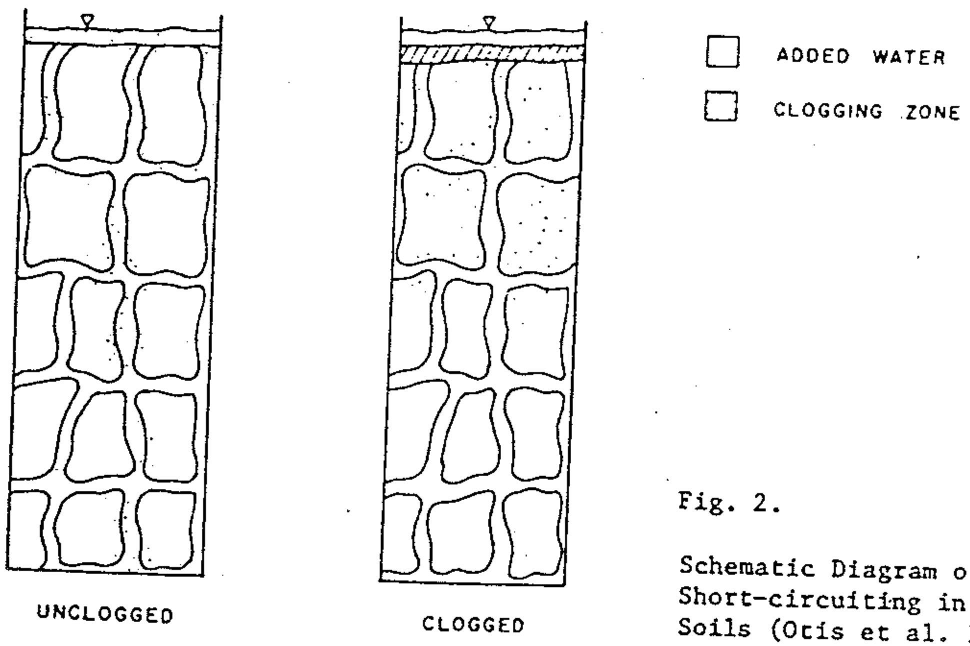

Fig. 2.

Schematic Diagram of Possible Short-circuiting in Structured Soils (Otis et al. 1977).

"Short circuiting" has been evaluated quantitatively using a chloride tracer by Anderson and Bouma (1977a, b) and a model defining the system through part of the breakthrough curve has been proposed by Skopp et al. (1977). It would appear that a high dosing load in the absence of a clogging layer on previously drained soils would allow very rapid break through (Anderson and Bouma 1977).

The interaction of septic tank effluent and the soil under different flow regimes is complex. Of major concern to public health and the environment is the removal of bacteria, and viruses and compounds of N and P. In some rare cases other substances may also be important.

BACTERIA AND VIRUSES

Bacteria and viruses causing intestinal or so-called enteric diseases such as typhoid and paratyphoid, food poisoning and other diarrheas and dysenteries are of major public health concern. In the intestine the bacteria and viruses are usually harmless, but when excreted with feces they are potential pollutants and must be contained in sewage until they can be eliminated by treatment.

Many intestinal bacteria are actually the same kinds as in soil and water in nature and are the agents of biodegradation of the wastewater within the absorption bed. It is recognized by bacteriologists that the Standard Bacteria Count (Standard Methods 1976) is far from a total count but the test reflects the general aerobic-facultative or heterotrophic types typical of sewage flora. As reported by Wilson and Miles (1964) and Smith and Crabb (1961) there are very large numbers of living bacteria in feces and even greater numbers of dead bacteria. The bacteria in waste disposal are responsible for hydrolysis of complex organic matter followed by oxidative decomposition to simple soluble, eventually mineralized compounds of N and C. This reduces the BOD of the sewage to a stable low level, acceptable for soil disposal.

Viruses differ from bacteria in that they are incomplete as living entities. They are very small and primitive in the sense of having limited molecular chemical apparatus consisting of a nucleic acid coated with protein. They cannot reproduce except in a host cell and are therefore only in a transmission stage in sewage. Viruses are found in sewage only from households with an infected person and they are most commonly contributed by children.

It is very difficult to detect all types of bacteria and viruses. Therefore indicator and tracer organisms are often used. The interpretation is that where the indicators are found the pathogens of public health significance may also be. Fecal streptococci and fecal coliform bacteria are used as indicators of fecal pollution because they are (1) present in high numbers in feces of man and warm-blooded animals, (2) able to survive outside the body, (3) detectable quantitatively and (4) found in high numbers relative to the pathogens. Actual pathogens such as Pseudomonas aeruginosa and Staphylococcus aureus are often determined to verify the findings established by the indicator bacteria. Poliovirus has been used as a tracer in laboratory studies of virus movement in soil materials (Green and Cliver 1974).

Removal of Bacteria and Viruses in Soil

The mechanism of removal of bacteria and viruses by the soil is very complex and probably a number of processes are operating simultaneously. Under some applications removal is very good, while in others it is not.

Bacteria and viruses are charged and therefore can be adsorbed on the soil particles. As mentioned before the bacteria can then grow on the nutrients producing slimy films over the soil particles ultimately producing the crust. The filtering action plus subsequent growth accounts for the higher bacterial counts found in the clogging zone of a trench soil absorption system, than in the septic tank effluent (Fig. 3).

At a distance of 1 foot into the soil surrounding the trench there was a 3 Log reduction in bacterial numbers and within the second foot counts are to the acceptable range for a fully treated wastewater.

The reduction in numbers of sewage bacteria in the soil is a complex phenomenon resulting from filtering action, die-off by attrition of nutrient, or action of toxic chemicals either in the environment or the accumulated end products of the bacteria themselves. In the 1 to 2 foot zone in the study illustrated in Fig. 3, significant counts of bacilli, actinomycetes and molds were found. These organisms are well known to produce antibiotics, and antibiotic potency was detectable in this zone. Die-off because of antibiotics would be additive to die-off by attrition.

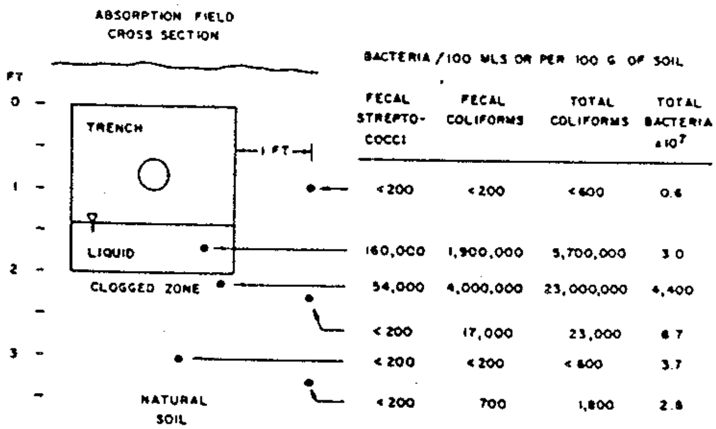

Fig. 3. Cross-section of Seepage Trench in Sand Showing Bacterial Counts at Various Points (Ziebell 1975).

Laboratory studies using columns containing different soils make the testing of specific design variables simpler to identify. Ziebell (1975) ran 60 cm long columns of sandy soils and of silt loam structured soils. The sands loaded with a 5 cm/day dose of septic tank effluent removed more bacteria than those sands loaded with a 10 cm/day dose. Once a clogging layer was formed, removal was enhanced greatly. In the silt loam textured soil a loading rate of 0.3 cm/day of septic tank effluent was necessary to adequately purify the effluent. At a loading of 1 cm/day doses it is believed that "short circuiting" occurred around the soil peds causing high transmission of bacteria. Viruses applied to a 60 cm long sand column were completely removed when added with a 5 cm/day dose while a 50 cm/day dose resulted in viruses passing through the column (Green and Cliver 1974). This experiment is illustrated in Fig. 4.

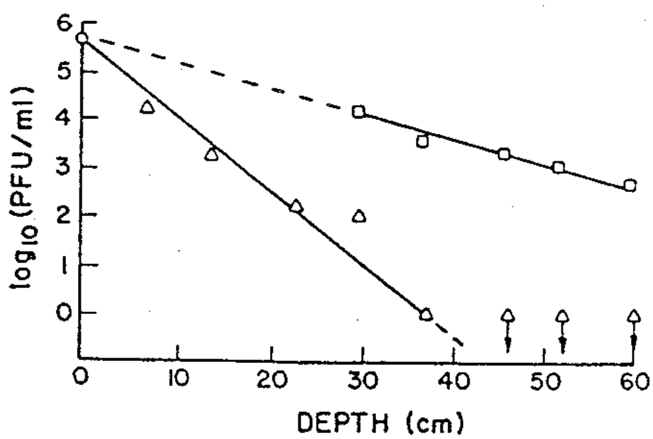

Fig. 4. Penetration of Poliovirus into a 60 cm Sand Column from a Δ 5 cm/day and □ 50 cm/day dose (Green and Cliver 1974).

It would appear from these studies that sandy soils without structure loaded at 5 cm/day or less should adequately remove bacteria and viruses. In structured soils without a crust, lower loading rates are required to achieve purification within 60 cm. High loading regimes which inhibit crusting should be given serious consideration since they may result in short circuiting. In crusted or clogged soils where infiltration rates are limited by the crust, loading rates themselves are less critical until surfacing of effluent occurs or the system "backs up".

Treatment of septic tank effluent in soil has also been shown to be a function of temperature. Ziebell et al. (1975a, b) and Green and Cliver (1974) have demonstrated that removal can be decreased at lower soil temperatures. The removal of bacteria at 5°C rather than at 20°C was improved over time, however, because a clogging mat rapidly formed (Ziebell et al. 1975a, b). In sand columns at 20°C, 2.5% of initially applied viruses were present, while at 8°C 57% remained (Green and Cliver 1974). Under a soil absorption system soil moisture would not be limiting to the activity of the microorganisms but soil temperature regimes may be very important particularly in the soil temperature regimes of mesic (mean annual soil temperature between 8° and 15°C) and frigid (mean annual soil temperature < 8°C) as defined by the Soil Survey Staff (1975).

NUTRIENTS

The nutrients N and P are of major concern to on-site wastewater systems using the soil. NO_3-N is an end product of the soil related reactions and excessive amounts of 45+ mg/L as NO_3-N are considered toxic (Standard Methods 1976). Phosphorus, on the other hand, has been shown to favor eutrophication of surface waters but does not appear to pose any problem in drinking waters.

Nitrogen

Many studies have reported levels and forms of nitrogen in septic tanks of which one example was shown in Table 1. Usually about 75% is NH_4-N and 25 % organic-N. Upon entering the soil further adsorption and ammonification with resultant ion exchange, volatilization, biological uptake, nitrification or denitrification may occur.

Ammonification: The biodegradation of organic N can occur in the crusting zone and underlying soil releasing NH_4-N. The simplified reaction may be represented by the equation (Hendricks and Pote 1974; Lance 1972):

$$\text{Organic-N} \xrightarrow{\text{Hydrolysis}} NH_4^+ \text{ and other products} \qquad (1)$$

Adsorption: In cases where nitrification does not predominate NH_4-N can persist and adsorption can be significant. If insufficient aeration exists in the crusting zone in fine textured soils or when the ground water table rises near the leaching trench to allow for nitrification; the NH_4-N will persist (Dudley and Stephenson 1973; Pruel 1967; Sikora and Corey 1975). This cation is adsorbed on the cation exchange sites in the soil. Adsorption capacity may vary from 2 mg N/100 gm of soil for a sandy soil to 10 mg N/100 gm soil or higher for a fine textured soil (Polta 1969; Pruel and Schroepfer 1968). Adsorption is reversible and NH_4-N is then subject to nitrification if an aerobic zone is reached, a carbon source is available and the proper bacteria are present. Under certain conditions the NH_4-N may be volatilized or fixed. Fixation can be in the clay mineral structure and/or the more stable organic fraction of the soil. This removes the ammonia from the mobile part of the soil system. In some soils the organic fraction may play a greater role in fixation than the mineral fraction (Baily 1968, 1969; Lance 1972) however, this may only account for a small percent of the total N present in the soil (Sikora and Corey 1975).

Ammonia Volatilization: Very little volatilization of ammonia (NH_3) is expected around subsurface seepage fields because the pH of domestic wastewaters (6.5 to 7.5) and the low air-water contact is not conducive to NH_3 loss (Lance 1972; Pound and Crites 1973).

Nitrification: Nitrification is an aerobic biological reaction that occurs in at least two steps to ultimately form nitrate. The first reaction is carried out by *Nitrosomonas* and to lesser extent by *Nitrosospira* and and *Nitrosoccoccus* and produces nitrite. A simplified equation is (Fair et al. 1971):

$$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 4H^+ + 2H_2O + \text{energy} \qquad (2)$$

The second reaction is accomplished by *Nitrobacter*. The simplified equation for this reaction can be represented by (Fair et al. 1971):

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^- + \text{energy} \qquad (3)$$

The bacteria affecting this reaction are referred to as chemoautrotrophic bacteria. Carbon dioxide is their only carbon source for production of new cell material. The energy for the synthesis is provided by oxidation of ammonium or nitrite.

Nitrification occurs very commonly in the zone of aeration between the seepage trench and capillary zone. It fails to occur in systems where the ground water is very near to the bottom of the leaching trench or in clay soils where the system operates at near saturation so that anaerobic conditions prevail (Dudley and Stephenson 1973). The public health significance of the nitrate ion coupled with its mobility in aqueous solution in soils make the nitrification reaction highly important. Danger to potable well water can sometimes exist in intensely populated areas where both absorption fields and well waters are used.

Biological Uptake: Plants can remove significant amounts of nitrogen from soil, if it is available in the root zone. Extensive root systems are not present in seepage fields and therefore only limited amounts of N would be taken up. Bacteria and other microorganisms consume NH_4-N, soluble N and to lesser extent NO_3-N but release N after death.

Denitrification: Denitrification, when it occurs, closes the loop of the nitrogen cycle by reducing nitrates to gaseous forms. The reaction is represented by the following equation (Lance 1972; Tilstra et al. 1972):

$$NO_3^- + \text{carbon source} \xrightarrow[\text{bacteria}]{\text{denitrifying}} N_2 + H_2O + CO_2 + \text{cells} \qquad (4)$$

The bacteria use the nitrate as an electron acceptor in anaerobic environments. Temperature should be above 10°C and pH above 5.5 for rapid denitrification (Lance 1972). The reaction can be carried out by *Pseudomonas*, *Achromobacter*, *Bacillus* and *Micrococcus* species (Reeves 1972).

For denitrification to occur nitrates must pass into an anaerobic environment along with a sufficient carbon source to support the denitrification reaction. Winneberger (1971) argues that significant denitrification occurs in soils in zones of "micro-anaerobiosis" such as around decaying roots. Other investigators (Glandon and Beck 1969; Patrick and Tasneem

1972) have been able to create the conditions for soil denitrification in laboratory simulation.

In leaching fields where several feet of unsaturated flow in aerobic soil between the seepage trench and the ground water is available, nitrification followed by leaching of the nitrate into the ground water occurs (Bouma et al. 1972; Dudley and Stephenson 1973 and Pruel 1967). Dilution is the main mechanism available to reduce nitrate concentrations to safe levels. In conditions of high ground water or very slowly permeable soils where anaerobic conditions exist adsorption of ammonia onto the clay and organic fraction of soils occurs and nitrification is avoided (Bouma et al. 1972; Dudley and Stephenson 1973 and Pruel 1967). As adsorption sites become exhausted (Soil Conservation Service 1976), ammonium travels. Most of the ammonium is subject to nitrification and leaching if aerobic conditions are reestablished (Lance 1972).

Phosphorus

Detergents and human wastes account for the bulk of P found in the septic tank effluent (Otis et al. 1975). In the tank most of the P is altered to soluble orthophosphate before reaching the soil. Phosphorus added to the soil initially can be chemisorbed on mineral surfaces. As the concentration of P increases in the soil solution precipitates may form. The Langmuir and Freundlich absorption isotherms along with precipitation reactions are most often used in agricultural research to relate solution concentrations to the amount of P sorbed by the soil and have been used to evaluate P removal from wastewater by soil (Enfield and Bledsoe 1975; Sikora and Corey 1975).

The phosphate ion forms relatively stable surface compounds or precipitates with compounds containing Fe or Al in neutral to acid systems or Ca in neutral to alkaline systems. Based on the reported pH's of the septic tank effluents compounds containing any of the cations could probably immobilize P (Sikora and Corey 1975). The Langmuir isotherm is most often used to relate the small portion of solution P with that sorbed. Deviations from the Langmuir isotherm may be due in part to decomposition-precipitation reactions.

If the P concentration in the soil solution is relatively high, as might be expected under an operating soil absorption bed some precipitates might form as predicted by solubility products. Enfield and Bledsoe (1975), have listed some of these reactions and their respective equilibrium constants and ion activities have been reported by Lindsey and Moreno (1960) as listed in Table 2.

Table 2. Ion Activity Products of Some Important P Compounds (Lindsay and Moreno 1960).

Mineral		pK*
Strengite	$FePO_4 \cdot 2H_2O$ or $Fe(OH)_2H_2PO_4$	33.6-35.0
Variscite	$AlPO_4 \cdot 2H_2O$ or $Al(OH)_2H_2PO_4$	30.5
Dicalcium phosphate	$CaHPO_4 \cdot 2H_2O$	6.56
Octacalcium phosphate	$Ca_4H(PO_4)_3 \cdot 3H_2O$	46.91
Hydroxyapatite	$Ca_{10}(PO_4)_6(OH)_2$	113.71

*pK = Log(Ion activity product)

Sikora and Corey (1975) report that at the P concentrations similar to those found in septic tank effluents, dicalcium phosphate or octacalcium phosphate are initially formed followed later by hydroxyapatite (Lindsay and Moreno 1960).

The rate at which P is initially sorbed onto the soil particle surfaces is rapid followed by a slower reaction. This slow reaction has been attributed to diffusion of P into the sorbing material or by a slow decomposition-precipitation reaction as reviewed by Sikora and Corey (1975). Since the concentration of P around a soil absorption system is fairly high it is expected that these reactions would be important.

Because of the decomposition-precipitation reactions the amount of P retained by a soil may exceed that predicted by the Langmuir adsorption maxima (Sawhney and Hill 1975; Beek and deHaan 1974). Walker (1973) reported from 100 µg/g to 300 µg/g of soil beneath the bed of a sandy soil and 121 µg/g was found in a sandy soil column (Magdoff and Keeney 1976). This is considerably more than the 90 µg/g soil estimated from a Langmuir adsorption isotherm. Based on this type of information Sikora and Corey (1975) estimated that the depth of penetration of P in sandy soils would be about 50 cm per year while on finer textured soils it might be as low as 10 cm per year. Therefore, problems with P contamination where clean sands are found may be possible after a considerable length of time. Of course, in situations with "short circuiting" this situation would not hold true.

OTHER SUBSTANCES

Literature search showed that heavy metals from individual homes have not been measured sufficiently to establish a firm data base. An analysis of tap water and grey water from a single family household is shown in Table 3 of Winneberger (1975).

Table 3. Chemical Characteristics of Tap Water and Grey Water with Garbage Disposal Solids. (Winneberger 1975).

Metal	Tap water mg/L	Grey water mg/L		
		Low	High	Average
Arsenic	<0.01	<0.01	<0.01	<0.01
Barium	<1	<1	<1	<1
Cadmium	<0.01	<0.01	<0.01	<0.01
Chromium	<0.05	<0.05	<0.05	<0.05
Copper	0.08	0.14	0.20	0.17
Iron	0.18	0.19	0.64	0.46
Lead	<0.01	0.02	0.04	0.03
Manganese	<0.05	<0.05	<0.05	<0.05
Nickel	<0.05	<0.05	<0.05	<0.05
Selenium	<0.01	<0.01	<0.01	<0.01
Silver	<0.05	<0.05	<0.05	<0.05
Sodium	8	71	78	75
Zinc	0.39	0.35	0.53	0.45

were found to be free of E. coli (Sandhu et al. 1976). More than 98% of these samples were drawn from wells of consumers using septic tanks for waste disposal. Statistical analysis relating the number of E. coli in well water to the depth of wells and distance between the well and septic field suggested the septic tank effluents as a possible source of bacterial contamination of these wells. It appeared certain soils were more efficient in filtering the bacterial pollutants than others.

SUMMARY AND CONCLUSIONS

In the soil horizons under a soil absorption system unsaturated flow will occur if a crusting layer is present at the infiltrating surface. In naturally well drained soils, the actual moisture condition will control the degree of aeration. In general, sands would be aerobic and clays anaerobic. Water movement would be by unsaturated flow and therefore considerably slower than if saturated flow were possible allowing a considerable time for efficient soil contact.

In the absence of a crusting layer, flow in sand is rapid and effluents may pass with limited treatment. Also, in structured soils "short circuiting" may occur when large continuous pores are in direct contact with free water. In system designs which inhibit the formation of crusts, control of loading rate and frequency will be critical to avoid short circuiting problems. In crusted systems flow control is not as critical.

Some bacteria and viruses added to the wastewaters are pathogens. Their movement during unsaturated flow is expected to be limited to within a meter. The bacteria and viruses are trapped in the clogging layer of the soil, die-off by attrition or are killed by antibiotics or lack of nutrients. During periods of cold the die-off of both bacteria and viruses may be inhibited considerably. Bacterial activity in the soil is very important to the operation of a system because they degrade considerable amounts of organic materials reducing the BOD. Statistical analysis has suggested, however, that septic tank effluents could be a source of bacterial contamination to wells.

Nitrogen added to the soil from the septic tank is transformed to NO_3-N if the soil is aerobic. If a carbon source and/or an anaerobic zone is lacking below the zone of NO_3-N formation, denitrification is generally very limited under soil absorption systems. The NO_3-N will pass with percolating waters to the ground water. The movement of the ground water will determine the dilution of NO_3-N and the density of the population contributing waste will determine the loading. Very little is known about the amount of NO_3-N reaching ground water from septic systems and much more work is needed. Particularly in well aerated sandy areas, ground water conditions need to be evaluated. If the soil below the absorption system is saturated N will move as NH_4-N as each increment of soil cation exchange capacity is exceeded.

A considerable amount of P is absorbed and precipitated in the soil system. Its movement, however, may exceed 50 cm a year in "clean" sands. Except in rare cases, other substances such as the heavy metals are not expected to be a problem because of the small amounts present and the high retention in the soil.

Though the soil does not do a perfect job of treating septic tank effluents proper design and management of soil absorption systems allows the soil to remove a very high percentage of the organisms and substances potentially harmful to human health or the environment. The soil is a good treatment system.

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