Ecological Research Series

ENVIRONMENTAL EFFECTS OF SEPTIC TANK SYSTEMS

Robert S. Kerr Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the ECOLOGICAL RESEARCH series. This series describes research on the effects of pollution on humans, plant and animal species, and materials. Problems are assessed for their long- and short-term influences. Investigations include formation, transport, and pathway studies to determine the fate of pollutants and their effects. This work provides the technical basis for setting standards to minimize undesirable changes in living organisms in the aquatic, terrestrial, and atmospheric environments.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

EPA-600/3-77-096
August 1977

ENVIRONMENTAL EFFECTS OF SEPTIC TANK SYSTEMS

by

Marion R. Scalf and William J. Dunlap
Ground Water Research Branch
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

and

James F. Kreissl
Systems and Engineering Evaluation Branch
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

DISCLAIMER

This report has been reviewed by the Robert S. Kerr Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques, and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate, and management of pollutants in ground water; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to that knowledge which is essential in order for EPA to establish and enforce pollution control standards which are reasonable, cost effective, and provide adequate environmental protection for the American public.

William C. Galegar
Director

ABSTRACT

Septic tank-soil absorption systems are the most widely-used method of on-site domestic waste disposal. Almost one-third of the United States population depends on such systems. Although the percentage of newly constructed homes utilizing septic tanks is decreasing, the total number continues to increase.

Properly designed, constructed and operated septic tank systems have demonstrated an efficient and economical alternative to public sewer systems, particularly in rural and sparsely developed suburban areas. However, because of their widespread use in unsuitable situations, they have also demonstrated the potential for contamination of ground and surface waters.

CONTENTS

FIGURES

TABLES

SECTION 1

INTRODUCTION

Almost twenty million housing units, representing about twenty-nine percent of the United States population, dispose of domestic waste through individual on-site disposal units. About eighty-five percent of these units are septic tanks and cesspools, which discharge approximately 3 billion cubic meters (800 billion gallons) of waste per year to the soil (1).

Septic tank systems were introduced into the United States almost one-hundred years ago but the major growth in use of these systems took place after World War II due to the combined effects of rural electrification and explosive development of suburban areas around major cities. Although the relative percent of newly constructed homes utilizing septic tanks is decreasing each year, the total number is increasing at a rate of about one-half million per year (2).

The basic septic tank system consists of a buried tank where water-borne wastes are collected, scum, grease and settleable solids are removed from the liquid by gravity separation, and a subsurface drain system where clarified effluent percolates into the soil. There have been few major design modifications in the past several decades and most systems are constructed and installed today in much the same manner as before World War I (2).

Although the concept and design are relatively simple, the septic tank system is a complex physical, chemical and biological system. Performance is essentially a function of the design of the system components, construction techniques employed, characteristics of the wastes, rate of hydraulic loading, climate, areal geology and topography, physical and chemical composition of the soil mantle, and care given to periodic maintenance (3).

Septic systems have performed a vital function of environmental sanitation, particularly in rural and sparsely developed suburban areas. However, some estimates indicate that less than one-half of all systems in use today perform satisfactorily for the entire design life of fifteen to twenty years (2). Many public health authorities feel that conventional septic systems are suitable only where population density is strictly limited and soil conditions are suitable for effective absorption. Otherwise, these systems may contaminate ground and surface waters and result in sanitary nuisances and health hazards.

In spite of their limitations and potential for pollution, millions of conventional septic tank systems will continue to be used throughout the United States. Even in areas where housing density and pollution problems may justify conversion to collecting sewers and treatment plants, several years are normally required for public systems to become fully operational after the decision has been made and funding has been secured.

SECTION 2

CONCLUSIONS

1. Almost one-third of the homes in the United States dispose of domestic waste through individual on-site disposal units.

2. Septic tank-soil absorption systems represent about eighty-five percent of the individual disposal units.

3. Because of improper design, improper construction or improper maintenance or a combination of these, a significant percentage of septic tank systems fail within their design life.

4. Soils in many areas, perhaps in as much as one-half of the United States, are not suitable for conventional septic tank-soil absorption systems.

5. Most of the numerical limits found in State and local codes governing septic tank system design and construction are without a sound scientific basis.

6. Septic tank systems are common sources of surface water and especially ground water contamination.

7. The most important factor influencing regional ground-water contamination by septic tank systems is the density of these facilities in an area.

8. Their success in some communities indicates that with proper design, construction and maintenance, septic tank systems can provide satisfactory disposal of wastewater.

9. There are several modifications available to conventional septic tank systems which significantly expand their area of applicability.

10. Despite the potential for pollution and the unsatisfactory performance of many systems, septic tank-soil absorption systems will continue to provide a valuable domestic waste treatment alternative, especially where housing density cannot economically justify sewers and treatment plants.

SECTION 3

RECOMMENDATIONS

Zoning and land use planning in areas of considerable septic tank activity should be based on a thorough understanding of soil variability, geology, topography and aquifer characteristics.

Research should be continued into the basic questions of septic tank use. What are the movement and fate characteristics in the subsurface environment of pollutants from septic tanks, especially viruses and organics? What density of septic tank systems can be tolerated in an area before pollution problems necessitate sewers or septic system modifications?

Research should be continued into the development of septic system modifications and into alternative individual sewage disposal systems.

The social and economic consequences of converting from individual units to sewered and central treatment facilities must be studied with consideration of the resultant loss of ground-water recharge.

SECTION 4

SYSTEM DESIGN

A typical septic tank-soil absorption system (ST-SAS), shown in Figure 1, consists of a building sewer, laid to specified grade, which discharges to the inlet of a septic tank. The septic tank effluent discharges to a series of distribution pipes laid in trenches (absorption trenches) or to a single large excavation (seepage bed). Since seepage beds are not generally satisfactory in soils other than sands, only the absorption trenches are discussed herein.

A typical cross-section of a septic tank is shown in Figure 2. Raw wastewater enters through an inlet structure which generally consists of either a baffle or a tee to dissipate energy and help prevent short-circuiting of the flow. In the main body of the tank, solids separation occurs with heavier solids settling to the bottom where they become part of the sludge layer and lighter solids (grease, wax, etc.) rising to the surface as part of the scum layer. Particularly during warm periods, some amount of anaerobic digestion can occur in these layers, reducing the overall volume of solids retained in the tank. The liquid effluent is discharged through an outlet structure which generally consists of either a baffle or a tee. The relative dimensions of the tank, the type of control structures, etc. are dictated by the State or local codes, as are the sizes and locations of the inspection parts and materials of construction.

A typical cross-section of a soil absorption field (trench) is shown in Figure 3. The intended purpose of the trench system is to distribute the septic tank effluent over a large area for absorption into the ground. Specifications for allowable width and depth of trenches; sizes, types, and depth of fill materials; distances between trenches; minimum cover; and piping materials and arrangements are dictated by local and State codes. More importantly, the overall size and horizontal and vertical distances from other physical and geological features of the site are determined by these codes. Ancillary devices such as dosing equipment and/or distribution boxes which are located between the septic tank and the absorption field are generally specified in each code as to their desirability, physical design, and materials and methods of construction.

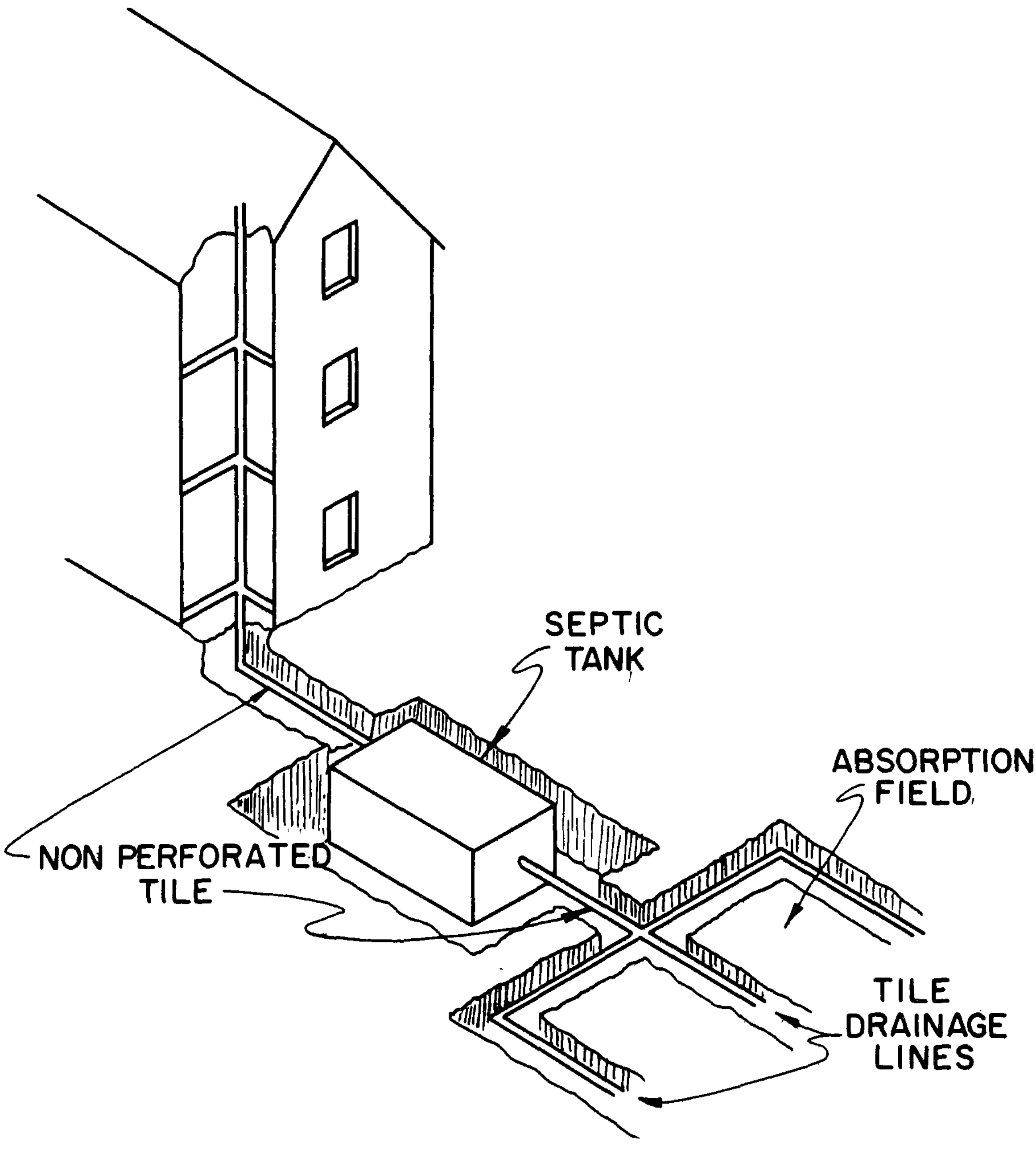


Figure 1. Typical on-site system.

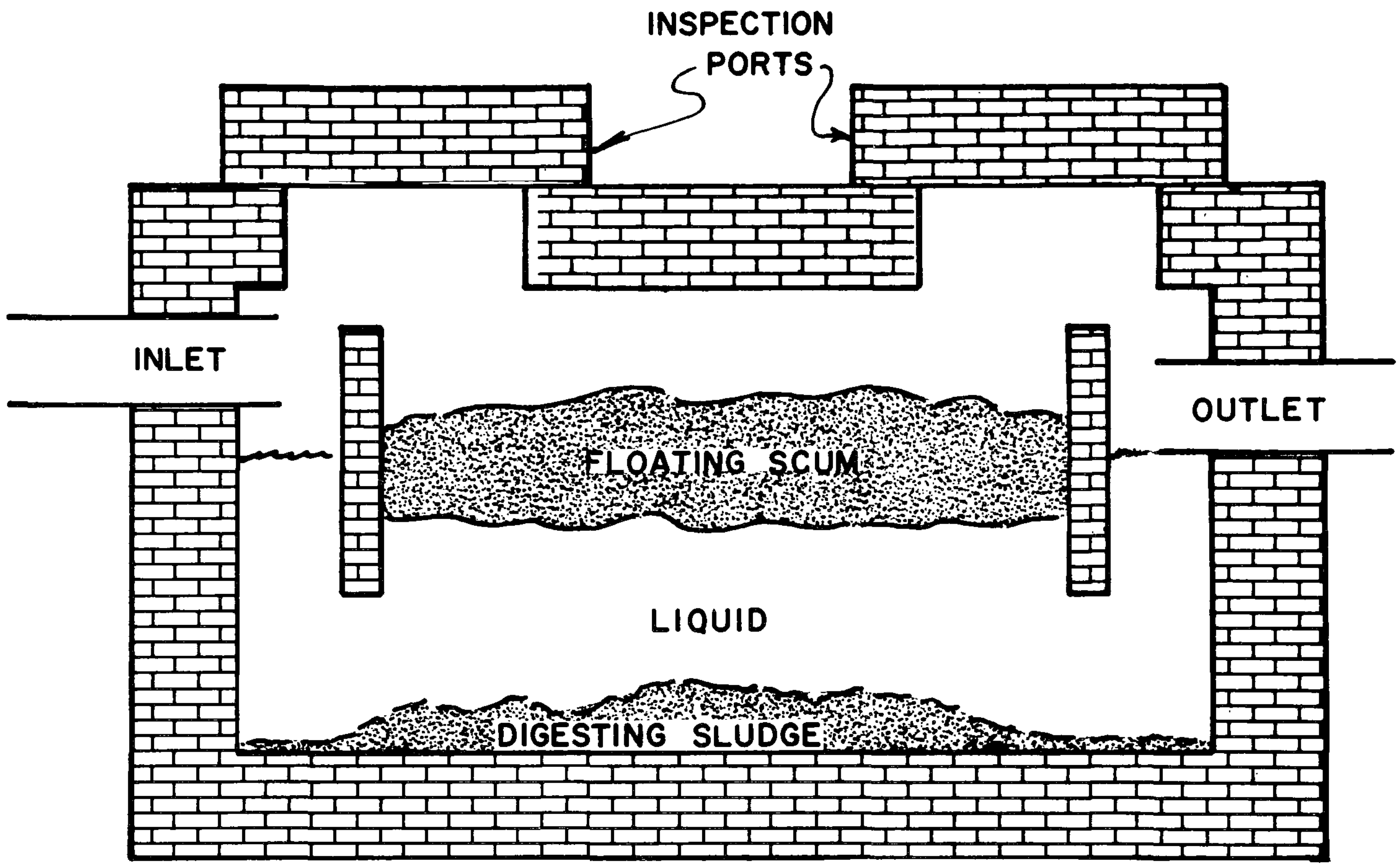


Figure 2. Septic tank.

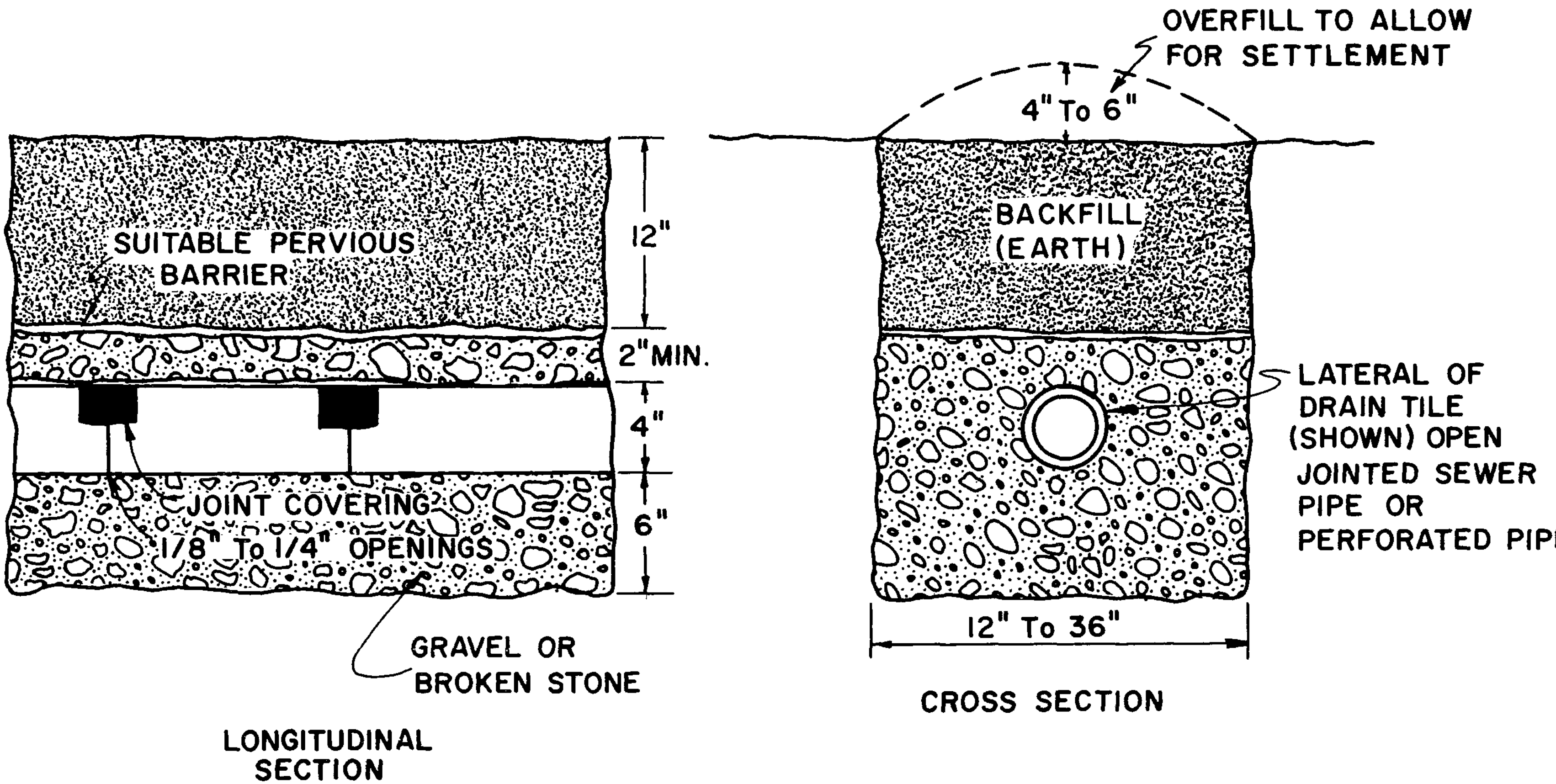


Figure 3. Absorption trench and lateral.

SECTION 5

PRESENT REGULATIONS

Present on-site system practice generally involves a design which must meet some State or local code of requirements. However, these requirements vary widely, as shown in Tables 1 and 2. Several States are not included, nor are several national organization publications such as the USPHS Manual of Septic Tank Practice and National Plumbing Code. However, the tables do illustrate not only the variability of criteria, but also some of the areas of concern to public health officials. Some of these concerns include the movement of pollutants from the absorption fields as indicated by setback distances and minimum percolation restrictions; the flow net below absorption trenches as indicated by the minimum spacings between trenches of varying widths; and aeration, freezing and evapotranspiration phenomena as indicated by minimum cover specifications.

Although not included in Table 1, each code considers the degree of purification imparted by the soil as indicated by minimum distances between trench bottoms and maximum ground-water level, and impervious strata and the hydraulic acceptance of the soil as indicated by flow per interfacial area of soil and soil permeability specifications.

Due to the lack of scientific knowledge concerning what actually happens in the ground, most of the numerical limits are without a sound basis. Between 1945 and 1965, significant data were produced by the U.S. Public Health Service and the University of California but some of these data have been misapplied into inflexible codes, thereby causing as many problems as they have solved. Although some articles on the design and functioning of septic tank-soil absorption fields appeared in the late 1960's, it was not until the advent of the Small-Scale Waste Management Project at the University of Wisconsin that a comprehensive study of on-site systems was attempted. Even though many of the new results have not yet been organized and reduced to practice, several States and local agencies have recognized the obvious lack of scientific background on which existing regulations are based. Some States, such as Maine, have completely revised their codes in an attempt to find new answers directly applicable to their problems.

One of the primary shortcomings of existing codes relates to absorption field sizing based on the percolation test. The percolation test is purported to measure the rate of hydraulic acceptance of a given soil. Unfortunately, the test is quite variable even in the hands of a competent, trained professional. To compound the problem, the test is rarely performed in the specified manner, the manner specified is also questionable, the test has frequently been faked, and the test can be quite costly (generally about $75 to $150).

TABLE 1. ABSORPTION FIELD DESIGN (4)

State	Setbacks: Well	Setbacks: Surface Water	Minimum Spacing (Feet)	Minimum Cover (Inches)	Minimum Percolation Restrictions	Trench Widths (Inches)	Sizing
Alabama	50-75		6	6	None	18-36	Perc
Alaska	50-100	50-100	6	12	None	12-36	Perc & Soils
Arizona	50-100	100	6	12	None	12-18	Perc
Arkansas	. . .	. . .	. . .	. . .	. . .	. . .	. . .
California	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Colorado	100	50	6	12	None	18-36	Perc
Connecticut	75	50	6-9	6	None	18-36	Perc
Delaware	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Florida	75-100	50	6-8	12	None	18-24	Perc & Soils
Georgia	100	50	10	12	None	18-36	Perc & Soils
Hawaii	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Idaho	100	100-300	6	12	None	12-36	Perc & Soils
Illinois	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Indiana	50-100	50	6-7.5	12	None	18-36	Perc
Iowa	100-200	25	7.5	12	None	18	Perc
Kansas	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Kentucky				None			Perc
Louisiana	100			6-12	None	12-18	Perc
Maine	100-300	50-100	10	2-6	None	24	Soils
Maryland	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Massachusetts	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Michigan	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Minnesota	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Mississippi	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Missouri	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Montana	100	100	6	12	Yes	12-36	Perc & Soils
Nebraska	100	50	6	6	No	18-36	Perc
Nevada	100	100	6	4-6	Yes	12-24	Perc
New Hampshire	75	75	6-7.5	6	None	12-36	Perc
New Jersey	. . .	. . .	. . .	. . .	. . .	. . .	. . .
New Mexico	. . .	. . .	. . .	. . .	. . .	. . .	. . .
New York	. . .	. . .	. . .	. . .	. . .	. . .	. . .
North Carolina	. . .	. . .	. . .	. . .	. . .	. . .	. . .
North Dakota	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Ohio	50		6	6	None	8-30	Soils
Oklahoma	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Oregon	50-100	50-100	10	6	None	24	Soils
Pennsylvania	100	50	6	12	Yes	12-36	Perc
Rhode Island	100	50	6	12	None	18	Perc
South Carolina	. . .	. . .	. . .	. . .	. . .	. . .	. . .
South Dakota	100	100	6		Yes		Perc
Tennessee	50	50	6	12	None	18-36	Perc & Soils
Texas	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Utah	100	100	6-7.5	12	None	12-36	Perc
Vermont	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Virginia	35-100	50-100	6-9	None	None	18-36	Perc & Soils
Washington	75-100	100	6	6	Yes	18-36	Perc & Soils
West Virginia	100	100	6	12	None	12-36	Perc
Wisconsin	50-100	50	10	12	None	18-36	Perc & Soils
Wyoming	100	50	6-7.5	6-12	None	12-36	Perc

TABLE 2. SEPTIC TANK DESIGN AND WATER DEPTH (4)

States	Tank Size in Gallons					Minimum Water Depth (Feet)	Open Discharge
	Number of Bedrooms						
	1	2	3	4	5		
Alabama	1000	1000	1000	1200	1400	4	
Alaska	750	750	900	1000	1250	4	No
Arizona	960	960	960	1200	1500	4	No
Arkansas	...	...	...	...	...	...	...
California	...	...	...	...	...	...	...
Colorado	750	750	900	1000	1250	No Minimum	Yes
Connecticut	1000	1000	1000	1250	1500	1.5	No
Delaware	...	...	...	...	...	...	...
Florida	750	750	900	1000	1200	1.5	No
Georgia	750	750	900	1000	1250	No Minimum	No
Hawaii	...	...	...	...	...	...	...
Idaho	750	750	900	1000	1250	4	No
Illinois	...	...	...	...	...	...	...
Indiana	750	750	900	1100	1250		No
Iowa	750	750	1000	1250	1500	1.5[A.]	Yes
Kansas	...	...	...	...	...	...	...
Kentucky	750	750	900	1000	1250		No
Louisiana	500	750	900	1150	1400	None	Yes
Maine	750	750	900	1000	1250	2	Yes
Maryland	...	...	...	...	...	...	...
Massachusetts	...	...	...	...	...	...	...
Michigan	...	...	...	...	...	...	...
Minnesota	...	...	...	...	...	...	...
Mississippi	...	...	...	...	...	...	...
Missouri	...	...	...	...	...	...	...
Montana	750	750	900	1000	1250	4	No
Nebraska	750	750	900	1000	1250		No
Nevada	1000	1000	1000	1000	1250	4	No
New Hampshire	750	750	900	1000	1250	4[A.]	No
New Jersey	...	...	...	...	...	...	...
New Mexico	...	...	...	...	...	...	...
New York	...	...	...	...	...	...	...
North Carolina	750	750	900	1000	1250	2[A.]	No
North Dakota	...	...	...	...	...	...	...
Ohio	1000	1000	1500	2000	2000	4[A.]	Yes
Oklahoma	...	...	...	...	...	...	...
Oregon	750	750	900	1000	1250	1.5[A.]	No
Pennsylvania	900	900	900	1000	1100	4	No
Rhode Island	750	750	900	1000	1250	3	No
South Carolina	...	...	...	...	...	...	...
South Dakota	1000	1000	1000	1250	1500	4	No
Tennessee	750	750	900	1000	1250	4[A.]	No
Texas	...	...	...	...	...	...	...
Utah	750	750	900	1000	1250	1	No
Vermont	...	...	...	...	...	...	...
Virginia	30 hour Detention 100 Gallons Per Day					No Minimum	Yes
Washington	750	750	900	1000	1250	3[A.]	No
West Virginia	750	750	900	1000	1250	4	No
Wisconsin	750	750	975	1200	1375	3[A.]	No
Wyoming	750	750	900	1000	1250	4	Yes

The tremendous difference in design requirements for absorption fields indicates a wide disagreement on how far pollutants travel in the subsurface, the importance of evapotranspiration assistance in the disposal of effluents, the purification capacity of soils, the hydraulics of trench drainage, and clogging mechanisms.

SECTION 6

POLLUTION PROBLEMS

As noted earlier, some investigators estimate that as many as one-half of all septic tank-soil absorption systems are not operating satisfactorily. It is probably more than coincidence that another estimate classifies more than half of the soil in the United States as unsuitable for septic systems with respect to the percolation rate.

Also noted earlier, the acceptability of a site for a septic tank system is commonly based upon the percolation rate or the ability of the local soil to absorb water at a fast enough rate to handle the anticipated volume of effluent. It is assumed that if the percolation rate is acceptable and the tile field is large enough, there will be removal of pollutants from the effluent by natural adsorption and biological processes in the soil zone immediately adjacent to the tile field.

Historically, system failure has meant that the capacity of the soil to absorb effluent from the tank has been exceeded and that waste added to the system moves to the soil surface above the lateral lines. This type failure results from soil clogging and loss of infiltrative capacity and is caused by combined physical, chemical, and biological factors.

Physical factors include compaction of the soils by excavating equipment and the movement of fine soil particles into the voids at the trench-soil interface. The most important chemical factor is the deflocculation of soils by high sodium waters. Some high sodium wastewaters may preclude the use of septic tank percolation systems, although insufficient data exists to confirm this theory.

Apparently, biological factors are the principal influences on soil clogging. The deposition of suspended materials, bacterial buildup, and bacterial decomposition of organic material at the liquid-soil interface produces an organic mat of only a few millimeters thickness that greatly reduces infiltrative capacity (3).

When system failure does occur from soil clogging and wastewaters do seep to the surface, overland flow from rainfall may carry contaminants directly to a stream or lake or into an inadequately sealed well, such as in Figure 4.

EFFECTS ON GROUND WATER

High absorptive capacity, however, does not necessarily correlate with the capacity of soils to remove pollutants from infiltrating wastewater. Many soils, of high hydraulic absorptive capacity (permeability) can be rapidly overloaded

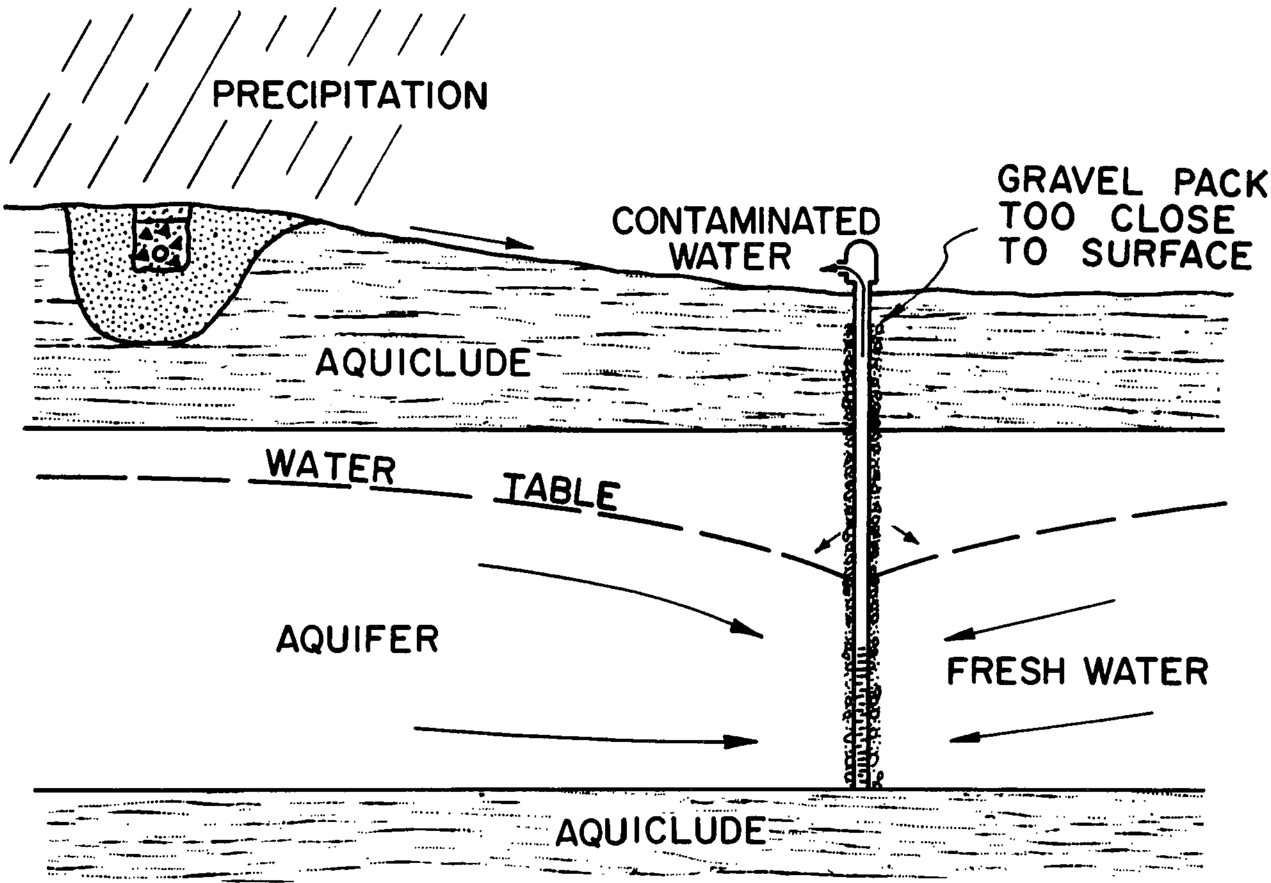


Figure 4. Effect of clogged absorption field on nearby well.

with organic and inorganic chemicals and microorganisms permitting rapid movement of contaminants from the lateral field to the ground-water zone, as in Figure 5. This type of system failure has been largely ignored until recent years.

Whether or not pollutants moving from the tile fields through the soil reach the ground water and subsequently a water supply depends to a large extent on the type of subsurface material involved and the thickness. Figure 6 presents four common aquifer types which may transmit pollutants great distances. Conventional septic tank systems should be avoided in any areas where fractured or cavernous formations, such as the bottom three rock types, are less than a few feet below the bottom of the absorption trench.

Such rock types provide a minimum of the three major processes necessary to retard or control the movements of pollutants--filtration, adsorption, and microbial degradation. Generally, the fissures and channels are too large to provide significant filtration. The detention time and active surface areas available are not great enough for appreciable adsorption or microbial degradation to occur. The same may be true of gravel aquifers and, to a lesser extent, coarse sand formations.

The type and thickness of soils overlying these rock types then becomes critical. Various research efforts in the past have demonstrated that most of the known contaminants in septic tank effluent--suspended solids, BOD, bacteria, and viruses--can be removed by movement through a few feet of soil under proper conditions. The amount of soil required is dependent on the particular contaminant; the pH, moisture, temperature, and oxidation-reduction potential of the soil; the size, shape, and interstitial voids of the soil; and the velocity of flow through the voids. Higher percentages of fine material such as clays in the soil provide more surface area and generally result in reduced mobility of pollutants. Viruses, for example, are known to be adsorbed more readily on soils of high clay content and low pH at lower flow rates (4).

Some other chemicals are not that easily removed. Chlorides and nitrates are essentially unaffected by movement through most soils. However, nitrogen requires special consideration. Most nitrogen from septic tank effluents occurs in the organic and ammonia forms which are readily adsorbed to soil particles within short distances. If anaerobic conditions are maintained in this soil, there is little nitrogen movement. However, under favorable moisture, temperature, and oxygen conditions such as generally occur in well-drained soils, soil bacteria will oxidize the nitrogen compounds to the more mobile nitrates, as shown in Figure 7 (5).

Nitrates, primarily from septic tanks and fertilizers, have penetrated hundreds of feet into an artesian aquifer underlying Nassau County, Long Island. The combined discharge from septic tanks and cesspools from the adjoining counties of Nassau and Suffolk is approximately 230,000 cubic meters per day (60 mgd or about 50,000 gallons per day per square mile). A nitrate front is moving into unaffected portions of the aquifer at a rate of 1.5-12.5 meters per year vertically and about 40 meters per year horizontally. Sixteen public supply wells serving thousands of residents in Nassau County now exceed EPA nitrate standards. Part of Nassau County was sewered between 1952 and 1964. In a 1970

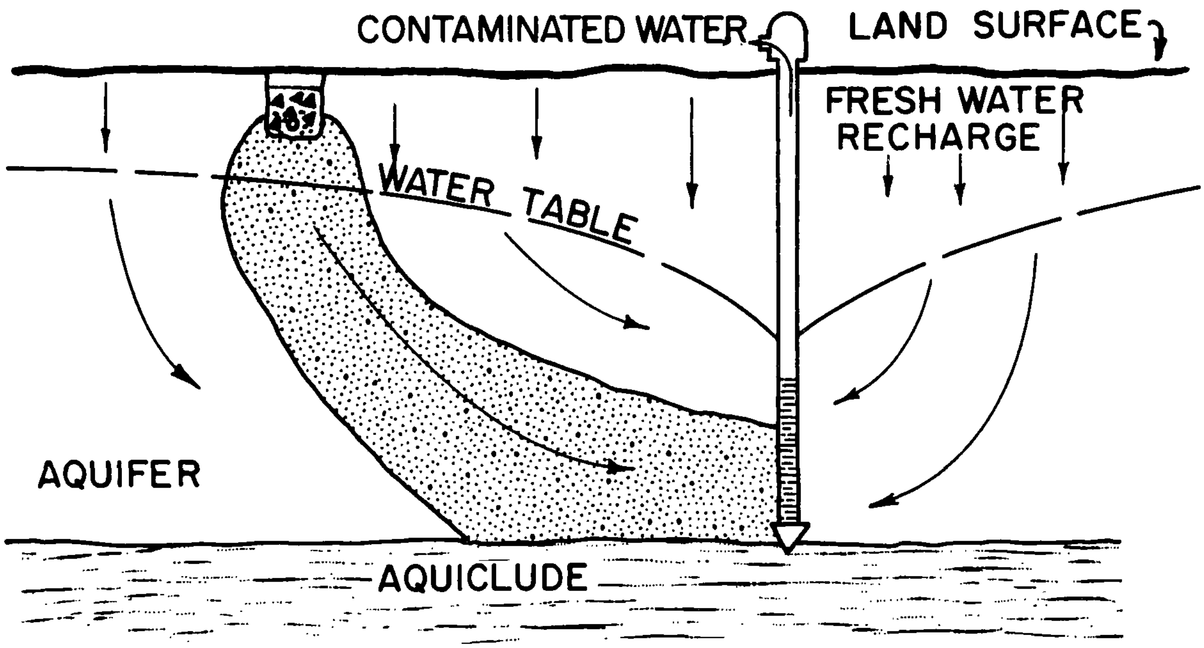


Figure 5. Effect of a pumping well on contaminated water movement.

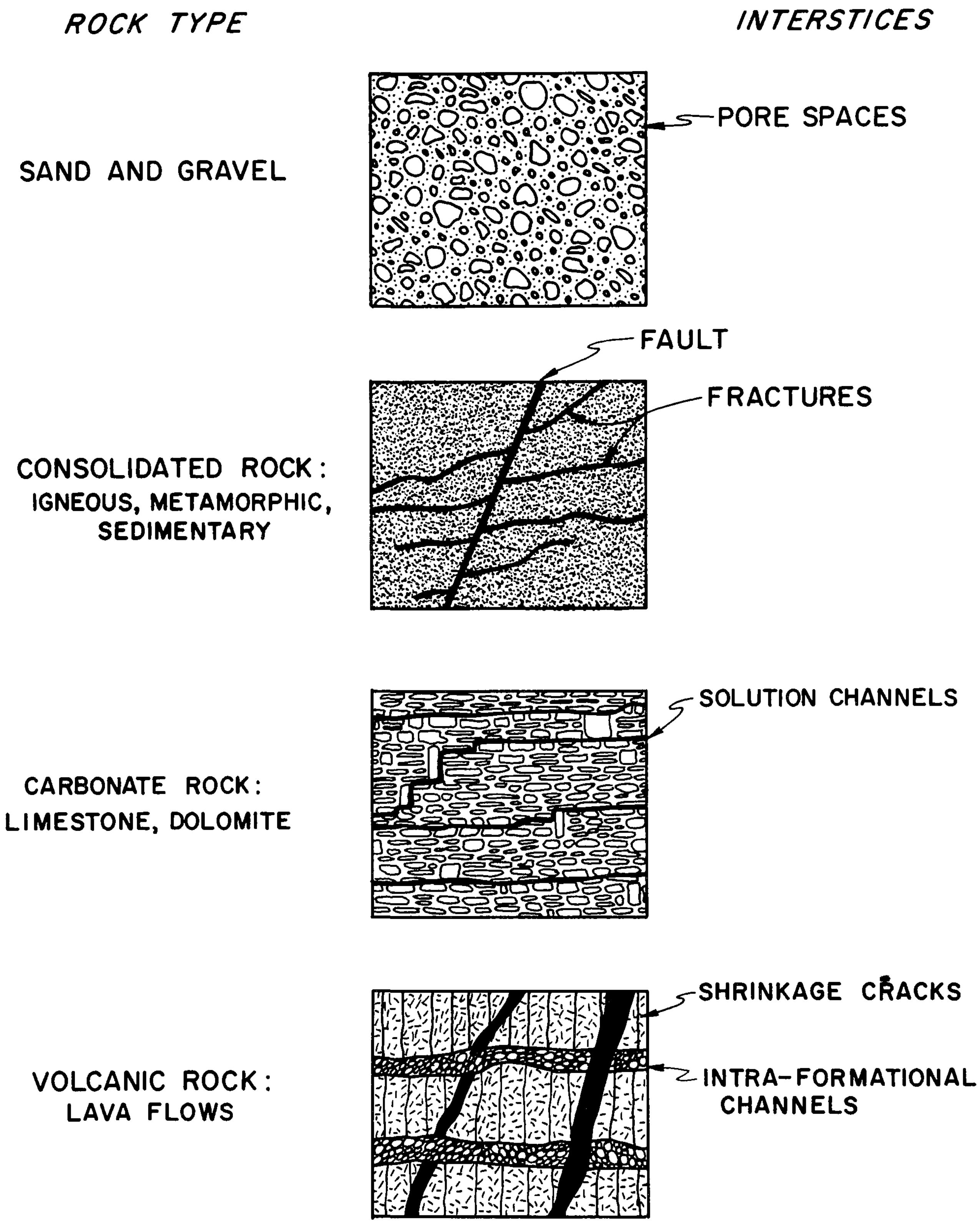
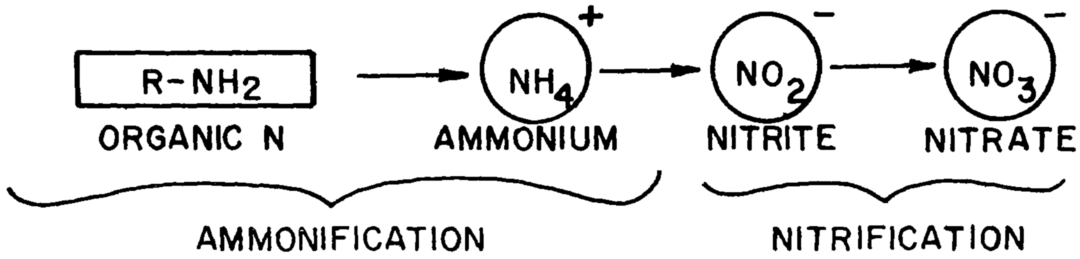
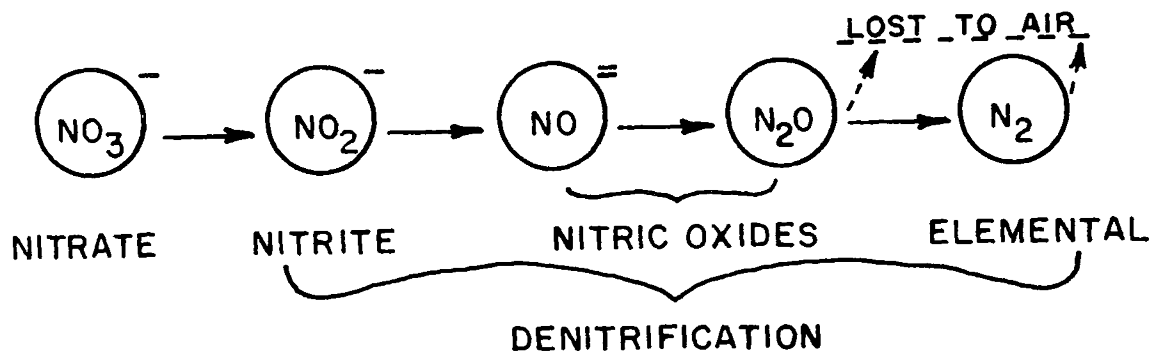


Figure 6. Major aquifer types (1).



This reaction occurs at temperatures above 60° F.
Nitrification occurs only under oxidizing conditions.



This reaction occurs only under conditions
of low oxygen tension.

Figure 7. Nitrogen reactions in soil (5).

survey of streams in the area, ground-water fed streams averaged 11 mg/l nitrates (as NO^3) in sewered areas and 25 mg/l in unsewered areas (6). In terms of the percolation test, Long Island would be considered acceptable by most public health agencies for septic tank systems.

A study conducted by the Delaware Geological Survey in the early 1970's demonstrates the dilemma of public health officials in properly locating septic tanks. Two suburban areas were selected with homes situated on one-quarter to one-half acre lots, each with its own septic tank and shallow well-water system. One area was characterized by an extremely high water table and poorly-drained soils. The other area was underlain by deep, well-drained soils on uplands.

In the first area of poorly-drained soils, soil clogging was a severe problem and a number of wells were contaminated by coliform bacteria but nitrate levels averaged only 6.9 to 11 mg/l during the period of sampling. In the second area of well-drained soils, nitrate concentrations ranged from 22 to 136 mg/l but none of the wells were found to be contaminated with coliform bacteria (6).

Septic tank ground-water contamination problems may be individual, local, or regional. A regional problem exists when many individual systems contaminate extensive aquifers which supply water over a broad area, such as one or more counties.

The most important parameter influencing regional contamination from septic tank systems is the density of these facilities in an area, although geology, depth to water table, and climate may affect the nature and degree of the problem. The potential for regional contamination in the United States may be indicated by the relative density of systems in Figure 8. The three density ranges indicated may be considered as low, intermediate, and relatively high. Adjoining counties falling into the same range form regions of varying regional ground-water contamination potential. In addition, there are a few large counties which have high densities in limited areas of the county which create potential regional problems but do not appear in the relatively high range on Figure 8.

Obviously, there is one major region of high contamination potential along the northeast coast and several other isolated regions are scattered over the eastern third of the country. Because they are such large counties, Los Angeles, San Bernardino, and Riverside are not shown as high density areas; however, they should be considered as such because of the great number of systems concentrated in urban areas of these large counties (1).

Although Figure 8 serves to indicate where to look for regional ground water that may be contaminated, calculation of the volume of wastewater discharged in any particular location cannot be used to determine the existence or magnitude without consideration of other parameters such as hydrology, geology, soils, etc.

In a series of five regional studies sponsored by EPA since 1970, local, State, and Federal officials, consultants, water well drillers, and other water resource professionals in 35 States were interviewed concerning ground-water pollution problems. Septic tanks and cesspools rank highest in total volume of wastewater discharged directly to ground water and were the most frequently reported sources of contamination (7). Contaminants identified included bacteria, viruses, ammonia, nitrates, chlorides, phosphates, and sodium.

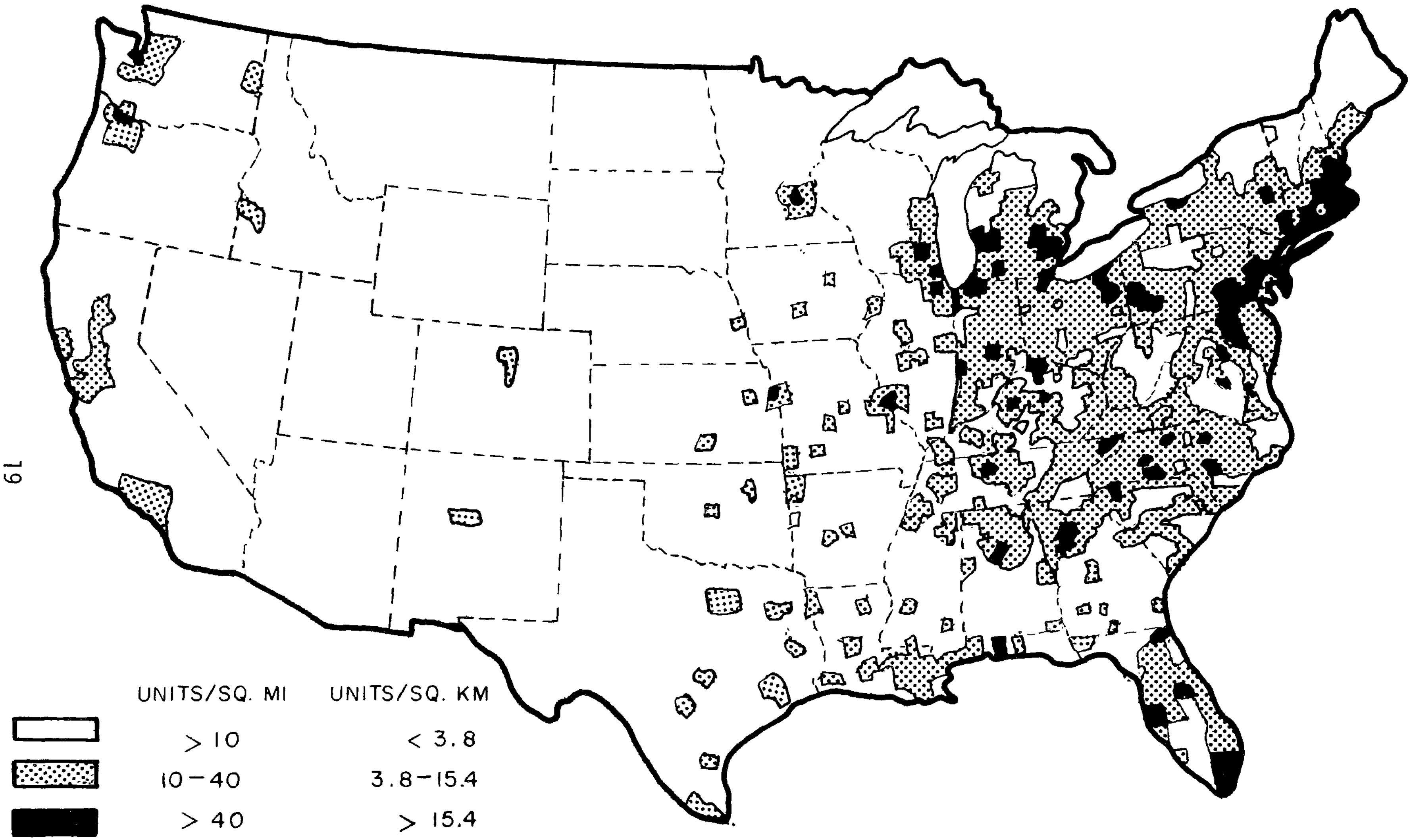


Figure 8. Density of housing units using on-site domestic waste disposal systems (by county) (1).

It may be significant that between 1946 and 1960, 61 percent of all waterborne disease outbreaks in the United States were attributed to contaminated ground water (8). It seems probable that septic tanks played a significant role in these outbreaks. Contamination of water supplies by septic tanks has been identified as causing diseases such as infectious hepatitis, typhoid fever, dysentery, and various gastrointestinal illnesses. It is also quite probable that contamination from septic tanks has been responsible for innumerable subclinical cases of waterborne diseases that go unnoticed and unreported.

SEPTIC TANK SLUDGE DISPOSAL

Pollutants which are removed in septic tanks accumulate in the form of scum and sludge. Since these accumulations occupy increasingly greater portions of the total volume, they eventually reduce the tank's effectiveness by causing an efflux of soil-clogging material to the soil absorption system. The amount of "septage" which must be pumped out and handled each year in the United States is estimated to be about 15 million cubic meters (4 billion gallons) (9).

Septage characterization data from EPA pilot plants at Lebanon, Ohio, and Blue Plains in Washington, D.C. are shown in Table 3 (10). Septage contains significantly lower concentrations of heavy metals than does municipal sludge but heavy metal content of any concentrated residue (sludge or septage) is obviously only one area of concern in the ultimate disposal of that residue to the environment.

TABLE 3. SEPTAGE CHARACTERIZATION

	Concentration (mg/l)	
Constituent	Arithmetic mean	Range
TS	38,800	3,600 - 106,000
TVS (%)	65.1	32 - 81
TSS	13,014	1,770 - 22,600
VSS (%)	67.0	51 - 85
BOD_5	5,000	1,460 - >18,600
COD	42,850	2,200 - 190,000
TOC	9,930	1,316 - 18,400
TKN	677	66 - 1,560
NH_3-N	157	6 - 385
TP	253	24 - 460
pH (units)	-	6.0 - 8.8
Grease	9,090	604 - 23,468
LAS	157	110 - 200
Fe	205	3 - 750
Zn	49.0	4.5 - 153
Mn	5.02	0.5 - 32
Cd	0.71	<0.05 - 10.8
Ni	<0.90	0.2 - 3.7
Hg	<0.28	<0.0005 - 4.00
Se	0.076	<0.02 - 0.3
Cr	1.07	0.3 - 2.2
As	0.16	0.03 - 0.5
Cu	6.4	0.3 - 34
Al	48	2 - 200
Pb	8.4	1.5 - 31

From an aesthetic standpoint, septage odors limit direct application to the land except in isolated areas. The Wisconsin Department of Natural Resources has reviewed the pathogenic aspects of sludge application and recommends that raw sludge not be applied to agricultural land (11). Since septage is partially digested domestic sludge, some intermediate processing may be required before land disposal. Such intermediate processing could include anaerobic or aerobic digestion, lime treatment, pasteurization or composting.

Alternative methods of septage treatment and disposal can be chiefly categorized as:

1. Treatment at Sewage Treatment Plant (STP)
2. Treatment at a septage facility
3. Direct land application

Treatment of septage at an STP can involve direct addition of the septage to the incoming municipal wastewater or addition of the septage to the sludge processing system.

Since the choice of where to add septage to an STP would likely influence effluent quality, as related to permit requirements, some emphasis on the sludge processing mode is inevitable. If excess sludge processing capacity is available, this choice becomes simpler. Since most smaller STP designs incorporate either anaerobic or aerobic digestion followed by sand drying beds or vacuum filters, the effects of septage addition on these processing steps should be determined. Bench-scale studies have indicated that anaerobic digestion of pure septage at loadings up to 1.3 kg VSS/m^3/day (.08 lb/ft^3/day) was successful, but at 1.6 kg VSS/m^3/day (01 lb/ft^3/day) was not. Continuous aerobic digestion at loadings of 0.4 to 21 kg VSS/m^3/day was quite effective in improving dewaterability, but foaming problems were experienced (12). Pilot plant studies of anaerobic and aerobic digestion of sludge-septage mixtures are now under way at the U.S. EPA Lebanon, Ohio pilot plant.

Separate or regional septage treatment facilities are in a relatively embryonic stage of development at this time, except for land disposal facilities. Political forces are likely to cause these type of facilities to proliferate in the future in areas where on-site wastewater treatment facilities alone are feasible. Such forces, in the name of public health or environmental aesthetics, may cause some conversion of direct land application sites to either modified land disposal sites with pretreatment facilities or complete treatment facilities with controlled effluent. The work presently under way to determine guidelines for municipal sludge application to the land will strongly impact the former possibility.

Table 4 contains a rough qualitative listing of the relative employment, future employment, costs, limitations, and environmental impacts of several classes of septage treatment and disposal methods currently used (10). It is estimated that almost all of the septage generated each year is disposed of either on the land or in existing sewage treatment plants (STP's). Based on projected trends, land disposal methods will continue to predominate, despite their potential environmental impacts.

TABLE 4. SEPTAGE DISPOSAL ALTERNATIVES

METHOD	ESTIMATED USE		ESTIMATED COSTS			PHYSICAL LIMITS		ENVIRONMENTAL IMPACTS		
	Present	Future	Land	Capital	O&M	Topography	Climate	Odor	Vectors	Gr. water
Untreated → land application	highest	decreasing								
a. surface			high	low	low	yes	yes	high	high	med.
b. soil injection			high	med.	high	poss.	yes	med.	med.	med.
c. pits, holes, deep trenches			low	low	low	no	yes	high	high	✓
d. sanitary landfills (*)			low	low	low	no	yes	high	high	high
Minimal treatment → land disposal of effluent	low	increasing								
a. anaerobic lagoons → sand recharge beds			med.	low	low	no	yes	high	high	med.
b. chemical treatment → sand recharge beds			low	high	high	no	yes	med.	low	med.
Conditioning → dewatering → effluent treatment	low	increasing								
a. aerobic digestion			low	high	med.	no	no	low	low	low
b. anaerobic digestion			low	high	med.	no	no	low	low	low
c. lime stabilization			low	med.	high	no	no	low	low	low
d. chemical coagulation			low	med.	high	no	no	med.	low	low
e. physical chemical oxidation			low	high	high	no	no	low	low	low
Sewage treatment plant addition (mainstream)	high	decreasing								
a. activated sludge (*)			low	low	med.	no	no	low	low	low
b. trickling filter (*)			low	low	med.	no	no	low	low	low
Sewage treatment plant addition (sludge h'dl'g)	low	increasing								
a. to conditioning step (*)			low	low	med.	no	no	low	low	low
b. to separate cond. step → dewatering (*)			low	med.	high	no	no	low	low	low
Septage treatment plant → eff. to stream	low	no change								
a. anaerobic-aerobic treatmt. → tert. filter			high	med.	med.	no	no	high	high	med.
b. AWT (chem, biol, tert)			med.	high	high	no	no	low	low	low
Composting	low	increasing	med.	low	med.	yes	yes	med.	med.	med.

✓ prohibitive

* assumes facility exists which can be used for this purpose with reasonable modification

SECTION 7

CURRENT RESEARCH

MOVEMENT AND FATE OF LEACHATES

Satisfactory resolution of most of the questions regarding the effects of septic tank systems on ground-water quality is ultimately dependent on the development of a better understanding of the movement and fate in the subsurface of leachates generated by such systems. For example, definitive information concerning the movement and fate of pollutants in both unsaturated and saturated subsurface environments, were such information available, would comprise the firm scientific basis needed for resolution of most of the disagreements which underlie the wide variation in existing codes and regulations presently governing the utilization and construction of septic tank systems. Considerable research, therefore, has been and continues to be directed toward the development of such information.

One aspect of current research on movement and fate of pollutants is concerned with the development of guidelines for allowable densities of septic tank systems for various geological and climatic conditions. Guidelines are urgently needed in order that utilization of septic systems can be logically controlled in situations where local or regional ground-water pollution problems may result from their intensive use. Such work was instigated at the request of and partially funded by the Office of Water and Hazardous Materials. It mainly entails the development of definitive, quantitative information concerning the movement in various soil types of chemicals and microorganisms, including various nitrogen forms, phosphate, sulfate, chloride, coliform organisms, viruses, and organics known to be constituents of septic tank leachate. Although considerable information concerning the movement and fate of most of these pollutants has been provided by many previous studies of septic tank systems, this information has not been sufficiently definitive nor quantitative to provide a basis for density criteria. This reflects inherent difficulties in conducting studies of the movement and fate of pollutants in subsurface environments. Field investigations have suffered because of sampling problems and difficulty in controlling experimental conditions, while laboratory studies have usually utilized packed columns of dried, sieved soils which bear little resemblance physically or biologically to natural soil profiles. One investigation being conducted at Texas A&M University seeks to obviate these difficulties by utilization of large lysimeters constructed from 2.1 x 1.5 x 1.8 meter monoliths of soil which retain the natural soil profile while permitting close control of experimental conditions and calculation of water and pollutant balances.

The density guidelines expected to result from the Texas A&M work should be extremely useful, but it should be noted that they will be only first approximations based on best available information. Hence, they will undoubtedly be revised and refined many times as new and improved information concerning the subsurface movement and fate of various pollutants, particularly viruses and potentially harmful organic compounds, is developed.

The movement and fate of viruses in the subsurface is of considerable importance in regard to pollution of ground water by septic tank systems, as well as other activities which involve introduction of wastes containing human excretory matter into the earth's crust. Over 100 different types of human enteric viruses have been identified, and some authorities feel that ingestion of only one or two virus particles is sufficient to produce disease in a suitable host (13).

Previous field and laboratory studies indicate that large numbers of viruses may be removed from wastewaters, including septic tank effluents, by percolation through soil. Removal is believed to result largely from adsorption on soil particles. However, viruses are apparently not inactivated by adsorption, but may remain viable in the adsorbed state for long periods, possibly to be released again when proper conditions for desorption develop. Research currently under way seeks to answer important questions concerning the extent of virus adsorption in different soils under various conditions, the longevity of adsorbed viruses, and the conditions under which desorption occurs.

Investigations pertaining to viruses in wastewaters, including septic tank effluent, are presently impeded by the absence of reliable, standardized analytical methods for detecting and measuring low but significant levels of potentially harmful viruses in water. Hence, several research groups are attempting to develop methods for concentrating enteric viruses from large volumes of water in order to significantly enhance the sensitivity of detection and quantitation of these organisms.

The possibility that other constituents of wastewater may be utilized as indicators for the presence of enteric viruses in subsurface waters and models for the behavior of these organisms in subsurface environments is also receiving attention, principally because of the difficulties inherent in handling and analysis of the pathogenic enteric viruses themselves. The use of coliform bacteria, which have traditionally been utilized as microbial indicators in surface waters, appears questionable for this purpose in highly structured subsurface environments where limited open space and sorptive forces are of prime importance in governing pollutant behavior. Certainly, the coliforms cannot be expected to behave analogously to the much smaller and biochemically dissimilar enteric viruses in such environments. The most promising candidates as indicators for enteric virus presence and behavior in subsurface work may be bacterial viruses which commonly occur in wastewaters of domestic origin and resemble enteric viruses in size and external chemical composition. A bacterial virus, f2 coliphage, is being utilized as an indicator for virus movement in the Texas A&M work mentioned above, while work being initiated in California will examine in more detail the utility of coliphages as models for enteric virus behavior in the subsurface.

The movement and fate of organic pollutants in wastewaters, including septic tank effluents, is also receiving increased attention in current research efforts. Although previous studies have indicated that the major portion of organic matter in septic tank effluent is readily removed by sorptive and degradative processes as the effluent moves through soil under proper conditions, the potential pollution of ground water by these substances cannot be dismissed without further study. There are two principal reasons for this concern. First, that small portion of organic matter which is not readily removed during movement of the effluent through the subsurface environment may be partly comprised of synthetic organic chemicals which are relatively intractable to microbial degradation and which may be hazardous to human health if ingested, even at low levels, over long periods of time. Although synthetic organics are not usually considered in regard to septic tank effluent, there are many household products, such as pharmaceuticals, disinfectants, deodorants, polishing agents, cleaning materials, cosmetics, paint, and pesticide products, that contain such chemicals and may be present in wastewater entering septic systems. Second, if those compounds which are initially removed from the effluent by sorptive processes are relatively intractable to degradation in the subsurface and are not irreversibly adsorbed, they may eventually migrate chromatographically into and through an underlying aquifer.

Research pertaining to the movement and fate of organic compounds in the subsurface is difficult because of the large number of substances which must be considered and the low levels which must be detected, identified, and measured in the complex subsurface water-soil matrix. The Texas A&M project includes an effort to identify individual organic pollutants which move through the soil in septic system leachates and to develop information concerning their mobility and longevity in the subsurface. Another current research effort seeks to develop systematic and definitive information concerning the sorption of organic pollutants on various soil types. Although this work is not concerned directly with septic tank systems, it should yield information of value in assessing the potential impact on ground water of organic pollutants from any source, including septic systems. One goal is the development of methods for early detection of organic pollution of ground water, using as indicators organic compounds that are not appreciably sorbed by soils and subsoils.

Current research pertaining to the movement and fate of phosphorus in the subsurface is also of interest in regard to the effects of septic systems on ground water. Phosphorus in wastewaters entering the earth's crust is generally not considered to be a potential water pollution problem because it is usually rapidly sorbed by the soil, and, hence, exhibits essentially no mobility. However, there is evidence that phosphorus does move in the soil under some conditions, and phosphorus from septic systems has been implicated in a few cases of pollution of subsurface waters. Research currently under way is seeking to better define the conditions under which phosphorus becomes mobilized in the soil and to develop mathematical models describing its movement and fate in the subsurface.

As previously noted, pollution of ground water by nitrate is a major problem associated with septic tank systems. As shown in Figure 7, the reactions which govern the form, and hence the mobility and ultimate fate, of nitrogen in the soil are fairly well defined. Current research pertaining to the movement and fate in the subsurface of nitrogen from septic tank systems is primarily concerned with manipulation of these reactions to minimize movement of nitrate into ground water. In this connection, at least two research groups are investigating the feasibility of achieving reduction of nitrate to elemental nitrogen in the soil profile underneath septic tank lateral lines (14). Also under way are tests to determine the feasibility of an ion exchanger to remove ammonia nitrogen from septic tank effluent before it reaches the laterals. Other research efforts seek to define the effect of soil type and environmental conditions on the fate of nitrogen in soils receiving wastewater.

IMPROVEMENT OF CONVENTIONAL SYSTEMS

Surveys in various areas have found septic tank-soil absorption system half-lives of 27 years in one Connecticut community and a 90 percent survival after 20 years of service in Fairfax County, Virginia (15, 16). Based on the concept that properly designed, constructed and maintained systems operate satisfactorily in many non-sewered areas of the country despite scientific gaps in knowledge, there has been a resurgence of interest in recent years in a better understanding of on-site wastewater disposal problems and in developing better design criteria. The primary approach has concentrated on increasing understanding of the controlling parameters which govern the performance and effects of traditional septic tank systems.

The reasons for system failure can be one or a combination of three factors--improper design, improper construction, or improper maintenance. All three can be significantly impacted through upgraded regulations for siting and design methods, better inspection and construction (installation) procedures, and mandatory inspections and pumping policies. The relative value of these improved institutional approaches is a function of the technical basis on which they are formulated and the level of enforcement provided.

Several design factors have been identified in recent years that can improve system performance and reliability. Larger and multi-compartmented septic tanks can improve effluent quality by increasing scum and sludge volume accumulations per unit volume of wastewater treated. Equalizing distribution and dosing can increase pollutant attenuation in some soils and increase life of absorption fields before clogging occurs (17).

A more accurate soil test for sizing soil absorption fields has been developed by the University of Wisconsin. Although too complicated for general use, it could be used by the Soil Conservation Service as part of its mapping procedure to help simplify sizing problems and to reduce the cost of designing systems which clearly lie inside mapping units (18).

Several investigations have shown that the greatest chance of system failure occurs within the first three years of operation and that most of these failures are due to faulty construction (and inspection) practices. Improper use of construction equipment can compact the absorption area and reduce the soil's liquid absorption capability. This situation is further compounded during periods of excess soil moisture. Additional problems of smearing of soil absorption faces have been noted when rainfall or excessive silt-laden wind occurred while trenches were open during construction (19).

Septic tanks should be inspected periodically to determine the need for pumping tank contents in order to prevent wholesale unloading of accumulated sludge and scum which will seriously degrade the performance of the soil absorption system. Inspection and cleaning ports of adequate size and extended to or very close to grade would make inspections more convenient and maintenance more practical.

Since it is widely known that old clogged soil absorption fields can recover their absorption capacity with sufficient resting, systems designed with dual fields for alternate use can significantly increase capacity and provide a safety factor where lot size permits.

A new method for restoration of clogged soil fields has also been developed. This method involves pumping of the septic tank and soil absorption trenches, followed by application of hydrogen peroxide to the trenches at appropriate intervals (20).

ALTERNATIVE ON-SITE DISPOSAL SYSTEMS

Despite the many successful systems currently in operation and options noted above to increase efficiency, there are widespread areas where conventional septic tank-soil absorption systems cannot be properly employed. Conditions which require alternatives include the following:

1. Thin soil over creviced bedrock
2. Highly impermeable soils
3. High ground-water conditions
4. Thin soil over impermeable strata on steep slopes

On-site alternatives may include modification at the household wastewater generation fixtures or at the distribution system, or a combination of both. Wastewater modifications may include reduced flow from all fixtures, elimination of certain fixture contributions from wastewaters, and recycle systems. Although such concepts have been strongly urged by environmentalists in recent years, there are several gaps in our present understanding of the primary and secondary aesthetic, health, and economic effects of such measures.

In recent years, individual home aeration units have been promoted for pretreatment of household wastewaters in place of the conventional septic tank. These units are capable of improved reductions in organic matter (COD, BOD, etc.) and detergents and, in certain cases, better suspended solids removal, when compared to septic tanks. However, effluents remain unsuitable for direct surface discharge and additional treatment, such as a sand filter, is necessary (21).

Several claims have been made to the effect that aerobic unit effluents result in fewer clogging problems than septic tank effluents. Studies at the University of Wisconsin have found this true only in coarser soils where clogging is not a significant problem anyway. However, one advantage for aerobic units is that the required sand filter area is only about 50 percent of that required for the analogous septic tank effluent to produce a high quality final effluent (21).

The relatively greater costs of aerobic units and greater routine maintenance required apparently preclude their wide applicability.

The use of evapotranspiration (Figure 9) for disposal of septic tank effluent has been employed for several years. In arid regions where the evapotranspiration (ET) potential greatly exceeds rainfall, the concept is quite viable. Unfortunately, although these regions account for almost one-third of the land area of the 48 contiguous States, they include only about 10 percent of the unsewered housing units in the United States. Some efforts are under way at the University of Colorado to demonstrate the feasibility of mechanical evaporation units which would potentially expand the areas of evaporative disposal applicability.

Mound systems, typified by Figure 10, have been successful for at least two of the difficult soil conditions previously cited; i.e., thin soils over creviced bedrock and high ground-water conditions. In the former case, the mound accomplishes most of the required treatment of the septic tank effluent prior to its introduction to the natural soil, thereby protecting the ground water. In the latter case, a similar treatment justification exists because of the known travel of pollutants under saturated flow (ground water) conditions. In this circumstance, the mound merely lifts the disposal system above the saturated zone during high ground-water periods to insure the protection afforded by a sufficiently thick zone of unsaturated flow. These mounds have also been applied with some success over slowly permeable soils normally considered unsuitable for on-site soil absorption systems.

Annual costs per household are compared in Figure 11 for several septic tank system modifications and a conventional sewer system based on a population density of five persons per acre (22, 23). Obviously, conventional sewer costs flucuate greatly with population density while the other alternatives are relatively unaffected.

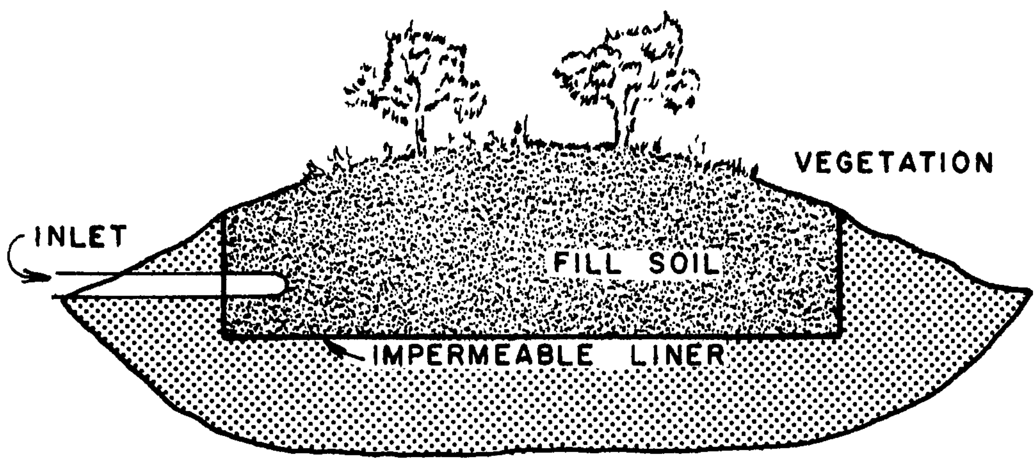


Figure 9. Evapotranspiration bed.

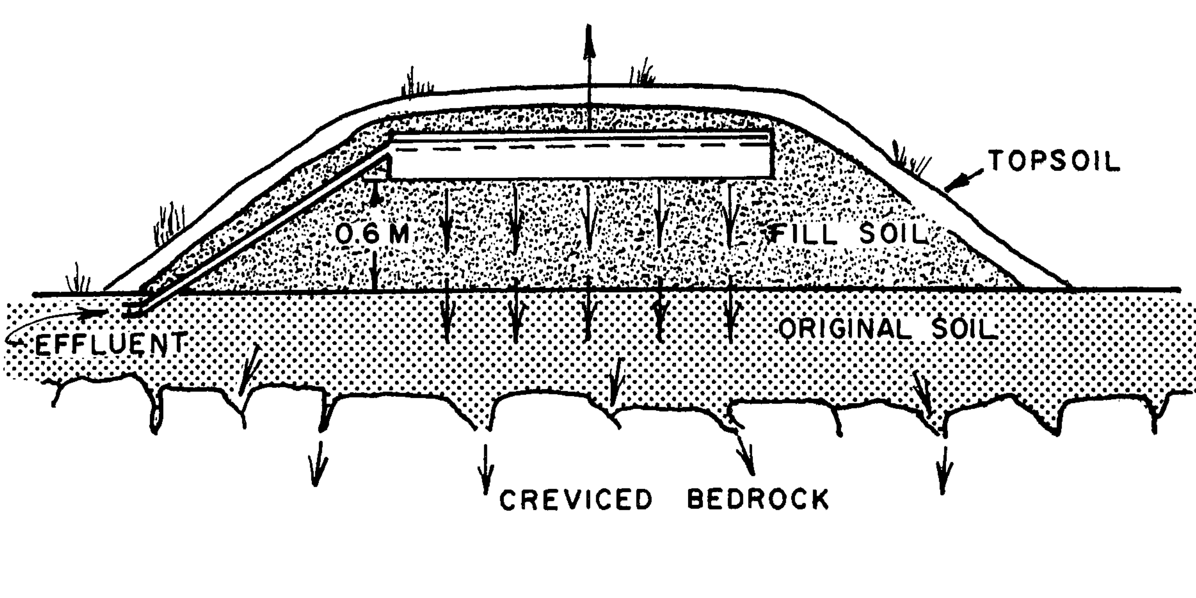


Figure 10. Mound over creviced bedrock.

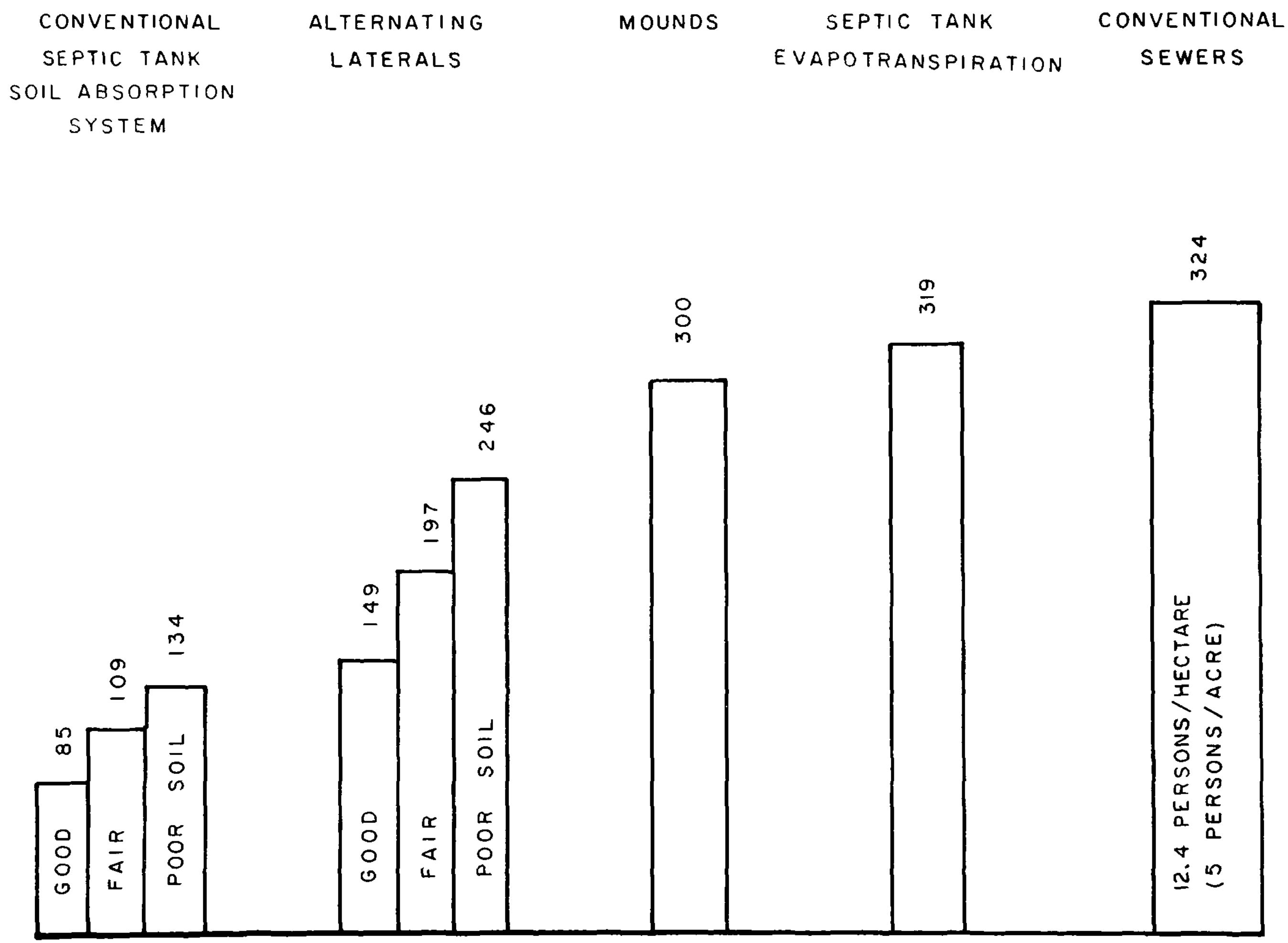


Figure 11. Total annual costs of alternatives.

SECTION 8

FUTURE TRENDS AND RECOMMENDATIONS

Continued migration to suburban areas is expected to stress State, county, and municipal governments in terms of regulations and providing those services required by the people. These services include water supplies, schools, transportation facilities, fire protection, and the collection and disposal of liquid and solid wastes.

In many cases, it will not be immediately feasible to connect these suburban developments to existing waste treatment facilities which were designed to serve the central city. Considerable costs arise in expanding intercepter sewers extended distances. Unfavorable differences in elevation often accentuate the complexities and costs of such extensions. Expanding existing treatment facilities to meet these additional demands also contributes excessive costs.

This urban sprawl results in the extensive use of individual sewage treatment units on relatively small lots which constitutes a high density and the possibility of ground-water contamination. Even after this critical density is reached, there is considerable resistance by residents to approve large expenditures for conversion to central sewage collection and treatment.

The best approach to limiting future problems is better governmental control and planning. Zoning and land use planning in areas where septic tanks will be required should be based on a thorough understanding of soil variability, geology, topography, aquifer characteristics, vegetation, and climate. This information would serve to establish limitations on the construction of housing units and the corresponding density of individual treatment facilities in areas which have not yet reached critical densities. As areas reach critical septic tank densities, further residential development would require the use of alternate methods of sewage disposal. Areas which already exceed critical densities could be individually evaluated to determine what corrective measures might be taken.

Research is needed to develop the tools that can be used in decision making related to septic tank feasibility and density. This includes studies concerning the time of survival of microorganisms in soil and ground water and the transport characteristics of organics in this media.

Additional work is required to develop more effective sewage disposal systems to replace septic tanks in rural and fringe urban areas. That research is needed on sludge disposal from septic systems is evidenced by the lack of information on the subject.

The basic design and operation of individual treatment units requires additional study, particularly from the standpoint of avoiding failure. Improved permeability tests, cleaning frequency, and dual lateral systems require particular emphasis.

The social and economic consequences of converting from individual units to sewered and central treatment facilities must be studied with consideration of the resultant loss of ground-water recharge.

SECTION 6

REFERENCES

1. U.S. Environmental Protection Agency. Waste Disposal Practices and Their Effects on Ground Water. Report to Congress, December 1975. 525 pp.

2. Patterson, J. W., R. A. Minear, and T. K. Nedved. Septic Tanks and the Environment. National Technical Information Service, Springfield, VA. PB-204 519.

3. Cotteral, Joseph A., Jr., and Dan P. Norris. Septic Tank Systems. J. Sanit. Eng. Div., ASCE, 95(SA4):715-746, 1969.

4. Plews, G. D. The Adequacy and Uniformity of Regulations for Onsite Wastewater Disposal--A State Viewpoint. In: Proceedings of 2nd National Conference on Individual Onsite Wastewater Systems, Ann Arbor, MI, November 1975.

5. Miller, John C., Paul S. Hackenberry, and Frank A. DeLuca. Ground-Water Pollution Problems in the Southeastern United States. EPA-600/3-77-012, U.S. Environmental Protection Agency, Ada, Oklahoma, 1977. 379 pp.

6. Miller, David W., Frank A. DeLuca, and Thomas L. Tessier. Ground Water Contamination in the Northeast States. EPA-660/2-74-056, U.S. Environmental Protection Agency, Washington, D.C., 1974. 338 pp.

7. Miller, David W., and Marion R. Scalf. New Priorities for Ground-Water Quality Protection. In: Proceedings of Second National Ground Water Quality Symposium, Denver, CO, September 1974. pp. 7-19.

8. Gerba, Charles P., Craig Wallis, and Joseph L. McInick. Fate of Wastewater Bacteria and Viruses in Soil. J. Irrig. & Drainage Div., ASCE, 101(IR3):157-174, 1975.

9. Kreissl, J. F. Rural Wastewater Research. In: Proceedings of 2nd National Conference on Individual Onsite Wastewater Systems, Ann Arbor, MI, November 1975.

10. Kreissl, J. F. Internal Memorandum on Septage Analysis. February 1976.

11. Keeney, D. R., K. W. Lee, and L. M. Walsh. Guidelines for the Application of Wastewater Sludge to Agricultural Land in Wisconsin. Wisconsin DNR, Technical Bulletin No. 88. 1975.

12. Jewell, W. J., J. B. Howley, and D. R. Perrin. Design Guidelines for Septic Tank Sludge Treatment and Disposal. 7th International Conference on Water Pollution Research, Paris, France. September 1974.

13. Malina, Joseph F., Jr., and Bernard Phillip Sagik, Editors. Virus Survival in Water and Wastewater Systems. Water Resources Symposium No. 7. The University of Texas at Austin, 1974. 264 pp.

14. Andreoli, Aldo, Suffolk County Department of Health, New York. Private communication. 1977.

15. Hill, D. E., and C. R. Frink. Longevity of Septic Systems in Connecticut Soils. Connecticut Agricultural Experiment Station, Bulletin 747. June 1974.

16. Clayton, J. W. An Analysis of Septic Tank Survival Data in Fairfax County, Virginia: 1952-1972. Ground Water, 11(3):29-32, May-June 1973.

17. Converse, J. C., J. L. Anderson, W. A. Ziebell, and J. Bouma. Pressure Distribution to Improve Soil Absorption Systems. In: Proceedings of the National Home Sewage Disposal Symposium, ASAE Publication No. PROC-175. 1975.

18. Bouma, J. Evaluation of the Field Percolation Test and an Alternative Procedure to Test Soil Potential for Disposal of Septic Tank Effluent. J. Soil Science Society of America Proceedings, 35:871, 1971.

19. Otis, R. J., and J. Bouma. Notes on Soil Absorption Field Construction for Septic Tank Systems. University of Wisconsin Small Scale Waste Management Project Technical Note. 1973.

20. Harkin, J. M., M. D. Jawson, and F. G. Baker. Causes and Remedy of Failure of Septic Tank Seepage Systems. In: Proceedings of 2nd National Conference on Individual Onsite Wastewater Systems, Ann Arbor, MI, November 1975.

21. Otis. R. J., W. C. Boyle, J. C. Converse, and E. J. Tyler. On-Site Disposal of Small Wastewater Flows. Prepared for U.S. EPA, Technology Transfer Seminars on Small Wastewater Treatment Systems. March 1977.

22. Kreissl, J. F. U.S. EPA Response to PL 92-500 Relating to Rural Wastewater Problems. In: Individual Onsite Wastewater Systems, Ann Arbor Science, Ann Arbor, MI, 1977.

23. Dearth, K., U.S. EPA, OWPO. Personal communication relating to analysis of 258 facilities plans from 49 states. 1976.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/3-77-096	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE "ENVIRONMENTAL EFFECTS OF SEPTIC TANK SYSTEMS"		5. REPORT DATE August 1977 issuing date
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Marion R. Scalf and William J. Dunlap - RSKERL, Ada, OK James F. Kreissl - MERL, Cincinnati, OH		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Robert S. Kerr Environmental Research Laboratory Office of Research & Development U.S. Environmental Protection Agency Ada, Oklahoma 74820		10. PROGRAM ELEMENT NO. 1BA609
		11. CONTRACT/GRANT NO. N/A
12. SPONSORING AGENCY NAME AND ADDRESS Same as above.		13. TYPE OF REPORT AND PERIOD COVERED In-House 1976-1977
		14. SPONSORING AGENCY CODE EPA/600/15

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Septic tank-soil absorption systems are the most widely-used method of on-site domestic waste disposal. Almost one-third of the United States population depends on such systems. Although the percentage of newly constructed homes utilizing septic tanks is decreasing, the total number continues to increase.

Properly designed, constructed, and operated septic tank systems have demonstrated an efficient and economical alternative to public sewer systems, particularly in rural and sparsely developed suburban areas. However, because of their widespread use in unsuitable situations, they have also demonstrated the potential for contamination of ground and surface waters.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Septic Tanks Waste Disposal Water Pollution Substitutes	Soil Treatment Septage Disposal Research Needs	13/B

18. DISTRIBUTION STATEMENT Release to Public.	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 43
	20. SECURITY CLASS (This page) Unclassified	22. PRICE