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Reports:

FINAL REPORT

RECOMMENDATIONS FOR ON-SITE WASTEWATER DISPOSAL ALTERNATIVES, FUTURE STUDIES AND MANAGEMENT OPTIONS

Prepared for the

NEW JERSEY PINELANDS COMMISSION

by

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1.0 RECOMMENDATIONS ON ALTERNATIVE TECHNOLOGIES

In order to draw conclusions from the research that has been done on alternative wastewater systems for the Pinelands, there are many factors to be weighed. Capital costs, operation and maintenance costs, public acceptance, management problems, operational difficulties, degree of treatment, etc. must all be considered to make intelligent recommendations. The following recommendations are made with all these inputs and the specific conditions of the Pinelands in mind. For both phosphorus and nitrogen removal techniques, the most appropriate choices in our opinion are listed in order of desirability. The exact choice of alternaties will depend on the environmental standards chosen, the results of research needs listed in Section 2.0, and the land use decisions that are made.

1.1 Phosphorus Control Techniques

1.1.1 From a cost-effectiveness perspective, the adoption of a phosphate detergent ban is the most attractive means of achieving significant phosphorus control. This method can reduce wastewater phosphorus discharges by 40 to 50% at essentially no cost to the homeowner. While a phosphate ban may be desirable form a technical perspective, it may be politically difficult to implement. To be most effective, the ban should be established over the widest possible geographic area, and should be accompanied by an extensive public education program.

1.1.2 The use of alum appears to be a viable technique for phosphorus removal from household wastewater. If a phosphate detergen ban is judged to be unfeasible or insufficient, this technique provides the most effective (80-90% removal) and most fully tested method of phosphorus control. While alum addition in standard septic systems has been shown to provide satisfactory performance, there is little long term operational experience. As a result, the initial installations of such systems should be considered demonstration projects. The particular operational characteristics that should be monitored include the state of sludge accumulation in the septic tank, the reliability of the alum feed equipment, and the fate of the sulfate added to the waste stream (including possible sulfide accumulation in the leaching area).

1.1.3 Filter Systems that use a medium such as alumina or limestone to precipitate and adsorb phosphorus have a higher capital and operation and maintenance costs than a phosphate detergent ban or alum addition system. The filter system would also be more difficult to operate and would require a detailed management program to replace the exhausted medium and regenerate or dispose of it. Additionally, the removal efficiency is not as great as with alum addition according to existing experimental data. However, there is enough evidence to suggest that some trial experiments be performed in the field to evaluate their usefulness.

1.2 Nitrogen Control Techniques

1.2.1 Compost toilets are the best demonstrated, most readily available technique for reducing the discharge of nitrogen to soil absorption systems, and therefore to groundwater supplies. By directing the toilet wastes to the composting toilet and away from the wastewater stream, approximately three-quarters of the nitrogen is removed from consideration in the soil absorption system. This is a major reduction and can be accomplished by an alternative that is commercially available and used in the field now for about 10 years in the U.S.

The major problem with this alternative technique is public acceptance. The use of a compost toilet requires a change in attitude from only knowing how to flush a toilet to being concerned with the operation of a device that is actually recycling human wastes. The major problem is that many people will feel that a compost toilet is aesthetically undesirable. A public relation and education program would be necessary to inform people of the purpose and operation of compost toilets. The advantage of a compost toilet in reducing pollution in the Pinelands will have to be emphasized so that people will accept the responsibility of owning and operating them properly. It is also a method of saving approximately 1/3 of the normal water use in the home and providing compost for the garden.

1.2.2 Batch Treatment Unit (Cyclical Aeration) is another technology that is presently available and has been shown to reduce nitrogen by approximately 50%. These systems operate in a cycle, first with an aerobic phase that oxidizes the organic matter, and produces nitrate from ammonia and organic nitrogen, followed by a quiescent period for settling of suspended matter. During this non-aerated period, the system becomes anaerobic and some of the nitrate is denitrified.

The main advantage of this system is an appreciable reduction of the nitrogen loading with a commercially available unit that can connect to conventional plumbing. These units are not inexpensive and do have high operation and maintenance requirements and costs. They cannot normally be maintained by homeowners themselves, and would therefore need a private contract for maintenance, or a public authority whose responsibility would be to inspect and maintain them in good operating order. A demonstration project should be initiated that would involve the operation of a number of systems in one community, and the observation of their performance over a period of time. A good sampling program will tell how much denitrification is occuring and what reduction in nitrogen loading to the groundwater can be achieved.

1.2.3 Sand Filter/Denitrification system uses an aerobic sand filter after the septic tank to nitrify the ammonia, and then an anaerobic tank or filter with methanol to denitrify the nitrate. This total system has had little experience, although the unit operations are known. Since multiple units are involved, the operation and maintenance requirements and costs will be rather high. The advantage is that a good removal rate should be attainable, and existing plumbing, septic tanks, and soil absorption fields can be used. A demonstration project should be performed to compare the performance, costs, and operation of this system with the other nitrogen removal options.

1.2.4 Clinoptilolite ammonia adsorption systems have little field experience but a large potential for significantly removing nitrogen from the waste stream before reaching the soil absorption system. Research has shown that this ion exchange material has the capacity to remove almost all of the ammonia from the septic tank effluent. A system such as this would offer little inconvenience to the homeowner, but would require that a public authority be responsible for monitoring the exchange filters for exhaustion and have a program for replacing and regenerating the exchange material. If these systems were used areawide, the municipality could collect and regenerate the filters, with the possibility of recovering and reusing the ammonia. The major problems are filter clogging, which appears to happen at the same time as the exchange capacity is exhausted, and increased discharge of sodium to the soil. Demonstration models should be developed to investigate their possibility as a worthwhile alternative.

1.2.5 Soil Absorption System (SAS) Denitrification phenomena have been documented by some investigators. The potential of achieving substantial denitrification in a SAS by dosing and/or field design should be investigated. The advantage of this method is that nitrogen removal can be achieved by a conventionally (to the user) designed SAS.

2.0 RECOMMENDATIONS FOR FIELD WORK

Many of the assumptions made in calculating the various treatment and soil effluents were based on small amounts of data and best engineering judgement. To make the best policy decisions, these assumptions should be based on facts determined by the following experiments:

2.1 Phosphorus Adsorption Capacity

There is a good deal of controversy and a lack of comprehensive information concerning the phosphorus adsorption capacities of different types of soils. Therefore it is recommended that a study be performed to measure these capacities so that more accurate predictions can be made on the environmental impacts of phosphorus from soil absorption systems.

Soil samples should be taken from the majority of the Pinelands soil types and subtypes at various depths down to about 6 feet. The phosphorus adsorption capacity can then be measured by passing a 15-20 mg/l (approximate concentration in septic tank effluent) solution of phosphate through small columns of soil. By following the phosphate concentration in the soil column effluent, breakthrough curves can be developed that will be used for predictions of phosphorus movement in subsurface soil absorption fields. The difference in the amount of phosphorus applied and eluted over the time of experiment will be the phosphorus adsorption capacity.. An easier procedure, called "isotherm studies," involves mixing the soil in a phosphate solution of a concentration similar to septic tank effluent until equilibrium is reached and and analyzing the decantate to calculate how much was adsorbed. To verify the data, a few field measurements in new soil absorption systems should be performed. to observe how long phosphorus is actually adsorbed in the subsoils. This should be done in soils that would expect to have low phosphorus adsorption capacities, so that the length of the observation period can be kept reasonable.

After knowing the phosphorus adsorption capacity and how much phosphorus will be percolating to the groundwater as the leachfield is used, decisions can be made on what size lots to allow for dilution of phosphorus by infiltrating rainwater. In addition, the time until all the soil under the leachfield is saturated with phosphorus can be calculated. Regulations can then be promulgated that require abandonment after this time period.

2.2 Denitrification Rates

Since denitrification phenomena in soil absorption systems are not well understood or quantified, it is difficult to determine precisely how much nitrogen from septic tank systems will enter groundwater aquifiers and in what form. Therefore, it is strongly recommended that in situ measurements in actual subsurface soil absorption systems be undertaken to study how much denitrification can be expected in different soils. It is suggested that soils with widely different denitrification potentials be chosen for these experiments.

The procedure would involve placing soil lysimeters at different depths within an existing or newly built leachfield to take samples of the percolating effluent. Some type of impermeable barriers would have to be placed around the leachfield so that dilution by infiltrating rainwater can be accounted for. By following the concentration changes in the various forms of nitrogen as the septic effluent percolates down through the subsurface soils. a nitrogen mass balance can be produced that should show some loss of nitrogen. To be sure if the loss is through nitrate denitrification or ammonia adsorption or volitalization, it would be necessary to undertake more complex analysis of any nitrogen or nitrous oxide given off in the soil. By measuring the nitrogen transformations in different types of soils and correlating them with certain soil characteristics, some judgement can be made on the mechanisms of nitrogen loss. It would also be beneficial to measure the nitrogen in groundwater under developed and undeveloped areas to compare the differences and correlate them to septic system densities.

Even the empirical data itself will allow predictions of the concentration of nitrogen leaching to the groundwater in different soils used for the disposal of septic tank effluent. Knowing this data will permit the development of a policy to control groundwater nitrogen contamination by regulating house lot sizes, as explained in the report titled "A Procedure for Evaluating Environmental Impacts of Alternative Wastewater Treatment Technologies."

Additionally, the research results may lead to the specific design of subsurface disposal systems that can induce denitrification in the soil.

2.3 pH and Alkalinity

The pH and alkalinity of the groundwater in the Pinelands needs to be measured at a number of points to observe the variation and consistency. The same parameters should also be analyzed in septic tank and leachfield effluents in the Pinelands, since they vary according to the particular water supplies and local household practices. Since this information is not easily available, it is recommended that a short but comprehensive monitoring program be undertaken.

The measurement of leachfield effluent pH and alkalinity can be done in conjunction with the soil denitrification investigations discussed previously. Groundwater samples form a good distribution of existing wells at different depths should be sufficient to characterize the groundwater. After this information is gathered together, it can be used to calculate possible pH changes in the groundwater due to soil absorption system leachates more accurately than shown in Appendix B of the Report "Assessment of Innovative Technologies for On-Site Wastewater Disposal."

2.4 Fertilizer Use

The values assumed for fertilizer use and leachate were based on values reported in K. Brown's report and do not necessarily apply to the Pinelands. A survey of fertilizer sales and homeowner's application practices in developed areas similar to that expected for the Pinelands should be undertaken to quantify the use of artificial fertilizers.

The next step that needs to be taken is to determine how much nitrogen and phosphorus leaches into the groundwater from fertilizers applied in the manner reported in the survey. This can be done by installing lysimeters at various depths in residential lawns away from soil absorption systems to monitor the fate of nitrogen and phosphorus. Sampling frequency should be concentrated immediately after fertilizer applications and rainfall periods, but continued throughout the year to obtain an accurate mass balance.

By performing this sampling with different fertilizers in various soil types and with different application rates and frequencies, it can be determined how all these factors control the amount of nutrients that actually reach the groundwater. The results can then be used to confirm or adjust the calculations and conclusions on groundwater contamination from lawn fertilization found in Section 3.5 of the report: "A Procedure for Evaluating the Environmental Impacts of Alternative Wastewater Treatment Technologies." Using this knowledge, home owner education (or regulatory action, if necessary) can then be instituted to insure that Best Management Practices that minimize groundwater contamination are followed. This may even mean a lawn fertilizer ban if the conclusions show that this is the most cost-effective alternative.

2.5 Infiltration

The values that different investigators have used for rainwater infiltration through the soil to the groundwater have not been consistent. If further literature searches do not produce a generally acceptable rate, measurements should be performed that lead to a result specifically for residential lots in the Pinelands soils.

2.6 Vegetative Uptake of Nutrients

2.6.1 Residential Lawns - The value Brown Associates proposed in their report to the Pinelands Commission ("An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization, and Agricultural Activities on Groundwater Quality") for the amount of nitrogen uptake by plants in soil absorption systems was 4.5-9%. However, these removal rates were based on data from research in other soils and climates than the Pinelands. Similar experiments should be done in different Pineland soil types to see to what degree plant uptake can be depended upon to remove nitrogen and phosphorus. This research may show that it is possible to design soil absorption fields to take advantage of nutrient uptake by plants, perhaps by having the leaching fields closer to the surface.

2.6.2 Wetlands - Section 4 of "A Procedure for Evaluating Environmental Impacts of Alternative Wastewater Treatment Technologies" noted that it is not completely understood how available nitrogen and phosphorus is to plants in wetland environments. Research by the Center for Coastal & Environmental Studies of Rutgers University is continuing to assess the growth and nutrient uptake of these plant communities, and how they can be affected by increased nutrient inputs. Without this valuable knowledge, it will be difficult to assess what amount of nutrients from sewage disposal systems can be allowed to contaminate groundwaters and therefore reach these wetland environments. Therefore, this type of research should be encourage and supported by the Pinelands Commission.

3.0 MANAGEMENT OPTIONS

Whichever type of management system is chosen by the Pinelands Commission to have authority over on-site wastewater disposal systems, it will have many responsibilities.

A. It will have to develop public education programs for the following subjects:

   1. Compliance with phosphate detergen use bans by consumers
   2. Proper septic system maintenance by homeowners
   3. Conscientious water conservation attitude
   4. Best management practices for home lawn fertilization
   5. Hazardous chemical disposal in septic tank systems
   6. Compliance with garbage grinder bans
   7. The proper use of alternative systems such as compost toilets

B. It will need to enforce certain regulations:

   1. Ban on sale of phosphate detergents, garbage grinders, and lawn fertilizers, if decided
   2. Design and installation of on-site wastewater systems according to site conditions
   3. Operational requirements of some on-site systems

C. It will have to operate centralized sewerage facilities and the operation of some communal or on-site wastewater disposal systems

D. It will have to decide certain public policy issues:

   1. On-site disposal alternatives allowed and/or required
   2. Concentration of nutrients in groundwater permitted
   3. Lot sizes and building densities
   4. Prohibition of phosphate detergents, garbage grinders, and lawn fertilizers
   5. Types of soils allowed for use with soil absorption systems
   6. Development in environmentally sensitive areas

It is conceivable that these responsibilities may be divided among more than one management agency. It may be an existing authority or a newly created one. Some of the possibilities are:

Pinelands Commission
New Jersey Department of Environmental Protection
County Health Departments
Township Health Departments
Township Sewerage Authorities
Regional Sewerage Authorities
Local Municipal Governments

It is strongly recommended that the Pinelands Commission examine the existing institutional/management agencies and assess management functions which could be best served by existing institutions and determine methods for management of functions not served by existing institutions.

FINAL REPORT

ASSESSMENT OF INNOVATIVE AND ALTERNATIVE TECHNOLOGIES FOR ON-SITE WASTEWATER DISPOSAL

Prepared for the
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1.0 INTRODUCTION

Septic tank soil absorption systems have performed a vital function of environmental sanitation in the past by removing the hazard of human waste contamination from privies, cesspools, and surface discharges. However, the past decade has brought research and concern about continued pollution of land and water from the millions of septic tank systems in use in the U.S.

The discharge of septic tank systems to the soil presents four potential problems to an environmentally sensitive area such as the Pinelands:

- Human Health hazards associated with pathogenic bacteria and viruses;
- High nitrate or ammonium levels in drinking water supplies;
- Potential for eutrophication of surface waters from increased loadings of nitrogen and phosphorus;
- Possibility of local increases in groundwater and surface water pH which may effect terrestrial vegetation including cranberry or blueberry production.

A principal reason why these contaminants are of such concern in the Pinelands is the high water quality of the groundwater and surface waters in the area. The amount of organic matter, suspended solids, and nutrients in the water are all very low, as is the pH and alkalinity.

2.0 WASTEWATER CHARACTERISTICS

2.1 Sources of Domestic Wastewater

In today's modern society, technological advances as well as social and economic preferences have led to a number of devices in the home that use a large amount of water to carry away solid and liquid wastes. The actual flow of wastewater from a particular household and the resulting quantity of pollutants which are generated are dependent on a number of factors including the number of occupants, lifestyles, diets, appliances, etc. Since there are so many dependent factors, the actual wastewater flow and characteristics can be highly variable from home to home. Appendix A lists the values that researchers have reported for household wastewater generation.

The flush toilet is the largest single user of water, consuming approximately one third of the water in the home. The resulting mixture of human solid and liquid wastes and paper is often called blackwater to differentiate it from the remainder of the wastewater collectively called greywater. From the kitchen comes wastewater from the kitchen sink, dishwater and garbage disposal. If an automatic washer is owned, a significant amount of wastewater can be generated depending on use. Lastly, the bathroom generates wastewater from personal cleansing in the sink, shower and bath. In addition, if water softening units are used, certain salts can add to the alkalinity or dissolved solids content even if no additional water is consumed.

The total distribution of water use among these various uses for a typical American resident in a single family home is given in Table 2.1.

TABLE 2.1

ORIGIN OF POLLUTANTS AMONG VARIOUS HOUSEHOLD WASTEWATER SOURCES ASSUMING GARBAGE DISPOSAL, PHOSPHATE DETERGENTS AND NORMAL WATER USE

		Flow		BOD		TOTAL N		TOTAL P		TOTAL SS		Bacteria and Viruses	pH#
		Liters/ Day	% of Total	g/c/d*	% of Total	g/c/d	% of Total	g/c/d	% of Total	g/c/d	% of Total		
KITCHEN	Sink & Dishwasher	9	5.3	9	14	0.7	6.1	0.4	6.9	3	4.3	minor fraction	6.7
	Dishwasher	13	7.6	8	12	0.4	3.5	0.6	10	4	5.7	minor fraction	7.8
	Garbage Disposal	7	4.1	15	22	0.7	6.1	0.12	2.1	22	31		6.5
LAUNDRY	Automatic Washer	41	24	10	15	0.4	3.5	2.4	41	7	10	minor fraction	8.8
BATHROOM	Sink	13	7.6	3	4.5	0.1	0.9	0.2	3.4	4	5.7	minor fraction	7.9
	Bath Shower	32	19	5	7.5	0.2	1.7	0.1	1.7	3	4.3	minor fraction	8.2
GREYWATER	TOTAL	115	68	50	75	2.5	22	3.8	66	43	61	minor fraction	6.5-9
TOILET WASTEWATER		55	32	17	25	9	78	2.0	34	27	39	vast majority	5.6-8.9
TOTAL HOUSEHOLD WASTEWATER		170	100	67	100	11.5	100	5.8	100	70	100		7.4

* g/c/d = grams per capita per day

Appendix A lists reference sources and wide variations of reported values

#the pH of household wastewaters will vary according to the pH and alkalinity of the water supply

2.2 Pollutants of Concern

Biochemical Oxygen Demand (BOD)

A measure of the amount of oxygen that will be consumed by microbes in oxidizing the organic matter in sewage. It is therefore, related to the concentration of organic carbon and nitrogen compounds in a sample. BOD generated in the home is of both carbonaceous and nitrogenous nature and originates approximately one third from toilet wastes and two thirds from greywater.

Analysis of BOD is important in assessing the effectiveness of septic tank treatment systems and judging what the effects of wastewater will be on ground and surface waters. If waters containing significant amounts of BOD enter ground or surface waters, the ensuing microbial action can lower the dissolved oxygen content of the water, thereby possibly causing changes in the aquatic plant and animal ecology.

Suspended Solids

A measure of the organic and inorganic particles that do not settle easily from a wastewater sample. This determination allows the effectiveness of septic tanks and leachfield in removing these solids to be judged. If too many suspended solids exit the septic tank, they can clog the soils of the leach field and possibly cause surfacing of effluent. If suspended solids are transported through the soil to groundwater or surface waters, they can add to its turbidity and harbor bacteria or viruses.

The distribution of suspended solids between toilet wastes and greywater is quite variable. A typical apportionment of suspended solids as well as other constituents is found in Table 2.1.

Bacteria and Viruses

Bacteria and viruses are of extreme interest because of the possibility of a disease outbreak from pathogenic bacterial and viral contamination. Some viruses are difficult to detect and quantify. There is a limited amount of data on their occurance and removal. Fecal coliforms are used as indicator organisms and by themselves do not represent any public health threat. When reporting coliform levels for water samples, it is assumed that the lack of certain levels of fecal coliforms indicates the absence of pathogenic organisms. Although the vast majority of fecal coliforms and other bacteria are found in toilet wastewaters, many have also been found in greywater samples.

pH and Alkalinity

pH is a measure of the hydrogen ion (acid) concentration in water, while alkalinity is a measure of the ability of a water to neutralize acid and resist a change in pH. (This ability is also termed buffer capacity.) Both these determinants are required to predict the pH changes upon the mixing and dilution of various waters. If the volume, pH and alkalinity of leachfield effluent is known, along with the same information on the groundwater, the pH change after dilution can be calculated.

Soils in the pinelands have a low pH of 3.4-4.5 (Trela & Douglas). Also, the natural waters of the Pinelands have a low pH (4.3-5.2, Harlukowicz and Alhert, 1978, pp. 10-12; 4.2-6.7, Forman, 1979, pp. 176-181), and a low alkalinity (0.7-12 ppm $CaCO_3$, Forman, 1979, pp 176-181), and therefor a low buffering capacity. So septic tank systems discharging an effluent with a high pH and alkalinity could cause pH increases in the Pinelands aquatic environment. The actual increase would depend on the specific characteristics of groundwater and effluent and the housing density. Appendix B lists the assumptions made and calculations performed that indicate possible increases of 0.5 to 0.8 in the groundwater pH after dilution of septic tank effluent.

Nitrogen

Nitrogen is a nutrient of major concern both in terms of surface water eutrophication and drinking water quality. U.S. Public Health drinking water standards place an upper limit on the allowable concentration of nitrate nitrogen of 10 mg/l. This standard has been imposed because of the direct relationship between nitrate concentrations in drinking water and the occurrence of methemoglobinemia (blue baby) in infants. The eutrophication threshold limit for nitrate in surface waters is much less than the drinking water standard, only 0.3 mg/l. (From Water Quality Criteria, California State Water Resources Control Board, ed. Jack McKee and Harold Wolf, 1963. Refs: Sawyer, C.N., "Fertilization of Lakes by Agricultural and Urban Drainage." Jour. N.E.W.W.A., 61, 109 (1947), Imhoff, K., "The Final Step in Sewage Treatment." Sewage and Industrial Waters 27, 332 (1955).)

The major contributor of nitrogen in household wastewater is toilet wastes. Approximately 78 percent of the total nitrogen generated is from this source. According to Gotaas, 87 percent of the nitrogen content of blackwater is derived from urine, while 13 percent is from feces. The nitrogen emanating from household wastes is in three forms: organic nitrogen (Org-N), Ammonia-Nitrogen (NH_4-N) and Nitrate-Nitrogen (NO_3-N). The percentage of nitrogen in each form is approximately 20% NH_4-N, 80% Org-N, and only trace amounts of NO_3-N. The quantity and concentration of each in household sewage is shown in Table 2.1

The transformations of nitrogen forms that will be referred to later in the text are:

$\text{Organic-NH}_2 \longrightarrow \text{NH}_4^+$ ammonification

$\text{NH}_4^+ \longrightarrow \text{NO}_2^- \longrightarrow \text{NO}_3^-$ nitrification

$\text{NO}_3^- \longrightarrow \text{NO}_2^- \longrightarrow \text{NO}^= \longrightarrow \text{N}_2\text{O} + \text{N}_2$ denitrification

Since the natural concentration of the nutrient nitrate in the water and swamps of the pinelands is very low, the introduction of nitrate would cause concern for possible changes in species growth and distribution if nitrogen was the limiting nutrient as it often is in marine and swamp ecosystems.

Phosphorus

The forms of phosphorus of concern in wastewater are organic phosphates and inorganic phosphates which together are usually termed total phosphate (TP). Inorganic phosphates are made up of condensed phosphates and orthphosphates, the later usually reported and referred to as PO_4^{-3}-P.

The use of detergents with high phosphate concentrations has a significant impact upon the quantity of phosphorus in household wastewater. Approximately 40%-50% of the phosphorus generated in household wastewater originates in the laundry. Of equal importance in terms of phosphorus is toilet waste which contributes another 25%-50% of the total phosphorus in household wastewater, depending upon whether or not high phosphate detergents are used. As with nitrogen, the origin of phosphorus in toilet wastes is mainly from urine. Approximately 75 percent of the total phosphorus is from urine while 25 percent is from feces.

Phosphorus is a nutrient of major concern in the euthropication of surfrace water bodies since phosphorus is often the limiting nutrient in freshwater bodies. There are no drinking water standards concerning phosphorus but the eutrophication threshold limit for total phosphorus is about 0.01 mg/l. (From Water Quality Criteria, California State Water Resources Control Board, ed. Jack McKee and Harold Wolf, 1963. Refs: Sawyer,C.N., "Fertilization of Lakes by Agricultural and Urban Drainage." Jour. N.E.W.W.A. 61, 109 (1947), Sawyer, C.N., "Some New Aspects of Phosphates in Relation to Lake Fertilization." Sewage and Industrial Wastes 24,768 (1952).) Therefore, there is concern for the possibility that phosphate from septic tank leachfields could reach surface waters and wetlands and cause accelerated eutrophication.

3.0 STANDARD SEPTIC TANK-SOIL ABSORPTION SYSTEMS

3.1 System Design

The septic tank-soil absorption system is the most common on-site wastewater treatment system used in the rural and suburban areas of the United States. Traditionally, design criteria for septic tank disposal systems has been based on the presence of soil types which can adequately handle the hydraulic load generated from households by percolation through the soil. The particular system design used in New Jersey is specified in "Standards for the Construction of Individual Subusrface Sewage Disposal Systems."

Septic tanks provide for the retention of the solids portion of domestic wastewater. The septic tank allows solids from incoming wastewater to settle to the bottom of the tank forming a sludge layer. Certain waste materials, such as grease, float to the top of the liquid in the tank to form a floating scum layer. This scum layer is held in the tank by baffels. The liquid effluent flows through an outlet pipe to the soil absorption system for disposal. The longer the liquid effluent remains in the tank prior to flowing into the soil absorption system the more organic material can be removed by anaerobic digestion. The period the effluent remains in the tank is called "detention time" and this time is influenced by the size of the tank and the number of persons using the system. In the N.J. Pinelands, a 3 bedroom home is assumed to generate 450 gallons per day of wastewater and requires a 900 gallon tank to produce a detention time of 48 hours, better than the 24 hour recommended minimum.

Conventional soil absorption systems following septic tank treatment can be generally categorized as leaching trenches, leaching beds, or leaching pits. The objective of all is the same; to allow for the adequate dispersal and treatment of the septic tank wastewater effluent through the native soil. In each situation, the effluent from the septic tank flows through a distribution box and into perforated piping or drain tiles laid in gravelbelow the land surface. In the Pinelands, four feet of soil is required between the bottom of the gravel leaching field and the seasonally high groundwater table or bedrock. According to the percolation rate of the natural soil, the surface area of the leaching field is chosen. For example, a 3 bedroom home with soils of 20 min./inch will require 435 ft^2 of leaching field while soils with a perc rate of 40 min./inch will dictate 720 ft^2. A diagram of the entire standard septic tank-soil absorption system can be seen in Figure 3.1.

3.2 Performance

As was stated previously, the primary purpose of the septic tank is to separate gross solids and scum from the wastewater. Secondary is the anaerobic digestion that takes place to reduce the volume of sludge that accumulates, and cause the uptake of a small amount of nutrients. Overall, a properly maintained septic tank should remove 60% of the BOD and 80% of the suspended solids. In addition, much of the organic nitrogen is broken down to ammonia, and the complex phosphates to orthophosphate. Appendix C list septic tank effluent quality as reported by various investigators. If the septic tank is thought of being the primary, physical treatment operation, the soils of the leachfield are the secondary, biological-chemical treatment system. In the soil beneath the distribution pipes in the leachfield, other transformations take place. At the immediate soil/gravel interface, a biological mat eventually develops that, along with the underlying soil, filters out bacteria, viruses and suspended solids, and acts as a support for microbes that can absorb and oxidize dissolved organic matter. In well drained soils, conditions are said to be unsaturated because the effluent can percolate downwards among the soil particles and air pockets. Under this aerobic enviornment of the soil, bacteria can continue to degrade BOD and oxidize ammonia from the septic tank to nitrate (nitrification).

The specific soil conditions beneath the leaching lines determine the degree of treatment afforded. For bacteria and virus, removal, it appears that a well drained soil that develops a clogging zone at the effluent-soil interface is optimum. Most researchers agree that 4-5 feet of soil between the leaching lines and groundwater table is sufficient to remove bacteria and viruses and prevent contamination. (Brown et. al, 1980 p. 31)

In aerobic unsaturated sandy soils, ammonia is easily oxidized to nitrate, a mobile and relatively unabsorable species. (Bouma et al, 1972) Most of this nitrate nitrogen passes through the leachfield and enters the soils or groundwater below. The only pathway of nitrate removal is by denitrification to nitrogen gas or nitrous oxide in the presence of organic carbon and an anaerobic environment. Usually, slowly permeable, low redox

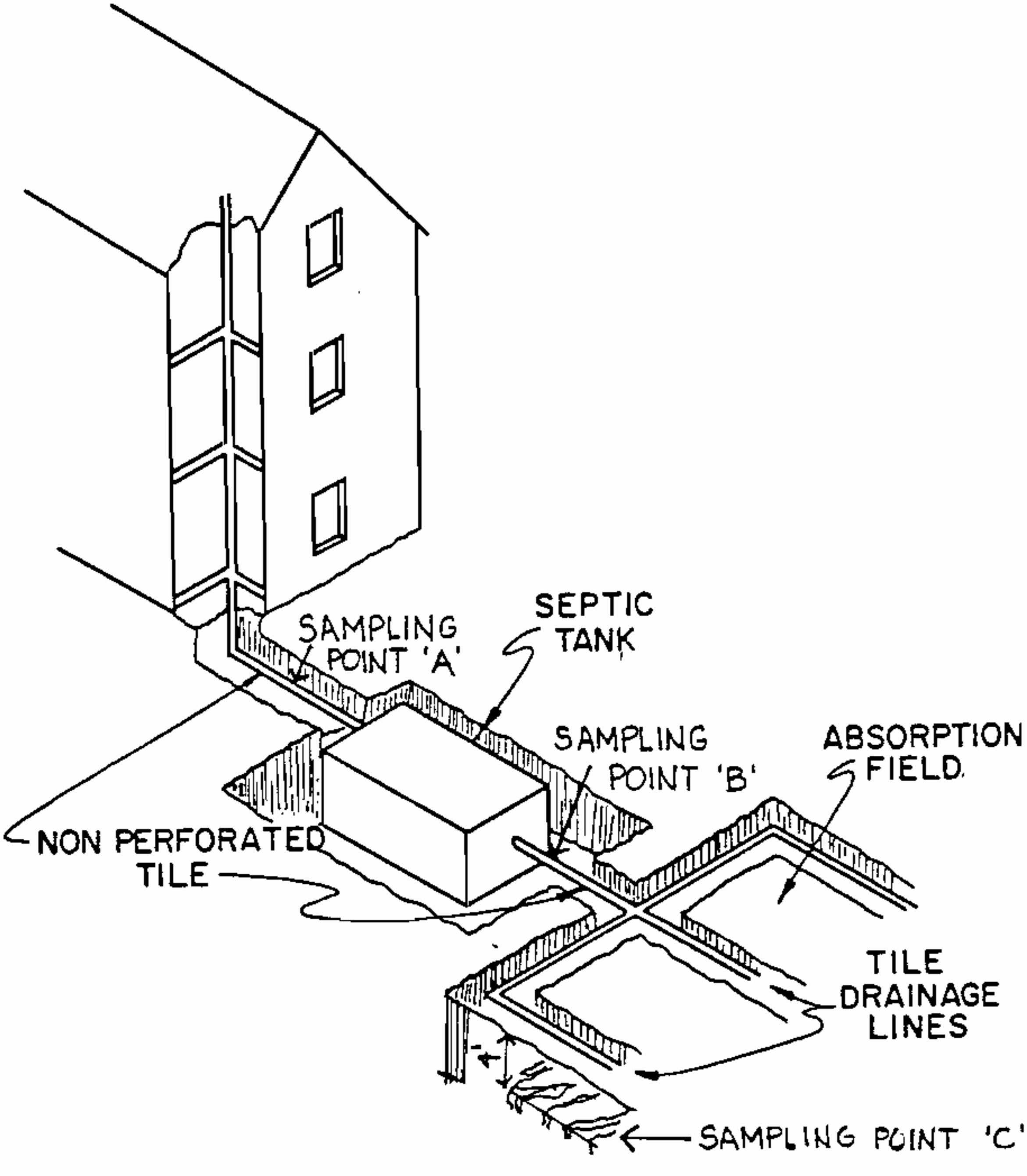


FIG. 3.1 STANDARD SEPTIC TANK - SOIL ABSORPTION SYSTEM

potential soils are required to produce the proper conditions that can denitrify approximately 30% of the nitrate. (Lance & Whisler, 1972; Magdoff et al, 1974.) However, Broadbent and Clark ("Denitrification," pp. 344-359, in W.V. Bartholomew and F.E. Clark (ed.) Soil Nitrogen, Am. Soc. Agron., Madison, Wisc.) report that microenvironments in an aerated soil, such as around soil particles in a leach field, can allow denitrification to take place when oxygen diffusion is limited. Most agree though that in coarse, sandy, rapidly permeable soils with low organic matter, denitrification is minimal. Trela and Douglas (p. 41) conclude that in these soils 99% of the applied nitrogen will reach the water table as NO_3^-.

If the ammonium ($NH+_4$) in the septic tank effluent is not immediately oxidized, there is also the opportunity for nitrogen removal through volatilization of NH_3 or adsorption of $NH+_4$ in certain soils with high cation exchange capacities. However, the low pH and low cation exchange capacities of Pinelands soils will minimize these removal properties.

Phosphate can also be removed from the soil via adsorption, ion exchange, or precipitation by iron or aluminum minerals in clay soils. The higher the clay fraction, the more phosphate that can be fixed in the soil. Thus, the sorption capacity of a specific soil is variable but finite; eventually the phosphate will pass through relatively unaltered to the subsoils or groundwater. In addition, the pH of the percolating wastewater will also affect the removal or dissolution of phosphates in the soil. The optimum pH for fixing phosphate in the soil is between 6 and 7 (Trela & Douglas p. 43). So it appears that the best conditions for nitrogen removal (slowly permeable, partially anaerobic, high organic content soils) and bacteria removal (well drained unsaturated sandy soils) are in opposition; while phosphate removal depends on the amount of clay and other minerals in the soil. A study in Delaware (Miller et al, 1974) found that in an 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 a 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.

There are many types of soils in the Pinelands but they can be generally divided between upland, sandy, acidic, low organic soils and lowland, organic, slowly well drained permeable, high groundwater soils. Harlukowicz and Ahlert (1978 pg. 16) feel that if residential development is restricted to upland areas of the Pinelands where soils are "slightly limited" (Woodmonsre, Downer, Eresboro, Lakewood, Pitts, Urban Land), nitrate and phosphate will be stable and non-absorbed, therefore reaching the water table.

Trela and Douglas group Pineland soils into three groups.

I - High Water Table - not acceptable for subsurface disposal (Alison, Berryland, Fallsington, Woodstown, Pocomoke, Lakehurst and Klej).

II - Sandy or loamy sand, low clay, rapid percolation, low denitrification and low phosphate fixing capacity - acceptable with regards to traditional disposal concerns (Lakewood, Evesboro, Downer, some Sassafras)

III - Soils with clay in subsurface layers that can afford up to 30% denitrification and phosphate removal for the life of the system. (Woodmansie, Aura, some Sassafras)

Brown et al (1980) divides the soils into 4 groups: Hydrological Group A - Sandy soils with rapid surface and subsurface permeabilities (Evesboro, Fort Mott, Fripp, Galestown, Lakeland, Lakewood, Lakehurst, Pemberton and Tinton), Group B - sandy soils with restrictive (less permeable) layers of sandy loam, sandy clay, and loams (Collington, Aura, Colts Neck, Downer, Freehold, Hammonton, Klej, Phalanx, Sassafras, Westphalia, and Woodmonsie. Groups C & D are soils with high groundwater tables and are unsuitable for leachfields with modifications such as mounds. Brown does not feet that any appreciable denitrification will take place in Group A or B soils, but that 4.5% and 9%, respectively of the nitrogen can be removed by plant uptake.

For the discussions and comparisons in this paper, we will assume that the subsurface absorption field is placed in upland sandy soils that will meet the percolation and soil depth regulations. Since these soils are very permeable and have low organic contents and sorption capacity, we are assuming only ~5% removal of nitrogen through plant uptake and volatilization, and 10% removal of phosphorus through uptake and adsorption. In many soils, phosphate removal will be high at first, but after the adsorption sites are exhausted essentially all the phosphate will pass through to the groundwater unchanged. The time for this breakthrough can vary according to the soil and site conditions from less than a year to 50 years (Brown et al, 1980).

Table 3.1 presents the concentrations and mass of pollutants as they pass through the septic tank and leachfield.

TABLE 3.1 PERFORMANCE OF STANDARD SEPTIC TANK-SOIL ABSORPTION SYSTEMS

Sampling Point (see Figure 3.1)	$NO_3^- + NO_2^-$-N		NH_4^+-N		ORG-N		TOTAL-N		BOD_5		$PO_4^{\equiv}$-P		TOTAL-P		SS		Fecal Coliform	pH
	mg/l	g/c/d	mgl/	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d		
A--Total Household Sewage Effluent[5]	0.5	.08	13.5	2.3	54	9.1	68	11.5	394	67	9.6	1.64	34	5.8	412	70	$\frac{10^6}{100\ ml}$	7.4 (5.6-9)[4]
B--Septic Tank Effluent[6]	0.3	0.05	33	5.6	11	1.9	44.3	7.6	143	24.3	11	1.9	14.5	2.5	73	12.4	$\frac{10^6}{100\ ml}$	7.3 (6.4-7.8)[4]
C--Soil Absorption System Effluent[1] (Sandy Well Drained Soil)	38	6.5	2	.34	2	.34	42	7.2	5	.85	10[2]	1.7[2]	13[2]	2.3[2]	6	1	$\frac{\sim 25}{100\ ml}$	~7 (5.2-8.4)[4]

[1] After percolating through 48" of sandy aerobic soil beneath leaching field. Values for ammonia, BOD, SS, and Org-N assumed from mound and sand filter data (Bouma et al, 1975; Peterson and Fritton, 1979; Otis et al, 1977; Schmidt, Boyle, et al, 1979).

[2] Values expected after exhaustion of phosphate fixing capacity in sandy soils. Lower values initially expected due to adsorption and precipitation.

[3] See Appendix E for literature values and ranges.

[4] Range of reported values depending on wastewater sources and soil types (Appendix A, Appendix C, Peterson and Fritton, 1979).

[5] Concentrations calculated from Table 2.1 and Appendix A loadings and a normal flow of 170 l/c/d; values assume the use of phosphate detergents and garbage grinders.

[6] Loadings calculated from Appendix C and 170 l/c/d.

4.0 INNOVATIVE AND ALTERNATIVE MODIFICATIONS TO SEPTIC TANK-SOIL ABSORPTION SYSTEMS

The modifications in this section do not require changes in wastewater generation within the household or the basic idea of treating sewage and then disposing of the effluent into the ground. Their goal is to reduce the amount of pollutants that will eventually enter and possibly contaminate groundwaters.

An alternative system or modification is a design not normally used when a conventional system is constructed. If should be a technique that has been used in practice and shown to perform as designed. An innovative system or modification is a technique that has been shown to work theoritically and experimentally but not tried extensively in real situations.

4.1 Modifications to Improve Nitrogen Removal

4.1.1 Mound Systems over Lowland Soils

Mounds have been used extensively in some states for sites where there isn't enough suitable soil above the water table or bedrock to install a leachfield. Instead, a sand or soil mound containing the leaching lines is built over the natural soil to provide satisfactory treatment of the effluent before reaching the native soils for final purification.

Research (Peterson and Fritton, 1979) has shown that mounds may be constructed specifically to stimulate denitrification by using proper soil mixtures. In the lowland, high groundwater, slowly permeable soils of the Pinelands, denitrification could occur if the effluent was first nitrified and purified by a sand mound above it. With high groundwaters, a mound would be necessary to meet the regulations of soil depth regardless. There is probably enough organic matter to denitrify up to 30% of the nitrate (Trela and Douglas p. 41) in some of these saturated soils. Therefore a total of 40% N removal (with plant uptake) could be achieved. BOD, phosphate, and bacteria removal would probably not be significantly affected in the long run.

4.1.2 Ammonia Adsorbtion Systems

Since septic tanks generally discharge about 60% of their nitrogen as ammonia (NH_4+), one strategy to achieve nitrogen removal is to remove ammonia from the effluent before applying it to the leachfield. The method of ammonia stripping by pH adjustment and aeration practiced in centralized sewage treatment plants is not feasible for individual on-site systems. Therefore, a system has been developed to use clinoptilolite, a naturally occurring cationic exchange resin, to remove ammonium ions from the waste stream.

The ion exchange procedures envisioned for ammonia removal for small flows employ a column operation in which septic tank effluent is pumped under pressure through a column of clinoptilolite resin. Once breakthrough of nitrogen occurs, it is necessary that the resin be replaced with regenerated material.

There is experimental evidence to indicate that clinoptilolite will effectively remove 90-95% of ammonia-nitrogen from ammoniated effluents. (Boyle and Otis, 1979) However, there has been only limited experience with actual septic tank systems. More research and trials will be needed to refine design criteria and determine optimum resin replacement intervals.

4.1.3 Denitrification Systems

Denitrification is a biological process that reduces nitrate to nitrogen or nitrous oxide gas by oxidizing a simple carbon source such as methanol. Since it takes place in an anaerobic environment, bacteria use nitrate, NO_3-, as an oxygen supply.

Application of the technology of denitrification to small scale wastewater systems has generally been restricted to research and demonstration projects. The basic processes involved, however, are well known as a result of their use in large-scale wastewater treatment plants.

One proposed system is shown in Figure 4.1 it is a conventional soil absorption system which has been modified to create an anaerobic zone below the leachfield. This is done basically to increase the natural denitrification process that takes place in soil. Anaerobic effluent from a septic tank is applied to the soil absorption field. Leachate is nitrified in the aerobic layer of soil above the liner, and nitrates in the leachate are denitrified in the anaerobic leachate-saturated zone contained by the liner. To insure that adequate carbon is available for the denitrification process, methanol is added to the soil immediately above the anaerobic zone.

If an aerobic treatment unit is substituted for the septic tank, effluent applied to the soil absorption trenches has already been nitrified. In this case the aerobic zone below the trenches can be minimized and the excavation depth required can be reduced. Similarly, use of a sand filter to nitrify septic tank effluent would reduce the required excavation depth.

Other designs have also been tested to make use of denitrification with anaerobic packed bed reactors (fixed film) and anaerobic suspended growth reactors. Both must receive fully nitrified influents from either an aerobic treatment tank or a septic tank followed by an aerobic sand filter, as well as a carbon source addition such as methanol. A packed bed reactor could simply be an anaerobic sand filter or a stone filled tank as shown in Figure 4.2. Denitrifying bacteria that develop on the sand or stone particles will reduce the nitrate flowing past and oxidize the methanol and other organics in the wastewater.

Similarly, an anaerobic suspended growth reactor could be a septic tank receiving nitrified effluent and methanol that would develop a population of denitrifiers. One additional system uses elemental sulfur instead of methanol in a packed bed nitrification column. (SSWMP, 1978, p.A-229)

Whichever denitrification system is chosen according to cost, reliability, acceptance, etc., the removal rate of nitrate should be 80-90%. (Boyle and Otis, 1979)

4.2 Modifications to Improve Phosphorus Removal

4.2.1 Alternating or Abandoning Fields

Alternating field systems have septic tanks that lead to a distribution box that can be adjusted manually or automatically to direct the effluent to one of two or more alternate leaching fields. The purpose of this system is to allow one leachfield to "rest" while the other is being dosed. During the resting period, the soils become fully aerobic and the "clogging mat" can be broken down.

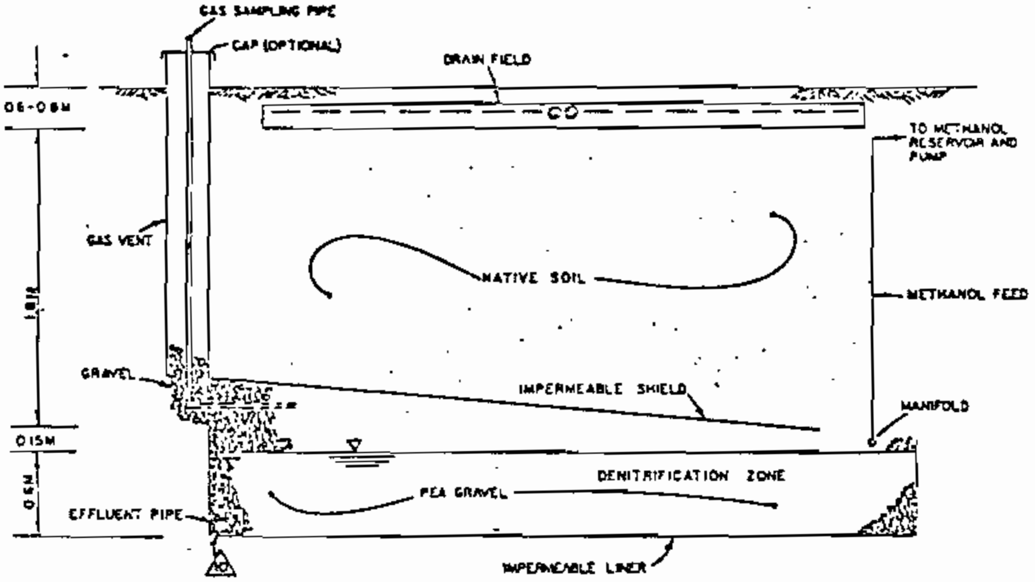


FIG. 4.1 MODIFIED SUBSOIL DISPOSAL/DENITRIFICATION UNIT (Andreoli et al., 1976)

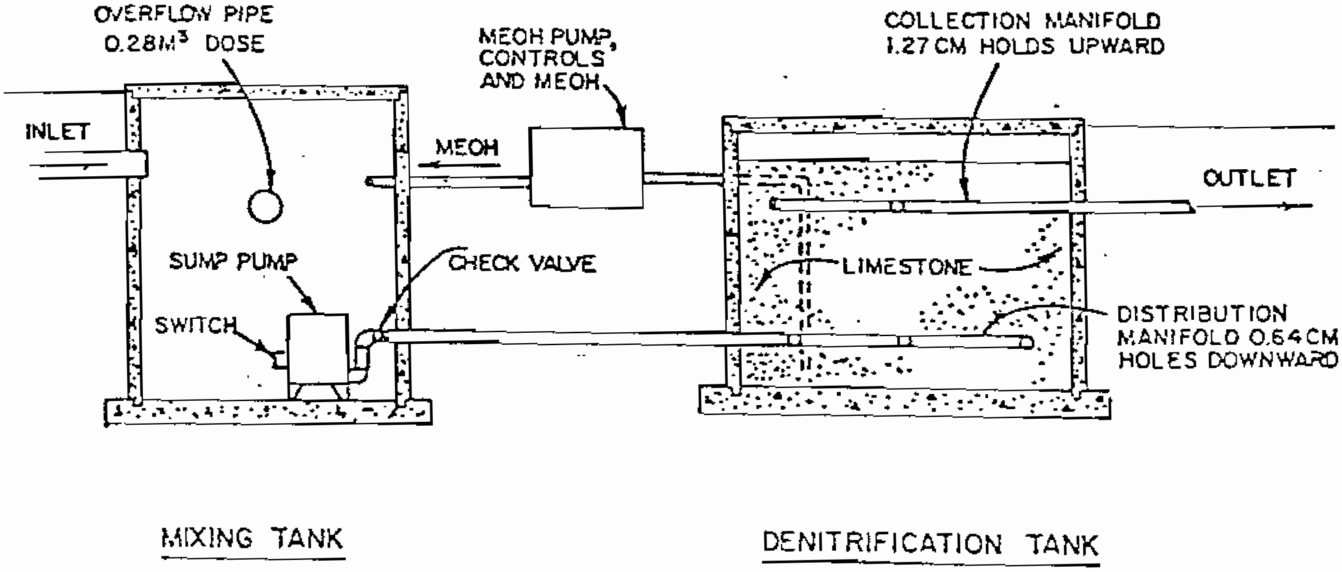


FIG. 4.2 ANAEROBIC PACKED BED REACTOR (Sikora et al., 1977)

If a specific soil is analysed for its phosphorus adsorption capacity, the time until breakthrough for a certain leachfield area can be calculated. The leaching fields can then be alternated up to the point where the soils are saturated and will begin leaching phosphate. The cost of this modification can be very expensive depending on the number of years before the leachfield must be abandoned. A problem to be concerned about is the possibility that infiltrating rain water could possibly dissolve and leach the phosphate from the soil and carry it to the groundwater. For our calculations, we have assumed 75% (80-90%) removal rate of phosphate during the adsorption phase (Trela and Douglas, p. 43, Brown et al, 1977, p. 61; Peterson & Fritton, 79, p. 56) and a policy of abandoning the field when exhausted for use of a new area.

4.2.2 Chemical Addition Systems

One of the current methods for removing phosphates from sewage effluents involves the addition of precipitating agents such as alum, iron salts, or lime. If these are added to the household wastewater, the phosphate containing precipitate can settle out in the septic tank. This, of course, increases the rate of sludge accumulation. A variation of this operation is to add the coagulants after the septic tank and allow the precipitates to settle and be filtered out in the leachfield. This will probably cause the leachfield to clog more quickly, therefore requiring more frequent replacement. The chemical feed devices for metering out coagulants to small flow systems have been reported to require regular maintenance. Because of the wide variations of phosphorus input from an individual home, chemical feed rates are generally based on flow volumes.

Although all three chemical coagulants have been experimented with, most researchers feel that alum is the most successful and suitable for septic tank systems. With the proper dosing and detention times, phosphate removal rates of 80-90% can be obtained. (Boyle and Otis, 1979)

4.2.3 Sand Filter Bed Systems

An other physical-chemical method of removing phosphate involves the use of a column or bed systems where wastewater would flow past a fixed, coagulating media and precipitate and be absorbed within the bed. The sand filter used today is designed primarily for removal of BOD and suspended solids so that the clarified effluent can be applied to less than optimum soils for disposal, or to surface water discharges. It can be modified for other purposes as well.

One design uses an upflow anaerobic filter packed with dolomite or calcite for phosphate precipitation and chemisorption. Septic tank effluent passes through this filter before being applied to the leachfield. The removal rates are significant at first but poor long-term performance is attributed to organic anion competion for the sorption sites.

Another design with potential consists of a sand filter with layers of "red mud," a waste product from aluminum processing plants, or limestone for removing phosphate by precipitation and adsorption. It has been reported that effluent from the filter containing less than 2.5 mg/1 of total phosphorus can be consistently achieved. (Ontario Ministry of the Environment, 1977) Depending upon the amount of chemicals available and the total cation exchange capacity of the chemically coated sand layer, there is a time limit beyond which the system capacity for phosphorus removal is exhausted and subsequently no significant phosphorus removal will occur. Unfortunately, no longterm operation data are available for an accurate assessment of the anticipated life of the system in terms of effective phosphorus removal. Additional experimental and theoretical studies need to be conducted to gain necessary in-depth understanding of system performance and controling variables in order to obtain an optimal design and establish operation and maintenance requirements.

With proper design and operation, filter beds using limestone, "red mud," alumina (another proposed absorber) or simply soils with high phosphate exchange capacities, could effectively remove 80-90% of the phosphates in septic tank effluents. (Boyle and Otis, 1979)

4.3 Modifications to Control other Pollutants

There are many other modifications of standard septic tank - soil absorption systems proposed and in use that can affect the disposal of household generated wastewater. The purpose of a number of them is to facilitate percolation of effluent through less than optimum soil and site conditions. Fill systems are used when native soils are not satisfactory; mound systems are used when the depth of soil to groundwater or bedrock is too shallow; alternating leaching fields are used to improve the use of easily clogged soils, etc. None of these systems are expected to have major effects on the amount of pollutants that will reach groundwater supplies, therefore they were not evaluated here.

BOD and Suspended Solids - Soil absorption fields normally remove BOD and Suspended Solids to levels below concern. If a major concern did develop to reduce these pollutants further, a sand filter between the treatment tank and soil absorption field should have the desired effect.

Bacteria and Viruses - Similarly, the percolation of septic tank effluents through the native soil in a soil absorption field is usually sufficient to remove bacteria and viruses to a level where adjacent uses are effected. If particular soil and groundwater conditions were not suitable for microbiological removal, a sand filter with disinfection could follow the septic tank and precede the leachfield.

Alkalinity and pH - If it was concluded that the pH of leachfield effluent was high enough to affect the pH of Pinelands waters, it could be adjusted by acid addition. This could either be done in the treatment tank or in a mixing tank between the septic tank and leachfield. However, acid addition would create a new problem of adding salts such as Cl - to the groundwater. There are no simple methods of removing the alkalinity content of household wastewater flows; but with the proper effluent pH, alkalinity levels should not be a major problem.

4.4 Performance of Septic Systems and Modifications

Table 4.1 summarizes the expected effluent quality from standard septic systems, and systems modified as discussed in sections 4.0 through 4.3. To permit the direct comparison of performance of these systems all values have been presented as grams per capita per day and mg/1. These figures are based upon the assumed wastewater characteristics presented in Table 2.1.

TABLE 4.1 POLLUTANT LOADING TO GROUNDWATER DUE TO INNOVATIVE AND ALTERNATIVE MODIFICATIONS OF CONVENTIONAL SEPTIC TANK - SOIL ABSORPTION SYSTEMS

Treatment Alternative of Table 2.1 Wastewater	Text Refer.	$NO_3^- + NO_2^-$-N		NH_4^+-N		ORG-N		TOTAL-N		BOD_5		$PO_4^{\equiv}$-P		TOTAL-P		Fecal Coliform	pH
		mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d		
Standard Septic Tank Soil Absorption System	3.1	38	6.5	2	.34	2	.34	42	7.2	5	.85	10	1.7	13	2.3	$\frac{\sim 25}{100\ \text{ml}}$	~7
Septic Tank, Ammonia Absorption Unit, SAS	4.1.2	6.1	1.0	0	0	1	.17	7.1	1.2	3	.51	10	1.7	13	2.3	$\frac{\sim 25}{100\ \text{ml}}$	<7
Septic Tank, Sand Filter to Dentrification Reactor, SAS	4.1.3	10	1.8	1	.17	1	.17	12	2.1	3	.51	10	1.7	13	2.3	$\frac{\sim 25}{100\ \text{ml}}$	>7
Chemical Addition to Wastewater Septic Tank, SAS	4.2.2	38	6.5	2	.34	2	.34	42	7.2	5	.85	1.5	.26	2	.34	$\frac{\sim 25}{100\ \text{ml}}$	>7
Septic Tank, Sand Filter Bed System, SAS	4.2.3	40	6.8	1	.17	1	.17	42	7.2	3	.51	1.5	.26	2	.34	$\frac{\sim 25}{100\ \text{ml}}$	>7
Septic Tank, Acid Addition, SAS	4.3	38	6.5	2	.34	2	.34	42	7.2	5	.85	10	1.7	13	2.3	$\frac{\sim 25}{100\ \text{ml}}$	<7
Septic Tank - Mound Over Poorly Drained Lowland Soils	4.1.1	24	4.1	2	.34	2	.34	28	4.8	5	.85	10	1.7	13	2.3	$\frac{\sim 25}{100\ \text{ml}}$	~7
Septic Tank - Alternating and Abandoning SAS	4.2.1	38	6.5	2	.34	2	.34	42	7.2	5	.85	2.8	.48	3.7	.63	$\frac{\sim 25}{100\ \text{ml}}$	~7

5.0 HOUSEHOLD MANAGEMENT MEASURES/PRACTICES

There are two "philosophies" for looking at the problem of decreasing the amount of pollutants in wastewater. One is to remove them from the total wastewater flow by various biological, chemical, and physical operations. The other is not to add them in the first place. Household management practices are methods of reducing pollutant input by non-technical, non-"treatment" means. These measures generally call for little or no expenditure by individual homeowners. Their effectiveness is particularly dependent upon voluntary public cooperation.

5.1 Phosphate Detergent Ban

Since phosphate containing detergents used in laundry washing contribute about half of the phosphate load in a typical household, banning the sale and use of such detergents can greatly reduce the amount of phosphate discharged. Non-phosphate detergents exist with a maximum phosphate content of 0.5%. If a ban is adopted, the phosphate level of the total wastewater will decrease to 40-50% of its former level. Since the non-phosphate detergents contain other "builders" instead of phosphates, the amount of silicates and carbonates in the wastewater will increase. In areas with hard water due to iron in the groundwater, residents may choose to use washing soda (sodium carbonate) to supplement detergents. Therefore the alkalinity of the wastewater will most likely increase accordingly.

5.2 Home Laundry Ban

If automatic washers are banned and laundry is done at a laundramat rather than at home, an additional reduction in pollutant loadings can take place. Phosphate loadings should be about half of normal, while BOD decreases by approximately a quarter, suspended solids by a fifth and nitrogen only by a small amount. Additionally, the volume of wastewater discharged will decrease by 20-25% because of the absence of laundry washwater.

5.3 Garbage Grinder Ban

In many on-site sewage disposal regulations, the use of a garbage grinder requires a larger septic tank and leachfield than usual do to the increase in organic matter. Therefore, a prohibition of the use of garbage grinders in homes with on-site disposal systems will effect a decrease in loadings from the norm. On the average, one could expect BOD to decrease almost a fifth, suspended solids almost a third, but only a slight decrease in nitrogen and phosphorus input. Therefore, the effect on water quality in regards to nitrogen and phosphorus is negligible from banning garbage grinders. The benefit is realized in the reduction of the amount of BOD and suspended solids discharged which will extend the functioning lifetime of the leachfield and the frequency of sludge pumping from the septic tank.

5.4 Water Conservation

While water conservation is certainly desirable from many standpoints (economics of water supply, design and operation of leachfields, etc.), the effect on pollutant loadings is probably marginal. If low flush toilets, low flow faucets and shower flow controls, etc. are used, the same wastes are simply carried by less water. There will be some benefit by having longer detention times in the septic tank to facilitate suspended solids settling and organic decomposition, but the amounts of nutrients discharged to the soil for percolation has not been shown to decrease. If water is saved in the home by the use of water conservation devices, it must be made up by an increased volume of infiltrating rainwater to achieve the same final dilution of nutrients. Therefore, lot sizes will need to be increased somewhat if the volume of effluent decreases while the loading remains the same. The flow rate of 115 l/c/d shown in Table 5.1 has been estimated from SSWMP (1978) and SCS (1978) and assumes 2½ gallon flush toilets, sudsaver washers, shower head and faucet flow reducers.

5.5 Hazardous Materials Disposal Ban and Education

One additional concern for protecting septic tank system and groundwater is homeowner education, since the proper operation and maintenance is primarily his or her responsibility. Occupants need to be educated on the function and operation of their wastewater treatment system. They should realize that problems can occur by flushing large solids down the toilet that can clog the septic tank. Chemicals that should not be disposed of into a septic system include paint thinners and other solvents, gasoline, large amounts of caustic drain cleaners, acids, chlorinated hydrocarbons, pesticides, and other possibly toxic or non-biodegradable chemicals. Some states have already banned purported "septic tank cleaners" that are actually toxic chlorinated hydrocarbons because of contamination of groundwaters and drinking supplies. All of these chemicals have the possibility of affecting groundwaters by their toxicity and strong pH levels.

5.6 Effectiveness of Household Management Measures

Table 5.1 shows the expected effectiveness of implementing the non-structural management measures discussed above.

TABLE 5.1 POLLUTANT LOADING TO GROUNDWATER DUE TO NON-TECHNICAL HOUSEHOLD WASTE MANAGEMENT MEASURES

Treatment Alternative of Table 2.1 Wastewater	Text	$NO_3^- + NO_2^-$-N		NH_4^+-N		ORG-N		TOTAL-N		BOD_5		$PO_4^{\equiv}$-P		TOTAL-P		Fecal	
	Refer.	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	Coliform	pH
Normal Flow & Prac. Septic Tank-Soil Absorption System Sandy Well Drained Soil	3.1	38	6.5	2	.34	2	.34	42	7.2	5	.85	10	1.7	13	2.3	$\sim \frac{25}{100\ ml}$	~7
Phosphate Detergent Ban	5.1	38	6.5	2	.34	2	.34	42	7.2	5	.85	6.3	1.1	7.8	1.3	$\sim \frac{25}{100\ ml}$	~7
Home Laundry Ban	5.2	37	6.3	2	.33	2	.33	41	7.0	4.3	.72	6.3	1.1	7.8	1.3	$\sim \frac{25}{100\ ml}$	~7
Garbage Grinder Ban	5.3	36	6.1	2	.32	2	.32	40	6.7	3.9	.66	9.8	1.7	13	2.3	$\sim \frac{25}{100\ ml}$	~7
Use of Water Conservation Devices Flow = 115 l/c/d	5.4	57	6.5	3	.34	3	.34	63	7.2	7.4	.85	15	1.7	20	2.3	$\sim \frac{25}{100\ ml}$	~7
Hazardous Materials Disposal and Education	5.5	No effect on the above parameters, but benefits the operation of the septic tank - SAS and the prevention of groundwater contamination from toxics.															

6.0 INNOVATIVE AND ALTERNATIVE WASTEWATER SYSTEMS

6.1 Aerobic Treatment Systems

Aerobic units have been used as a substitute for septic tanks. They usually consist of three chambers: pre-settling, aeration and final settling (with sludge return). The pre-settling chamber separates gross solids prior to aeration/biological renovation in the aeration chamber. The final settling chamber allows for collection and return of biologically active sludge (like activated sludge return in large-scale plants) to the aeration chamber. Properly supervised units produce an effluent with better characteristics than that of a septic tank. This improved treatment efficiency is said to reduce the potential for soil clogging, thus allowing smaller leaching fields for wastewater disposal, although not all researchers agree with this statement. Typically, however, lack of required homeowner attention has resulted in effluent characteristics similar to septic tanks. Researchers have found that although the average BOD and suspended solids concentration is lower than that from a septic tank, the variability in concentration over time is greater. Other disadvantages of this system include: need for monthly homeowner attention, high cost (capital and operating), and system malfunctions resulting from wastewater surges that can easily send unwanted solids to the leaching area where they can cause premature clogging and disposal field failure.

The effluent from an aerobic tank should have about the same phosphate and nitrogen concentrations as septic tank effluent, although the nitrogen will be primarily nitrate rather than ammonia. Therefore, the amount of nitrate output from the leachfield might be slightly higher due to the absence of much ammonia absorption. Figure 6.1 shows the layout of a typical aerobic treatment unit.

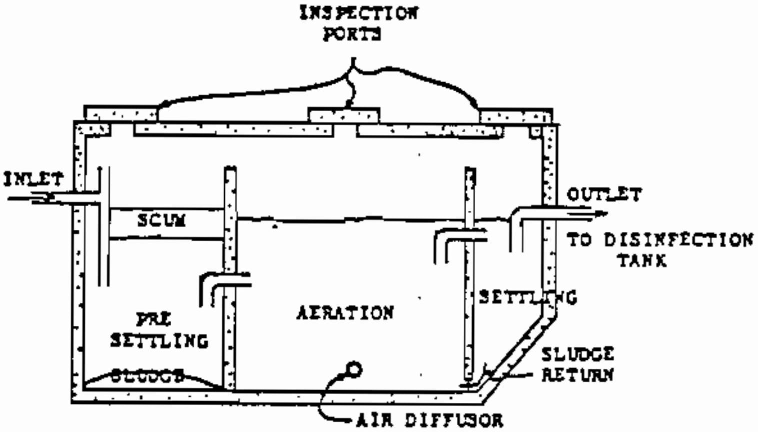


FIG. 6.1 AEROBIC TANK

6.2 Greywater Reuse Systems

Greywater reuse for toilet flushing is a useful technique for reducing water consumption and wastewater flows by approximately 35-50 percent. It is particularly useful in areas where soils with low permeability necessitate the installation of large leaching areas. Additionally, a failing subsurface wastewater adsorption system may perform adequately if wastewater volume is reduced by this method. However, older homes with a conventional wastewater collection system will require expensive retrofitting with a dual piping system for sanitary wastewater and greywater separation.

For reuse purposes, greywater is collected and usually treated by a filtration system and optional disinfection before being stored in a pressurized tank. The primary use of this treated greywater is for toilet flushing. Other proposed uses such as garden and lawn irrigation will not be considered in these calculations.

After being reused for toilet flushing, the greywater turned blackwater and any excess greywater can be treated in a conventional septic tank - S.A.S. It is not expected that the pollutant loading to the soil and groundwater would change significantly because most of the wastes will still be discharged. Due to the filtering of the greywater, some BOD, SS, and phosphate from the laundry may be removed, but this has not been quantified.

6.3 Non-discharge Toilets and Greywater Disposal

Segregation of blackwater (toilet wastewater) from greywater (other household wastewater) is a concept which is currently receiving increased attention as a wastewater disposal alternative in areas of the United States encountering water shortages, water pollution problems and on-site wastewater disposal limitations. The purpose of separating the blackwater from the remainder of the household wastes is to substantially reduce loadings both in terms of flow and contaminants. As indicated in Table 2.1 a flow reduction of approximately one-third and substantial reductions in the pollutant loadings can be anticipated through the treatment of blackwater separately from the remaining household wastewater.

The blackwater portion of the household waste stream is conducive to several different types of treatment and handling that do not require any on-site wastewater discharge, including:

- Compost toilets
- Oil Flush Toilets
- Incinerating Toilets
- Recycle Toilets

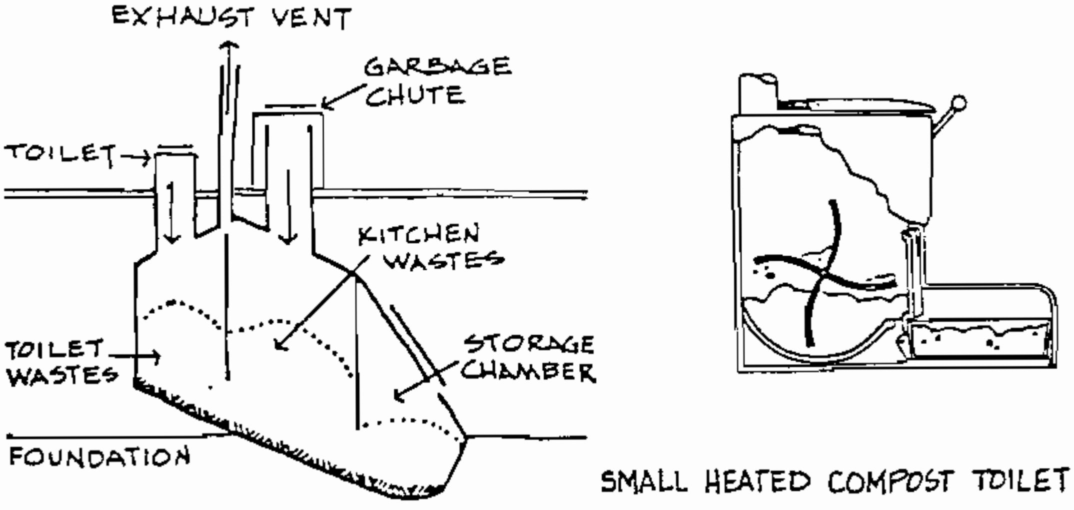
Since blackwater usually contributes about two-thirds of the nitrogen and from a quarter to a half of the phosphorus in household wastewater, nutrient inputs can be greatly reduced by removing toilet wastes from the flow. BOD and suspended solids concentrations will also be greatly reduced.

The greywater remaining after segregation can be treated and disposed of by any method applicable to normal household wastewater, or by new alternative greywater treatment systems which will be discussed later.

6 .3.1 Compost Toilets

The compost or humus toilet allows for the aerobic, biological decomposition of wastes deposited in a chamber to produce a humus-like material. Compost toilets optimize the aerobic biological decomposition process that occurs when manure is plowed into soil. Two types of compost toilets exist - the small electrically assisted unit and the larger non-electrically assisted unit. The smaller units attempt to operate in the thermophilic composting process temperature range while the larger units operate in the lower mesophilic composting process temperature range. Figure 6.2 shows the two types of commercially available units.

The smaller units fit easily in the space required for a conventional toilet, while the larger units have a toilet component attached to a large collection chamber in the basement. Kitchen scraps (replacing a garbage grinder) and lawn clippings can also be added to this collection chamber through a garbage chute. The small units require a heat source (usually electric heating coils) for maintenance of the 140° - 160° F thermophilic compost temperature and evaporation of excess liquids. With both units, a family of four will produce about 3-10 gallons of stabilized compost annually. The compost from both units can be used as a garden mulch or soil additive, although it is recommended that it be buried as a public health precaution and for further breakdown. The technology for compost toilets is still developing and liquid overload, odor and fly problems have occurred. However, they have been shown to operate satisfactorily under proper conditions.



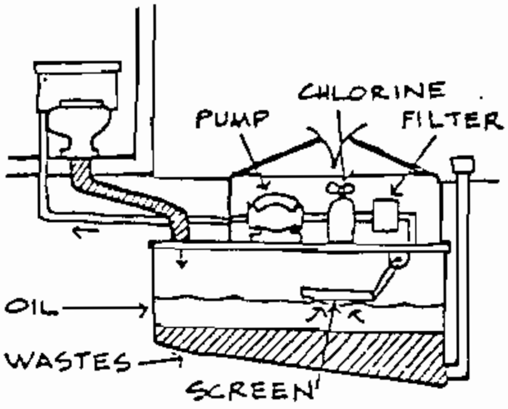
SMALL HEATED COMPOST TOILET

LARGE COMPOST TOILET

FIG. 6.2

6.3.2 Oil Flush Toilets

Instead of water, oil is used in the oil flush toilet as the waste transport medium. The collected oil/waste mixture is allowed to remain quiescent for separating the two phases for oil reuse and periodic waste disposal. Manufacturers usually have supplied a service contract to owners of these toilets for operation (including tank pumping, oil change, filter change, and routine maintenance). The pumped wastes will have to be disposed of in an approved treatment facility. A schematic of a typical oil flush toilet is shown in Figure 6.3.



OIL FLUSH TOILET

FIG. 6.3

6.3.3 Incinerating Toilets

Incinerating toilets reduce human wastes to an ash by burning them in an electric or gas-operated compartment. A blower is provided to reduce odors during waste burning. After use, a timed incineration cycle of 10-15 minutes occurs after which time the toilet is ready for reuse. Due to the unconventional nature of operation, regular need for cleaning and high energy costs, public acceptability of this toilet has been limited. Periodic ash disposal is also required. Figure 6.4 depicts the design of one type of incinerating toilet.

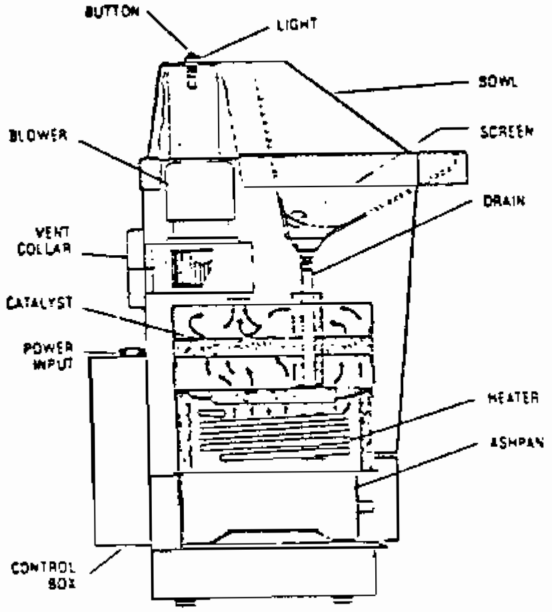


FIGURE 6.4 INCINERATING TOILET

6.3.4 Recycle Systems

The closed loop recycling toilet uses a conventional toilet with flush water provided from treated wastewater. The collected waste is treated by settling, aeration, biological treatment, filtration to remove color and solids, and disinfection prior to reuse. Homeowner acceptance, large expense and additional maintenance requirements hinder wide-scale use of this technique. The residual waste stored in the settling chamber must be periodically disposed. The filters and adsorbers must also be replaced when spent. Although these recycle systems are very expensive, the systems have been used in commercial areas where inadequate areas exist for wastewater disposal and are gaining in user acceptance. It is reported that such systems are presently size only to handle twelve or more homes, a diagram of the treatment process is presented in Figure 6.5.

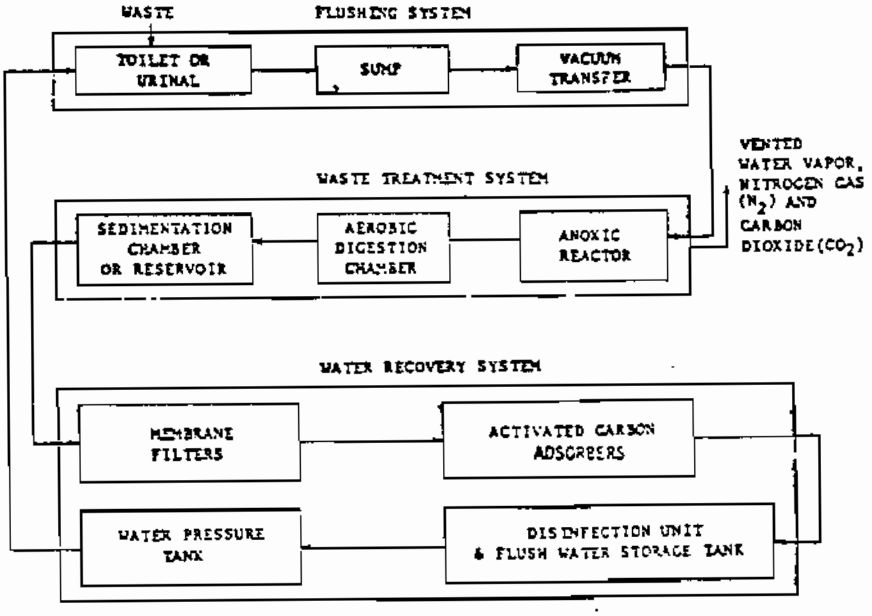


FIG. 6.5 COMPLETE BLACKWATER RECYCLING SYSTEM

6.3.5 Greywater Treatment Systems

Greywater can be used or disposed of in a number of different ways. The range of treatment, disposal and resue options is illustrated in Figure 5.6. Depending on the greywater source, certain treatment and reuse schemes are more appropriate than others. The simplest solution is to use the standard septic tank-soil absorption system. Another proposed system employs a septic tank, a sand filter and disinfection before discharge to a surface water. The loadings from these two options are presented in Table .1.

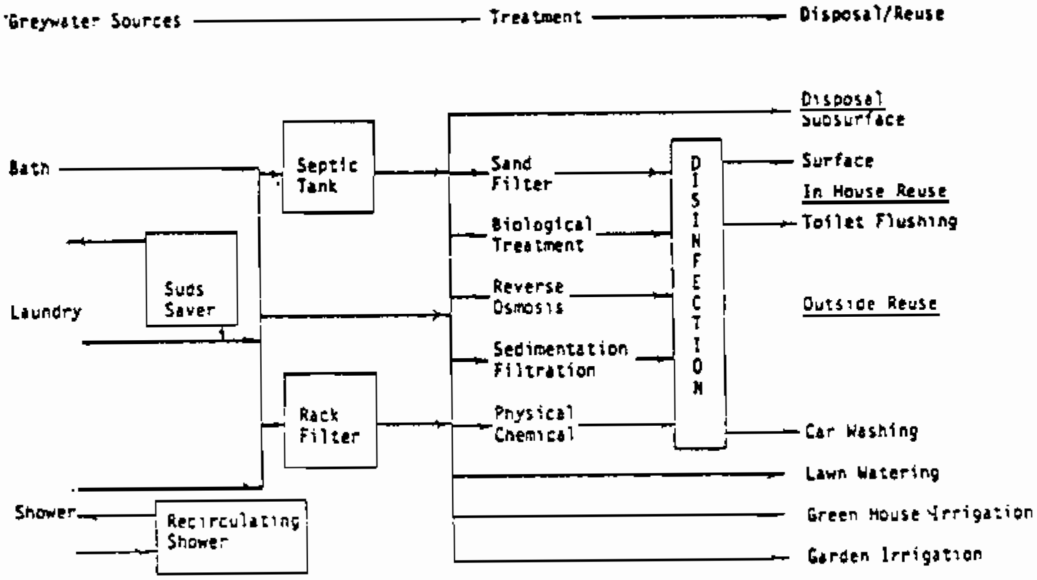
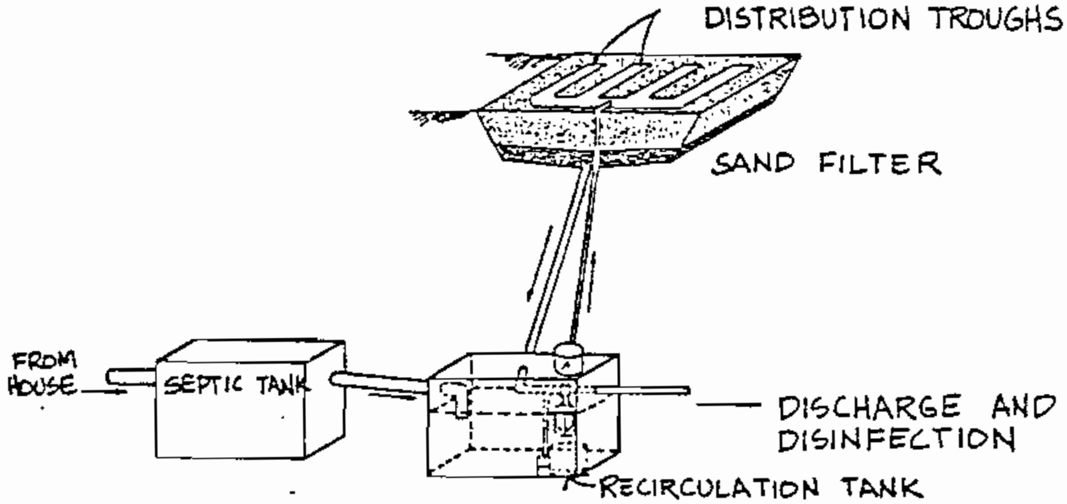


Fig. 6.6: Range of Greywater Treatment/Disposal/Reuse Options

6.4 Sand Filter - Disinfection - Discharge

Sand filters are normally used for suspended solids removal (phosphorous removal can also occur as discussed in 3.3.1) after the wastewater has passed through a septic tank (or aerobic unit) and prior to subsurface disposal or effluent disinfection for surface discharge. Generally, sand filters are appropriate where soil permeability is low and they can be combined with a conventional septic system to reduce loadings (clogging potential) to the disposal field. However, unless sand filters are constructed specifically for phosphate or nitrogen removal, the application of a sand filter effluent to a SAS will generate about the same nutrient input to the groundwater as a SAS alone. There might be instances though when it would be more desirable to discharge properly treated effluent to a surface water than the groundwater. In this case, a sand filter with disinfection should be appropriate if properly operated.

Three configurations are typical: buried sand filters, intermittent slow sand filters and recirculating sand filters. Because buried sand filters have been shown to be very inaccessible for repairs and maintenance, the other two configurations are usually recommended. Typically, maintenance of these units is substantial for both pumping requirements and filter restoration, but effluent quality is greatly improved in all three cases. Figure 6.7 shows what a typical recirculating sand filter system design would be.



RECIRCULATING SAND FILTER SYSTEM

FIG. 6.7

Because of the hazard of pathogenic bacteria contamination from sewage effluent, most regulatory agencies will not permit surface discharges without disinfection. Four different disinfectants - tablet iodine, chlorine crystals, ultraviolet irratiation, and ozone are particularly useful for preparing household wastewater for on-site surface discharge. Disinfection reduces the bacterial content and thus the potential for pathogenic bacterial disease outbreaks. Wastewater treatment is necessary prior to disinfection for effective and efficient bacterial kills.

This septic tank-sand filter-disinfection-discharge system could be used for total household wastewater flow, but it may be more suitable for only the greywater flow when a non-discharging toilet is used. The lower flow and BOD and SS content of greywater should make the operation of this system more reliable.

The surface water loadings from both sources are listed in Table 6 .1.

6.5 Systems Generating No On-Site Discharge

For situations where soil, groundwater, or surface water conditions prohibit any discharge; several options are available.

6.5.1 Holding Tank/Truck Transport

The use of a holding tank simply provides temporary wastewater storage in a steel, concrete or fiberglass tank for subsequent transport via a pumping truck to a central wastewater treatment facility. Holding tanks are typically several thousand gallons and require periodic pumping depending on flow. From a normal household flow, the pumping cost would be enormous. However, by using very low flow flow pressure toilets, low flow showers and faucets, and eliminating laundry washing; the daily flow could be reduced to approximately 100 gallons per household per day. By using some of the non-discharging toilets presented earlier, only greywater would have to be stored and pumped, lowering the costs even further.

6.5.2. Evapotranspiration Beds

Evapotranspiration (ET) beds rely upon natural evaporation and plant uptake (transpiration) for wastewater disposal by net transport of water out of the system. An evapotranspiration system is similar to a mound system except that stone and an impermeable liner of clay or plastic is placed below the leaching area. The liner prevents wastewater from percolating to the subsoils and groundwater. The ET system can store a certain volume of water (from rain and wastewater) for the period when rainfall and wastewater exceeds evapotranspiration. The storage volume required will obviously influence the system's cost. Maximum loading rates and system sizing for lined beds are variable and not agreed upon by all researchers since the specific design and plantings are felt by some to greatly affect ho much wastewater can actually be evapotranspirated.

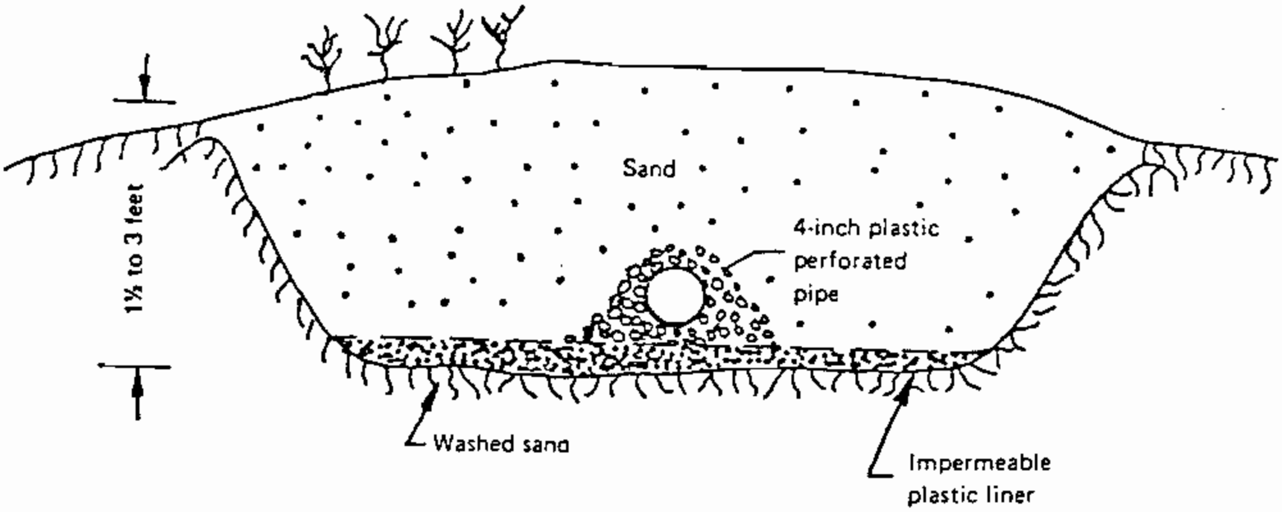


Fig. 6.8: Lined Evapotranspiration Bed

Modified evapotranspiration beds are similar to mounds and rely on both percolation and evapotranspiration for disposal of wastewater. Since it is not lined, the loading of nutrients to the soil and groundwater will not be much different than from a regular mound or standard subsurface disposal system.

In the northeastern U.S., it is likely that evapotranspiration beds will be practical only for summer vacation homes.

6.6 Performance of Innovative and Alternative Systems

Table 6.1 compares the expected performance of each of the alternative wastewater treatment systems discussed in this section.

TABLE 6.1 POLLUTANT LOADING TO GROUNDWATER FROM INNOVATIVE AND ALTERNATIVE WASTEWATER TREATMENT AND DISPOSAL TECHNIQUES

Treatment Alternative of Table 2.1 Wastewater	Text Refer.	$NO_3^-+NO_2^-$-N		NH_4^+-N		ORG-N		TOTAL-N		BOD_5		PO_4^{-3}-P		TOTAL-P		Fecal Coliform	pH
		mg/l	g/c/d	mg/l	g/c/d	mg/	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d	mg/l	g/c/d		
Standard Septic Tank Soil Absorption System (Sandy Well Drained Soil)	3.1	38	6.5	2	.34	2	.34	42	7.2	5	.85	10	1.7	13	2.3	$\frac{\sim 25}{100\ ml}$	~7
Aerobic Tank, SAS	6.1	37	6.3	0	0	1	.17	38	6.5	2	.34	10	1.7	13	2.3	$\frac{\sim 25}{100\ ml}$	~7
Greywater Reuse for Toilet, Septic Tank, SAS (Flow = 115 l/c/d)	6.2	57	6.5	3	.34	3	.34	63	7.2	5	.58	15	1.7	20	2.3	$\frac{\sim 25}{100\ ml}$	~7
Non-Discharge Toilet, Greywater to Septic Tank, SAS	6.3	13	1.5	.5	.08	.5	.08	14	1.7	5.5	.64	10	1.1	13	1.5	$\frac{\sim 25}{100\ ml}$	~7
Septic (or Aerobic) Tank Tank, Sand Filter, Disinfection and Discharge to Surface Waters	6.4	39	6.7	2	.34	3	.51	44	7.6	5	.85	11	1.9	14.5	2.5	$\frac{<5}{100\ ml}$	#
Non-Discharge Toilet, Greywater to Septic (or Aerobic) Tank, Sand Filter, Disinfection and Discharge to Surface Waters	6.4	15	1.7	.7	.08	.7	.08	16	1.9	5.5	.64	11	1.3	14.3	1.7	$\frac{<5}{100\ ml}$	#
Very Low Flow Fixtures with Holding Tank, Pump and Transport	6.5.1	No on-site discharge															
Septic (or Aerobic) Tank with Lined Evapotranspiration Bed	6.5.2	No on-site discharge															

pH depends on disinfection method chosen

7.0 IDENTIFICATION OF MANAGEMENT REQUIREMENTS

The effective operation of standard septic systems and alternative technologies depends upon proper management exercised by both the individual homeowner and the concerned public agencies. Together these two groups must assure the following:

- Adequate system design,
- Proper system installation,
- Proper system operation (including only the disposal of compatible wastes),
- Adherence to a preventative maintenance program,
- Prompt repairs when needed,
- Monitoring of system performance,and
- Proper handling and disposal of any residual materials generated.

The management functions which must be performed by public agencies fall into four basic categories:

- Establishment of design, operation and performance standards and regulations,
- Enforcement of regulations,
- Monitoring of system performance, and
- Public education.

These functions must be performed regardless of the technology employed. However, the use of alternative technologies may alter the amount of effort that must be devoted to specific activities. For example, in the area of design standards, a body of regulations, criteria and procedures is presently in place to deal with standard septic systems. These regulations make it relatively easy to evaluate the adequacy of a proposed design. Before one or more alternative techniques could come into widespread use, however, a comparable set of design, operation and performance standards would be necessary to guide engineers in the proper design of such systems, and to guide public officials in reviewing designs, inspecting new system installations and evaluating the adequacy of proposed maintenance measures. Without such a set of guidelines, each proposed alternative disposal system would have to be evaluated on an individual basis. This would add substantially to the time and cost involved with the design and installation of alternative disposal systems in comparison with the effort presently required for septic systems.

In the area of enforcement, the use of alternative technologies may require an increase in effort over that devoted to septic systems. This increase is related to the fact that several of the alternative technologies (such as alum addition or denitrification) demand a much higher level maintenance than do septic systems in order to function as designed. When a septic system is not properly maintained (regular septic tank pumpouts), the result is a conspicuous wastewater overflow which most homeowners would move quickly to repair. With some alternative systems, however, a lack of maintenance will not produce such dramatic symptoms. Rather, the system may continue to dispose of the wastewater but fail to achieve the level of treatment required. For example, if a denitrification system using methanol as a carbon source is allowed to run out of methanol, the nitrogen removal process will stop but the wastewater will continue to be disposed of into the ground. As Table 7.1 shows, the maintenance demands of alternative systems are often greater than those for a standard septic system. Because of the vital role that maintenance plays in the performance of alternative systems, it is expected that provision of the needed maintenance would be a condition of approving such systems. This implies a need to develop an enforcement mechanism to ensure that any needed maintenance is being provided.

The third area of management by public agencies concerns the monitoring of system performance. With two exceptions, the use of alternative technologies is not expected to require an expansion of monitoring activities beyond what is required for standard septic systems. These exceptions are 1) the use of any technique that produces a surface water discharge and 2) the monitoring of novel or experimental designs for which insufficient performance data exists. In the case of surface water discharges, a monitoring and reporting program similar to that applied to holders of NPDES permits would be required. Depending on the number of such systems allowed, this could mean a very significant increase in the amount of monitoring and related paper work over that provided at present. The second type of performance monitoring that could be required concerns the verification of operating characteristics for experimental or demonstration type treatment systems. This type of monitoring would essentially be a research effort to document the efficacy of particular treatment system designs under actual operating conditions in the pinelands. Such an effort might be needed to develop design standards for alternative technologies that have not received extensive field testing in other locations.

Public education is a fourth area of management concern. This function is crucial to the success of any on-site based wastewater mangement program since the homeowner is, in essence, acting as a treatment plant operator. For both septic systems and alternative technologies the demands placed on the homeowner are minimal. However, to be able to provide even this minimal service, the

TABLE 7.1

TREATMENT SYSTEM MAINTENANCE REQUIREMENTS *

Treatment System	Septage/Sludge Removal (every 3 years)	Annual Replenishment of Chemicals	Replacement of Adsorption Media (every 6 months)	Annual Repair of Pumps & Motors
Standard Septic System (SS)	x			
Compost Toilet with SS for Greywater	x			
SS with Alum Addition for Phosphorus Unit	x	x		x
SS with Greywater Reuse for Toilet Flushing	x	x		x
Aerobic Treatment Unit with Soil Absorption System	x (Annual)			x
SS with Ammonia Adsorption Unit	x		x	
SS with Sand Filter for Phosphorus Removal	x		x	
SS with Denitrification by Methanol Addition	x	x		x

* Listed in order of increasing homeowner maintenance requirements.

homeowner must know what to do and be convinced that it is in his interest to do it. In the case of septic systems, for example, the homeowner must be made aware of the need to have the septic tank pumped out on a regular basis to avoid clogging of the leaching area. Because of the general lack of public knowledge of the proper operation of on-site disposal systems and the constant influx of new residents, public education should be viewed as continuing rather than temporary management requirement. Particular items that should be included in the public education program include:

- Identification of wastes incompatible with the treatment system,
- Routine maintenance requirements,
- Symptoms of system malfunction,
- Who to call for help, and
- Consequences of imporper operation or maintenance.

In addition to the regular pumpouts that standard septic systems require, they also need occasional repairs to the leaching system. For well designed and maintained systems such repairs may only be needed every 30 to 40 years if at all. For undersized or poorly maintained system, however, leachfield repairs may be needed every 10 to 15 years. The need for these repairs arises when the infiltrative surface of the leaching trench or pit becomes clogged with an organic mat and/or sulfide precipitates which form under anaerobic conditions. The two basic strategies for dealing with this problem are to chemically oxidize the soil clogging material or to install an alternate leaching area. Chemical Oxidation is accomplished through the injection of hydrogen peroxide or other oxidizing agent into the leaching area. Such a solution will not correct the original cause of the soil clogging and thus may need to be repeated at regular intervals. A more permanent repair can be effected through the installation of an alternate leaching area. While the new leaching system is being used, the clogged system will be recovering its infiltration capacity as a result of natural oxydition of the soil clogging materials. Once this recovery has taken place, the two leaching systems can be used on an alternating basis. By providing a 6 to 12 month resting period for each leaching area the original problem of soil clogging can be effectively ellíminated.

Homeowners clearly have a major role in the management of septic systems and alternative technologies. They are the group with primary responsibility for proper operation and maintenance of the disposal systems. To carry out this function, they must be both knowledgeable of what is required of them and willing to do it. As Table 7.1 illustrates, the standard septic system requires as little attention as any on-site disposal system. This has been a major reason for its widespread use. The additional requirements imposed by alternative techniques are not particularly demanding upon the homeowner in absolute terms, but in comparison with the effort required to maintain septic systems there is a substantial difference. Whereas a septic system may need pumping out every 2 or 3 years, most alternative systems require the annual (or more frequent) attention of the homeowner and/or a maintenance technician. As mentioned previously, an active public education program is an essential tool in bringing about the needed homeowner management of individual wastewater treatment systems.

8.0 COST AND ACCEPTABILITY OF ALTERNATIVE WASTEWATER TREATMENT SYSTEMS

The feasibility of using alternative wastewater treatment systems depends not only on their performance characteristics and management demands, but on their cost and public acceptability as well. The issues of system performance, cost and acceptability are closely interwoven. To improve the performance of a standard septic system it is generally necessary to add additional removal processes. These add to the system cost and maintenance requirements which, in turn, decrease their public acceptability.

The costs of various individual treatment systems are presented in Table 8.1. The capital costs shown may vary depending upon manufacturer and local site conditions, however, they are representative of the typical cost of serving a three bedroom single family home. The annual operating and maintenance costs include (where applicable) the cost of septage pumping and disposal, electricity, chemicals, filter or adsorbtion media, inspection and repair of mechanical compenents and the replacement of any parts that may be needed during a 20 year period of use. The present worth of each system is presented to provide a means of comparing the combined capital and operation and maintenance costs. This economic analysis technique which is prescribed by the Environmental Protection Agency for determining cost-effectiveness, is based on an interest rate of 7 1/8% and a term of 20 years.

Because of their comparitively limited use to date, there is little hard evidence concerning the public acceptability of alternative wastewater systems. Although some systems such as compost toilets have developed almost a cult following in some areas, there has been a general lack of incentive for the use of anything other than the standard septic system.

Cost is certainly a major factor in the public acceptability of alternative systems. As Table 8.1 shows such systems are generally more expensive than the standard septic system. In addition to financial considerations, there are other perceived costs that may be acting to limit the present use of alternative systems including:

TABLE 8.1

TREATMENT SYSTEM COSTS

Option	Text Ref.	Capital	Operation & Maintenance	Present Worth (20yr. 7 1/8%)
Standard Septic Tank & SAS[2]	3.0	$3,000	$ 25	$3,260
Septic Tank, Ammonia Absorption Unit, SAS[2]	4.1.2	$4,100	$285	$7,090
Septic Tank Sand Filter, Denitrification, SAS[2]	4.1.3	$6,250	$200	$8,350
Chemical Addition, Septic Tank, SAS[2]	4.2.2	$3,200	$180	$5,090
Septic Tank Filter Bed, SAS[2]	4.2.3	$4,000	$150	$5,580
Septic Tank, Acid Addition, SAS[2]	4.3	$3,200	$130	$4,560
Aerobic Tank, SAS[2]	6.1	$4,500	$300	$7,650
Greywater Reuse for Toilet Flushing, SS[1]	6.2	$4,400	$110	$5,550
Non-Discharge Toilet, Greywater Septic Tank SAS[2]	6.3	$3,150[3]- $5,900	$ 70[3]- $250	$3,880- $8,520
Septic Tank, Sand Filter Disinfection & Discharge	6.4	$3,100[3]- $4,900	$140[3]- $180	$4,570- $6,790
Non-Discharge Toilet, Greywater Septic Tank, Sand Filter, Disinfection	6.4	$3,850[3] $8,400	$190[3] $410	$5,840- $12,700
Very Low Flow Fixtures, Holliston Tank, Pump, Transport	6.5.1	$1,800	$750	$9,670
Septic Tank, Evapotranspiration Bed	6.5.2	$4,300	$ 85	$5,200

1. SS - Standard Septic System
2. SAS - Soil Absorption System
3. Depending on which non-discharge toilet and disinfection system is used.

- Convenience
- Aesthetics
- Reilability
- Impact on property value

These concerns can, in turn, be related to the general lack of information presently being made available to the general public. To establish a favorable public attitude toward the use of alternative systems a basic supportive structure is needed which includes at least the following:

- Endorsement of alternatives as a public policy supported by design standards and regulations,
- Acceptance of alternative systems by mortgage lenders and realtors,
- Assurance that the technical skills needed to maintain alternative systems are available, and
- Dissemination of information on the successful use of alternative systems.

It is difficual to speculate on the degree to which public acceptance could foster or impede the use of alternative systems. For use in new homes, the use of such systems must be place in the context of buying a home. In such cases, decisions are likely to be made based on factors other than the type of waste dispsoal system (factorssuch as house size, location and taxes). Thus the emotional inertia against trying something new may be overcome by other factors that make the house attractive. The retrofitting of existing homes, however, may be more difficult due to the lack of obvious offsetting benefits and the disruption that inevitably accompanies such reconstruction.

A brief summary of the research and use of various alternative wastewater treatment systems is included in Appendix D.

9.0 COMMUNAL WASTEWATER TREATMENT SYSTEMS

An alternate wastewater management strategy to the use of individual systems as discussed previously in this report is the use of communal treatment systems. Such systems collect all or a portion of the wastewater from a group of homes and treat it centrally in one location. Under the appropriate conditions, communal treatment systems can offer significant advantages over on-lot systems including the following:

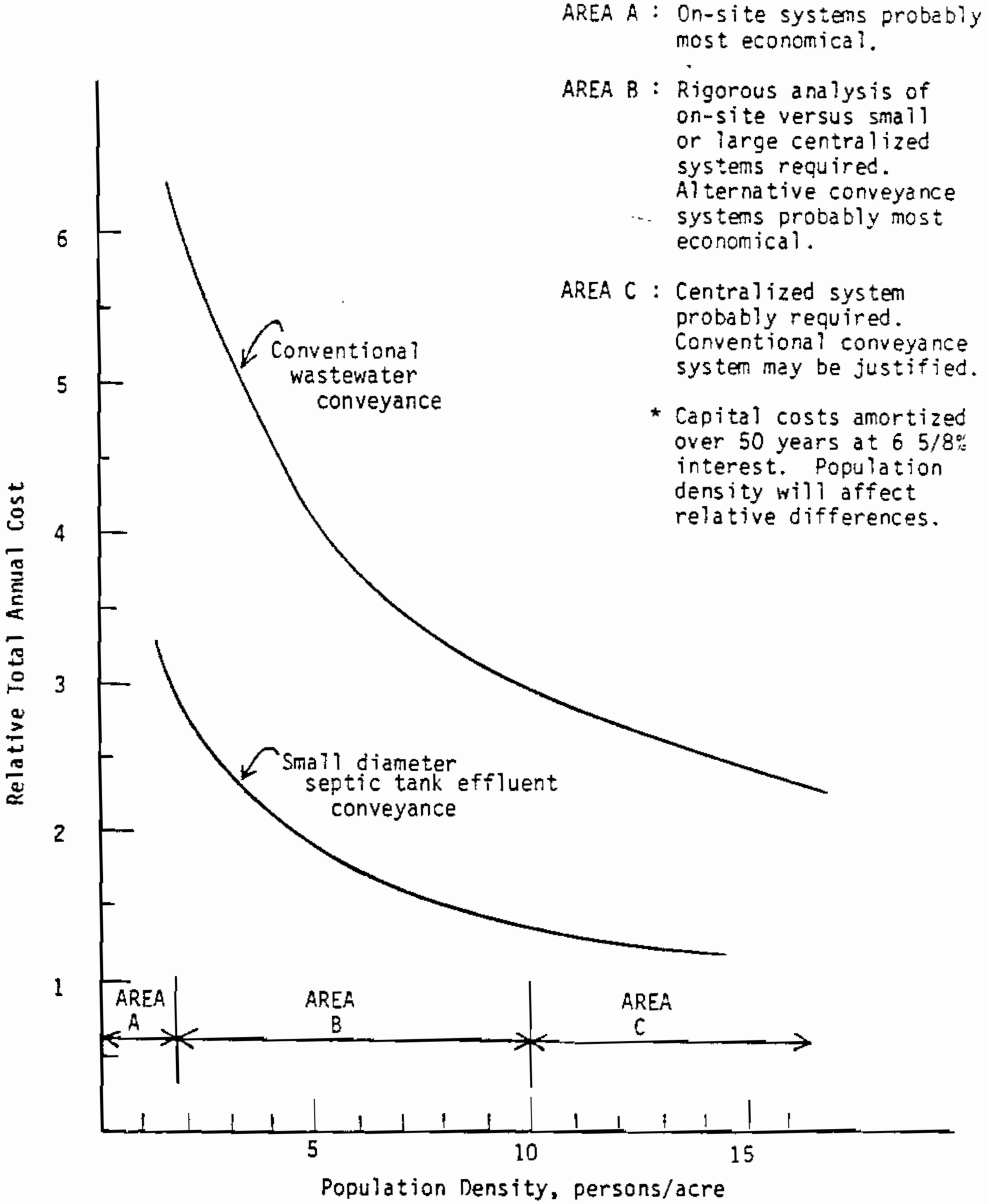
- Lower cost per household due to economies of scale,
- Elimination of the need for homeowners to provide treatment system maintenance,
- Ability to employ treatment techniques that are impractical for individual homes, and
- Simplified management and monitoring by public health officials.

Although communal systems require the installation of a wastewater collection system, this cost can often be offset by savings in the construction and operation of the treatment facility. Figure 8.1 shows that as the population density of an area increases, the attractiveness of communal systems from a financial standpoint also increases.

The use of communal systems can broaden the range of technical options available for two reasons. First, the economies of scale can make treatment processes which are inefficient for use at individual homes practical for use on a group of homes. Second, systems which might be resisted by indvidual homeowners due to the extensive maintenance requirements could win public approval if that maintenance burden were shifted to the communal treatment facility. Among the additional technical options which could become available when wastewater management needs are met on a communal basis are:

Figure 9.1

Relative Costs* for Conventional and Small-Diameter Conveyance Systems as a Function of Population Density



AREA A : On-site systems probably most economical.

AREA B : Rigorous analysis of on-site versus small or large centralized systems required. Alternative conveyance systems probably most economical.

AREA C : Centralized system probably required. Conventional conveyance system may be justified.

* Capital costs amortized over 50 years at 6 5/8% interest. Population density will affect relative differences.

- Packaged treatment plants employing treatment by extented aeration or the use of rotating biological contactors,
- Lagoon treatment systems,
- Lime clarification treatment,
- Aquaculture systems using open, confined or natural marshes, and
- Land application systems.

By using communal wastewater systems, the management and monitoring of waste disposal operations for a neighborhood can be greatly simplified. The role of the homeowner in such a system is much less than it is with alternative on-lot systems. Instead of a number of individual units, each of which requires individual design and maintenance, there is a single large system. Thus, the homeowner is relieved of responsibility for system maitenance, and public health officials are required to review the design and monitor the operational performance of only a single system.

The economics of communal treatment systems are particularly attractive in situations where site conditions are less than ideal for the use of conventional septic systems. For example, consider a development of 43 three-bedroom homes built in an area where the percolation rate is 30 minutes per inch and groundwater conditions would necessitate the addition of two feet of fill in leaching areas. Installing conventional septic systems on each lot would cost approximately $4,950 or a total of $212,850 for the development. If a good leaching site were located at a distance of say 1/4 mile from the development, however, savings might be realized by collecting septic tank effluent in small diameter gravity pipes and pumping it to a communal leach field. If the lots have an average street frontage of 120 feet and the leaching area has more suitable soil conditions with a 10 minute per inch percolation rate, the cost of installing a communal treatment system would be as follows:

Septic tanks for all homes	$ 24,100
Collection System (including house connections and pressure line)	88,800
Pump/Dosing System	12,200
Land (1½ acre)	15,000
Leach Field	57,500
TOTAL	$197,600

10.0 SUMMARY

Previous sections of this report have discussed a variety of alternative wastewater management techniques and issues associated with their implementation. While methods are available for achieving a higher level of treatment than a septic system can provide, additional information of two types is often needed. First, additional field demonstrations may be needed to permit the refinement of designs and the evaluation of operational performance. Second, information needs to be made available to local officials and the public to develop an atmosphere of support for the use of alternative systems. Thus, two key steps toward implementing alternative technologies are the use of demonstration projects and a program of public education.

Before specific steps can be taken to improve wastewater treatment practices, it is necessary to identify priority water quality concerns. If, for example, the discharge of nitrogen is considered to be of prime importance, attention should be focussed on those techniques that are most effective at controlling nitrogen. Similarly, certain techniques are particularly appropriate for the control of phosphorus or other contaminants. Tables 10.1 and 10.2 provide a ranking of the effectiveness of various treatment and management options in limiting nitrogen and phosphorus discharges, respectively. This performance data, together with the information on maintenance requirements and system cost (Table- 7.1 and 8.1, respectively) can be used to identify technologies and techniques worthy of further investigation. Once this identification has been made, demonstration projects can be persued. Such demonstrations can serve the dual purpose of refining design and performance data, and of increasing public awareness and understanding of alternative systems.

TABLE 10.1

SUMMARY RANKING OF SYSTEM EFFECTIVENESS IN ORDER OF DECREASING ON-SITE NITROGEN LOADING

Option or Combination of Options	Text Reference	Total Nitrogen Discharged(g/c/d)
Holding Tank, Pump and Transport	6.5.1	0
Septic (or Aerobic) Tank and Lined Evapotransportation Bed	6.5.2	0
Non-Discharge Toilet, Greywater to Septic Tank, Ammonia Adsorption, SAS[2]	4.1.2 6.3	0.3
Non-Discharge Toilet, Greywater to Septic Tank, Sand Filter, Denitrification, SAS[2]	4.1.3 6.3	0.5
Septic Tank with Ammonia Adsorption, SAS[2]	6.2.1	1.2
Non-Discharge Toilet, Greywater Septic Tank to Soil Absorption System	6.3	1.9
Non-Discharge Toilet, Greywater Septic Tank to Sand Filter to Disinfection to Discharge	6.4	1.9 (to surface waters)
Septic Tank to Sand Filter to Denitrification to Soil Absorption System	6.2.2	2.1
Septic Tank to Mound over Poorly Drained Lowland Soils	4.1.1	5.1
Aerobic Tank to Soil Absorption System	6.1	6.5
Septic System with Garbage Grinder Ban	5.3	6.7
Septic System with Greywater Reuse for Toilet Flushing	6.2	7.2
Septic Tank to Sand Filter Beds to SAS[2]	4.2.3	7.2
Standard Septic Tank - SAS[2]	3.1	7.2
Septic System with Water Conservation	5.4	7.2
Septic Tank to Alternating or Abandoning Soil Absorption Systems	4.2.1	7.2
Septic (or Aerobic) Tank to Sand Filter to Disinfection and Surface Discharge	6.4	7.6 (to surface waters)

[2] SAS= Soil Absorption System

g/c/d= grams per capita per day

TABLE 10.2

SUMMARY RANKING OF SYSTEM EFFECTIVENESS IN ORDER OF DECREASING PHOSPHORUS LOADING

Option or Combination of Options	Text Ref.	Phosphorus Discharged g/c/d w/o Phosphate Detergent Ban	Phosphorus Discharged g/c/d w/ Phosphate Detergent Ban
Holding Tank, Pump, and Transport	6.5.1	0	0
Septic (or aerobic) Tank and Lined Evapotranspiration Bed	6.5.2	0	0
SS* with Phosphate Removal by Chemical Addition or Filber Bed	4.2	0.34	0.2
SS with Home Laundry Ban	5.2	1.3	1.3
Non-Discharge Toilet, Greywater Septic Tank to SAS**	6.3	1.5	0.9
Greywater Reuse for Toilet Flushing, Septic Tank to SAS	6.2	2.3	1.4
Standard Septic Tank System	3.1	2.3	1.4
SS with Garbage Grinder Ban	5.3	2.3	1.4
SS with Water Conservation	5.4	2.3	1.4
SS with Nitrogen Removal Systems	4.1	2.3	1.4
Aerobic Tank to SAS	6.1	2.3	1.4
Non-Discharge Toilet, Greywater Septic Tank to Sand Filter to Disinfection and Discharge	6.4	1.7 (to Surface Waters)	1.0 (to Surface Waters)
Septic (or aerobic) Tank to Sand Filter to Disinfection and Discharge	6.4	2.5 (to Surface Waters)	1.5 (to Surface Waters)

* SS - Septic System

** SAS - Soil Absorbtion System

g/c/d= grams per capita per day

BIBLIOGRAPHY

Andreoli, A., R. Reynolds, N. Bartilucci, and R. Forgione. Pilot Plat Study - Nitrogen Removal in Subsurface Sewage Disposal Systems. Suffolk Co. Dept. of Health Services, Riverhead, NY, 1976.

Bennett E.R. and Linstedt, K.D. "Individual Home Wastewater Characterization and Treatment". July 1975. Env. Resources Center, Colorado State University Fort Collins. Completion Report Series No. 66. p.36.

Bernhardt, A.P., 1967. "Wastewater from Homes, "University of Toronto, Ontario.

Bernhart, A.P. "Proceedings of the Illinois Private Sewage Disposal Symposium", Urbana-Champaign, Ill. Sept. 29- Oct.1, 1975.

Bouma, Converse, Otis, Walker and Ziebell "Mound System for On-site Disposal of Septic Tank Effluent in Shallow Soils over Creviced Bedrock." J. Env. Qual. 4(3): 382-388. 1975

Bouma, J., Ziebell, W.A., Walker, W.G., Oliott, P.G., McCoy, Hole, F.D., 1972, Soil Absorption of Septic Tank Effluent. University of Wisconsin. Extension, Soil Survey Division, Circular No. 20.

Boyle, W.C. and Otis, R.J. "on-Site Treatment", prepared for Environmental Research Information Center, Cincinnati, Ohio, July, 1979.

Brandes, Marek, Characteristics of Effluents from Gray and Blackwater Septic Tanks", J.W.P.C.F. Vol. 50, Nov. 1978, p. 2547.

Brown, K.W. etal. June, 1977. "Accumulation and Passage of Pollutants in Domestic Septic Tank Disposal Fields". Texas A&M Research Foundation, College Station, Texas. Project #R801955-01-2.

Brown, K.W. and Associates. "An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization and Agricultural Activities on Groundwater Quality". prepared for the New Jersey Pinelands Commission. February 15, 1980.

Brown, K.W. etal, "The Movement of Salts Nutrients, Fecal Coliform and Virus below Septic Leachfield in Three Soils," Proc. of the National Home Sewage Disposal Symp., 1977, ASAE, St. Joseph. MI, p. 209

Cochrane Associates, Boston, "Household/On=Site Wastewater Treatment Systems", Chapter 5 of Wastewater Facility Plan for Town of Sherburne, VT. September 1977.

Cohen, Sheldon and Wallman, Harold. "Demonstration of Waste Flow Reduction from Households". by Electric Boat, Groton, CT. EPA-6702-74-071 p. 16.

DSI Environmental Engineers, December 1979. "Alternative Wastewater Management Systems and Their Applicability to Arkansas". Winthrop Rockefeller Foundation, Little Rock, Arkansas.

DSI Environmental Engineers, December 1979. "State of Art Assessment of Compost Toilets and Greywater Treatment Systems". Winthrop Rockefeller Foundation, Little Rock, Arkansas.

E.P.A. "Management of Small Waste Flows" by Small Scale Waste Management Project. Univ. of Wisconsin, Madison. September 1978 EPA-600/2-78-173. Table A-113.

Gotaas, H.B., *Composting, Sanitary Disposal and Reclamation of Organic Wastes.* World Health Organization, Geneva, 1956.

Harlukowicz, Thomas J., and Ahlert, R.E. November, 1978. "Effects of Septic Tank Effluent on Groundwater Quality in the New Jersey Pine Barrens". Rutgers, The State University of New Jersey. Bureau of Engineering Research, Piscataway, N.J.

Hickey, J.L.S. and Duncan, D.L. 1966. "Performance of Single Family Septic Tank Systems in Alaska." Journal of WPCF, 38(8): 1298-1309.

Karikari T.J., etal "Treatment of a Residential Septic Tank Effluent in an Aerobic Lagoon, *Proceedings of the National Home Sewage Disposal Symposium 1974*, ASAE, St. Joseph, MI. p.144-151.

Laak, R. Relative. "Pollution Strengths of Undiluted Waste Materials Discharged in Households and the Dilution Waters used for Each". In: Manual of Greywater Treatment Practice, Ann Arbor Science, Ann Arbor, MI. 1974. p. 77.

Lance, J.C. and Wisler, F.D. 1972. "Nitrogen Balance in Soil Columns Intermittently Flooded with Secondary Sewage Effluent". Journal of Environmental Quality 1:180-186.

Ligman, K., N. Hutzler, and W.C. Boyle. 1974. "Household Wastewater Characterization". Jounal of the Env. Eng. Div. ASCE, Vol. 100, No. EE1, Proc. Paper 10372.

Magdoff, F.R. et al, 1974. "Columns Representing Mound-Type Disposal Systems for Septic Tank Effluent:II Nutrient Transformation and Bacterial Populations. J. of Environmental Quality, 3:228-234.

Means, Jeffrey Lig Yuretich, Richard, F., Crerars, David A., Kinsman, David J.J., nd Maria P. Borcsik. "Hydrogeochemistry of the New Jersey Pine Bauers", Dept. of Geological and Geophysical Sciences, Princeton University, N.J.

Miller, David W., Frank A. DuLuca, and Thomas L. Tessier. "Groundwater Contamination in the N.E. States". EPA-660/2-74-056

Milne, Murray. March 1976 "Residential Water Conservation". California Water Resources Center, U.C. Davis, Report No. 35.

Milne, Murray. Sept. 1979. "Residential Water Reuse". California Water Resources Center, U.C. Davis, Report No. 46.

Moore, Alan. October 1978. "Alternative Methods of Individual On-Site Wastewater Treatment and Disposal in Vermont". Vermont Agency of Environmental Conservation, Montpelier, VT.

New Jersey State Dept. of Environmental Protection. July 1, 1978. "Standards for the Construction of Individual Subsurface Sewage Disposal Systems".

O'Brien and Gere Engineers, May 1978. "State wide 208 Rural Sanitary Waste Disposal Study-Technology Analysis". New York Dept. of Environmental Conservation, Albany, N.Y. Interim Report No. 2.

Olsson, E., L. Karlgrem and V. Tullander. 1968. "Household Wastewater", Report 24:1968, The National Swedish Institute for Building Research, Stockholm, Sweden.

Ontario Ministry of the Environment, "Septic Tank Sand Filter System for Treatment of Domestic Sewage", No. W64, June 1977.

Otis, R.J., Boyle, W.C., Converse, J.C. and Tyler, E.J. 1977. "on-Site Disposal of Small Wastewater Flows". Small Scale Waste Management Project, Univ. of Wisconsin, Madison.

Otis, R.J. and Boyle, W.C. 1976, "Performance of Single Household Treatment Units", J. of Environmental Engin., 102 (EE1):175-189.

Otis, Richard J. etal. October 1977 "Alternatives for Small Wastewater Treatment Systems-On-Site Disposal". EPA-Technology Transfer. EPA-625/4-77-011.

Otis, R.J. W.C. Boyle, and D.K. Sauer, "The Performance of Household Wastewater Treatment Units under Field Conditions", Home Sewage Disposal, Proc. AM. Soc. Ag. Eng., 175, Dec. 1974.

Otis R.J., Boyle, W.C. and Sauer, D.K. "The Performance of Household Wastewater Treatment Units Under Field Conditions". Proceedings of the National Home Sewage Disposal Symposium, 1974, American Society of Agric. Eng. St. Joseph, Mich. pp. 191-201.

Peterson, G.W. and Fritton, D.D., December 1979. "Evaluation of Mound Systems for Renovation of Septic Tank Effluent". Pennsylvania State Univ. Institute for Research on Landlord Water Resources, University Park, PA.

Pio Lombardo and Associates, 90 Canal St., Boston, MA. April 1978 "Water Quality Impact Assessment Methodology for Septic System Pollution Sources"

Popkin, R.A. and Bendixen, T.W. 1968. "Improved Subsurface Disposal." J. of Water Pollution Control Federation, 40(8): 1499-1514.

Pio Lombardo and Associates, Boston, MA. April 1978 "Water Quality Impact Assessment Methodology for Septic System Pollution Sources

Preul, H.C. 1967. Travel of Nitrogen Compounds in Soils. Ph.D. Thesis, as quoted by T.J. Harlukowicz and R.C. Ahlert, 1978. Effects of septic tank effluent on groundwater quality in the New Jersey Pine Barrens. Report of Bureau of Engineering Research, Rutgers University. 83 pp.

Reneau, R.B. and Pettry, D.E. 1976. "Phosphorus Distribution from Septic Tank Effluent in Coastal Plain Soils." J. of Environmental Quality, 5(1): 34-39.

Robeck, G.G., Bendixen, T.W., Schwartz, W.A. And Woodward, R.L. 1964. "Factors Influencing the Design and Operation of Soil Systems for Waste Treatment." J. of Water Pollution Control Federation, 36(8): 971-983.

SCS Engineers (Reston, Va.) August, 1978. "Draft Final Report, Identification, Evaluation and Comparison of On-site Wastewater Alternatives". EPA, Cincinnati, Ohio. Contract No. 68-03-2627.

Salavato, J.A. Experiences with Subsurface Sand Filters. Sewage and Industrial Wastes, 27(8). 1955.

Sauer, David K and Boyle, W.C. "Intermittant Sand Filtration and Disinfection of Small Wastewaters Flows", Proceedings of the National Home Sewage Disposal Symposium, 1977, ASAE, St. Joseph, MI. p. 104-174.

Sauer, D.K., Boyle, W.C. and Otis, R.J. 1976. "Intermittent Sand Filtration of Household Wastewater". J. of Environ. Engineering, 102(EE4): 789-803.

Scalf, Marion R. and Dunlap, William J., August, 1977. "Environmental Effects of Septic Tank Systems". Environmental Protection Agency, Ada, Oklahoma. EPA 600/3-77-096.

Schmidt, Curtis J., SCS Engineers, Boyle, William C., Rural Systems Engineering, et al. "Manual for On-Site Wastewater Treatment and Disposal Systems" U.S.E.P.A. Contract 68-01-4904, Washington D.C. September 1979.

Sikora, L.J., J.C. Converse, D.R. Keeney, and R.C. Chen, Field Evaluation of a Denitrification System. In: Proceedings of the Second National Home Sewage Disposal Symposium, AM. Soc. Agric. Eng., St. Joseph, MI, 1977.

Silbermahn, P.T. 1977. On-Site Disposal Systems and Septage Treatment and Disposal. U.S. Environmental Protection Agency National Conference on 208 Planning and Implementation, Washington, D.C. as quoted by T.J. Harlukowicz and R.C. Ahlert, 1978. Effects of septic tank effluent on groundwater quality in the New Jersey Pine Barrens. Report of Bureau of Engineering Research, Rutgers University, 83 pp.

Small Scale Waste Management Project. September, 1978. "management of Small Waste Flows". EPA, Cincinnatti, Ohio. EPA-600/2-78-173.

Thomas, R.E. and Bendixen, T.W. 1969. "Degradation of Wastewater Organics in Soil". J. of Water Pollution Control Federation, 41(5): 808-813.

Trela, John J. and Douglas, Lowell A. "Soils, Septic Systems and Carrying Capacity in the Pine Barrens". New Jersey Agricultural Experimental Station. 1978

Viraraghavan, T. and Warnock, R.G. 1976. "Efficiency of a Septic Tile System" J. of Water Pollution Control Federation, 48(5): 934-944.

Walker, W.G., Bouma, J., Keeney, D.R. and Magdoff, F.R. 1973a. "Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluents in Sands: 1. Soil Transformations. J. of Environ. Quality, 2: 475-480.

Weibel, S.R., C.P. Straub, and J.R. Thomes. "Studies on Household Sewage Disposal Systems-Part I". Federal Security Agency, Public Health Service, Environmental Health Center, Cincinnati, OH. 1949, pp. 94.

Witt, M., R. Siegrist and W.C. Boyle. 1974 "Rural Household Wastwater Characterization. Proc. National Home Sewage Disposal Symposium, Amer. Soc. Agr. Eng. St. Joseph, MI. pp. 85.

APPENDIX A: Values Reported for Flow, Ammonia, BOD, and Suspended Solids in Household Wastewater

		Flow 1/c/d								NH$_4^+$ -N mg/c/d			
		Laak	Wallman & Cohen	Bennett & Linstedt	SSWMP	Witt et al	Ligman et al	Mean	Value Used	Laak	Witt et al	Mean	Value Used
KITCHEN	Sink	13.6	(68.3)[1]	9.8	(20.4)[2]	5.7	--	9	9	74	32.3	53	53
	Dishwasher	--		4.2	18.5	12.1	13.2	13	13	--	54	54	54
	Garbage Grinder	--		3.0	(20.4)[2]	10.6	5.7	6.5	7	--	9.6	9.6	10
LAUNDRY	Machine	28	39.8	43.9	39.7	56.5	37.8	41	41	316	30.8	173	172
BATHROOM	Sink	7.9	(68.3)[1]	18.9	(20.4)[2]	--	--	12.7	13	9	--	9	9
	Bath/Shower	32.2	23.8	32.9	37.8	18.5	47.2	32	32	43	40	41.5	42
TOILET WASTEWATER		74.9	65.1	55.6	34.7	26.6	75.6	55.4	55	2,780	1,114	1,947	1950

		BOD$_5$ g/c/d							Suspended Solids g/c/d				
		Laak	Bennet & Cohen	Witt et al	Olsson	Ligman	Mean	Value Used	Bennett & Linstedt	Witt et al	Ligman et al	Mean	Value Used
KITCHEN	Sink	9.2	10.6	8.3	17[3]	--	9.2	9	2.1	4.1	--	3.1	3
	Dishwasher	--	.5	12.6		5.9	6.9	8	0.1	5.3	3.0	2.8	4
	Garbage Grinder	--	12.3	10.9		31	18	15	20.2	15.8	43.6	26.5	22
LAUNDRY	machine	7.9	8.7	14.8	3	9.6	8.8	10	3.4	11	7.4	7.3	7
BATHROOM	Sink	1.9	4.9	--	5[3]	--	3.1	3	4.3	--	--	4.3	4
	Bath/Shower	6.2	3.2	3.1		8.9	4.8	5	0.9	2.3	5.7	3.0	3
TOILET WASTEWATER		23.5	6.9	10.7	20	23.6	16.9	17	36.5	12.8	30.9	26.7	27

1. 68.3 = kitchen sink and dishwasher and garbage grinder and bathroom sink, distribute evenly for calculating mean
2. 20.4 = kitchen sink and garbage grinder and bathroom sink, distribute evenly for calculating mean.
3. Distribute evenly among subparts.

APPENDIX A continued: Values Reported for Nitrate, Total Nitrogen, Organic Nitrogen, Total Phosphorus, Ortho-phosphate and pH in Household Wastewater.

		$NO_3^-+NO_2^-$-N mg/c/d				Total -N						Organic-N by subtraction
		Laak	Witt et al	Mean	Value used	Witt et al	Bennett & Linstedt	Olsson	Ligman	Mean	Value Used	g/c/d
KITCHEN	Sink	8.	1.8	4.9	5	.424	1.1	.6[3]	--	.61	.7	.64
	Dishwasher	--	4.1	4.1	4	.487	0		--	.39	.4	.34
	Garbage Griner	--	.2	.2	1	.632	.2	--	9.1	.58	.7	.69
LAUNDRY	Machine	35	27.3	31.2	31	.725	.2	.2	--	.38	.4	.20
BATHROOM	Sink	2.	--	2	2	--	0	.3[3]	--	.15	.1	.09
	Bath/Shower	12	7.4	9.7	10	.306	0		--	.23	.2	.15
TOILET WASTEWATER		16	27.4	21.7	22	4.14	5.2	11	16.8	9.3	9	7.0

		PO_4^{-3}-P g/c/d		Total -P g/c/d							pH		
		Witt et al	Value Used	Laak	Witt et al	Bennett & Linstedt	Olsson	Ligman	Mean	Value Used	Olsson	Bennett & Linstedt	Value Used
KITCHEN	Sink	.18	.2	.173	.42	0	.3[3]	--	.29	.4	7.3[3]	6.6	6.7
	Dishwasher	.38	.4	--	.82	0		.454	.47	.6		7.6	7.8
	Garbage Grinder	.09	.1	--	.13	.1	--	--	.12	.12		6.4	6.5
LAUNDRY	Machine	.52	.6	4.79	2.15	.6	1.3	2.3	2.2	2.4	9.8	7.8	8.8
BATHROOM	Sink	--	.02	.39	--	0	.6[3]	--	.35	.2	8.1	7.9	7.9
	Bath/Shower	.02	.02	.03	.04	0		--	.12	.1		8.2	8.2
TOILET WASTEWATER		.30	.3	6.47	.55	3.1	1.6	1.4	2.6	2.0	8.9	5.6	6.8

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[3] Divide evenly among subparts

APPENDIX B: CALCULATIONS OF pH CHANGES IN GROUNDWATER DUE TO SEPTIC TANK LEACHFIELD EFFLUENT MIXING

PINELANDS WATER QUALITY	Rivers & Streams		Lakes & Ponds	
from Forman, Richard T.T., 1979	pH	Alkalinity	pH	Alkalinity
100% range of all sites and concentration variations	3.0-9.1	0-129ppm as $CaCO_3$	4.1-6.9	3-68ppm as $CaCO_3$
90% confidence interval	3.8-7.4	0- 20ppm	4.2-6.7	3-22ppm
Mean of the midpoints of all ranges for all sites	5.7	6.5ppm	5.3	11.5ppm

from Harlukowicz and Ahlert, 1978	Surface water quality-pH
range	4.0-11
90% confidence interval	4.3- 5.2
mean	4.7

from Jeffrey et al	pH	PO_4^{-3}	organic carbon	total dissolved solids
River water	4.51	.037ppm	1-30ppm	20ppm
Ground water deep	4.65	---	0.5- 2ppm	28-99ppm
" " shallow	4.43	---		

Assumption made:	Groundwater Quality
pH	5.2
Alkalinity	9ppm $CaCO_3$
Alkalinity	0.18 meg/l
C_T	2.78 m Moles (C_T= total carbonate species)

Alkalinity of septic tank effluent has been reported to be 317ppm as $CaCO_3$ (Brandes, 1978). Since the water supply in the Pinelands has a low alkalinity, it is likely that the septic tank effluent will be lower in alkalinity than this value.

In the following table, a housing density of .6 acre/family and a flow of 680 l/d has been assumed. The infiltrating rainwater has been estimated at 20 in/yr = 5,632 l/d/acre (Brown, 1980). The pH values shown in the table are for a completely mixed solution of 680 l of effluent and 3380 l of groundwater with the characteristics already discussed. C_T, the sum of all carbonate species was interpolated from the C_T - Alkalinity - pH diagram on p. 133 of Aquatic Chemistry by Stumm and Morgan, 1970, Wiley-Interscience.

Leachfield Effluent	Effluent from Leachfield Reaching Groundwater			
Alkalinity (ppm $CaCO_3$)	250	250	150	150
Alkalinity (meg/l)	5	5	3	3
pH	6.5	8.0	6.5	8.0
C_T (mM)	8.6	5.1	5.1	3.05
Groundwater mixed with effluent				
Alkalinity (ppm $CaCO_3$)	48	48	32	32
Alkalinity (meq/l)	.97	.97	.64	.64
C_T (mM)	3.73	3.16	3.16	2.82
pH	5.92	6.01	5.72	5.8
ΔpH	+0.7	+0.8	+0.5	+0.6

APPENDIX C: CHARACTERISTICS OF SEPTIC TANK EFFLUENT

Reference	Comments	$NO_3^-+NO_2^-$-N mg/l	NH_4^+-N mg/l	ORG-N mg/l	Total N mg/l	BOD_5 mg/l	PO_4-P mg/l	Total -P mg/l	SS mg/l	pH
Otis R.J. et al.,1974	mean (# samples) 95% confidence interval	0.56 (67) 0.39 - 0.82	38.7 (63) 34.3 - 43	16 (53)	55.3	158 (94) 142 - 174	11.5 (43) 10.2 - 12.8	14.6(54) 11.4 - 17.7	54 (93) 49 - 62	
Cochrane Assoc, 1977	mean 95% conf. inter. mean 95% conf. inter.					144 101-162 92 72-112			102 72-122 69 64-92	
Bernhardt, 1975	mean 95% conf. inter.					180 160-200			100 50-150	
Sauer, David K. et al,'77	(# samples)	0.2 (32)	22 (32)			97 (36)	12 (3)		40 (36)	
Brown et al., 1977	50 samples	0.24	24.7	6.8	29.8		6.9	8.2		7.4
Karikari et al., 1974	8 weekly reports				73	134				
Silbermahn, P.T., 1977	mean	0.2	36.3	7.3	43.8					7.1
Wiebel, S.R. et al., '49	(# samples)					138	10.0	15.1 (49)	155 (55)	7.2
Otis et al., 1977	1 unit	0.3	19.2	4.4	23.9	123	8.7	10.2	48	
Salvato, J.A., 1955	51 samples				36	140			101	
Berhardt, 1967						240 (21)			95 (18)	
Thomas & Bendixen, '69	1 unit	2.1	25.4	7.9	33.4	93			45	7.7
Robeck et al., 1964	mean	.12	22	5.4	27.5					7.8
Hickey & Duncan, '66	mean		37	3.4	40.4					7.3
Preul, H.C., 1967	mean	.1	25	10	35.1			20		7.3
Popkin & Bendixen, '68	mean	.21	24.6	5.6	30.4					
Pio Lombardo, 1978	mean	0.6	39	16	55			15	54	
Walker et al., 1973	mean		66.3	13.7	80			10		6.4
Magdoff et al., 1974	mean				42			21		7.5
Otis & Boyle, 1976	6 units	.5	35.6	16.1			11.6	15.2		
Viraraghaven & Warnock, 1976	mean range	.03 0-.1	97	97 77-111	280 140-666			11.6 6.3-30	176 68-624	6.9 6.5
PA-600/2-78-173 ble A-113	mean (# samples) 95% conf. int.	.4 (114) 0-0.9	31 (108) 28-34	17.6 (107)	49 (99) 41-49	138 (150) 129-147	11 (89) 10-12	13 (99) 12-14	49 (148) 44-54	
Total # Samples		463	493	410	484	520	332	372	521	229
Mean (weighted)		0.35	35	13.1	47.2	147	10.6	14.5	76.9	7.3
Median		0.21	31	7.0	41	138	11.3	14.6	69	7.3
Value Used in this Study		0.3	30	11	44.3	143	11	14.5	73	7.3

Note: For calculating the weighted mean, a "unit" was assumed to be a reporting of 10 samples, the weekly reports were assumed to be the average of 3 samples/week, other single values were assigned a value of 20 samples.

Appendix D

Wastewater Management Alternatives Being Used, Demonstrated or Researched

1) Denitrification by Methanol Addition

Researched

- Posner, H.S., "Biohazards of Methanol in Proposed New Uses," J. Toxical Environmental Health, 1:153-171 (1975).
- Sikora, L.J. and D.R. Keenery, "Denitrification of Nitrified Septic Tank Effluent," JWPCF, 48 (8): 2018-2025 (1976).
- Andreoli, Aldo, N. Bartilucci, R. Forgione and R. Reynolds," Nitrogen Removal in a Subsurface Disposal System," JWPCF, 51 (4): 841-854 (1979).

2) Ammonia Removal by Adsorption

Researched

- Battelle Northwest, "Wastewater Ammonia Removal by Ion Exchange," Water Pollution Control Research, USEPA Series No. 17010 ECZ 02/71 (1971).
- Mercer, B.W., et al., "Ammonia Removal from Secondary Effluents by Selective Ion Exchange," JWPCF, 42 (2-Part 2): R95 (1970).
- Koon, J.H. and W.J. Kaufman, "Optimization of Ammonia Removal by Ion Exchange Using Clinoptilolite," Sanitary Engineering Research Laboratory, University of California, Berkely, California, SERL Report No. 71-5 (1971).

- "Management of Small Waste Flows," U.S. Environmental Protection Agency. EPA-600/2-78-173 (September 1978).

3) Phosphorus Removal by Alum

   Researched
   - Brandes, Marek "Effective Phosphorus Removal by Adding Alum to Septic Tanks," JWPCF, 49 (11): 2285-2296 (1977).
   - "Management of Small Waste Flows," U.S. Environmental Protection Agency, EPA-600/2-78-173 (September 1978).

4) Phosphorus Removal by (sand filter) Adsorbtion

   Researched
   - Chowdry, N.A. "Septic Tank-Sand Filter System for Treatment of Domestic Sewage," Publication No. W64, Ontario Ministry of the Environment, Toronto (1977).
   - Otis, Richard J. and W.C. Boyle "On-Site Disposal of Small Wastewater Flows," University of Wisconsin (1977).
   - Detweiler, J.C. "Phosphorus Removal by Adsorption on Alumina as Applied to Small Scale Waste Treatment," M.S. Report, University of Wisconsin, Madison (1978).

5) Aerobic Treatment Units

   Demonstrated
   - Boyd County, Kentucky Project Appalachian Regional Commission, Washington, D.C.

   Used
   - Widely used in the United States

6) Greywater Reuse for Toilet Flushing

   Used
   - A number of operating systems in Tiburan, California
   - Dr. Frank Buckley, Baltimore, Maryland

7) Compost Toilet/Greywater Disposal System

Used	• Widely used in United States and Canada
Some Private Users	• Abbey Rockefeller - Cambridge, Massachusetts • Peter Gillis - Boston, Massachusetts • A. Hallet - Dover, New Hampshire • Derrick Owens - Concord, New Hampshire
Some Public Users	• Maine Audubon Society - Falmouth, Maine • St. Goudens Mermorial Site - Windsor, Vermont

8) Oil Flush Toilets

Used	• U.S. Forest Service, San Dimas, California

9) Incinerating Toilets

Demonstrated	• Victor Manufacturing, West Hartford, Connecticut
Used	• Widely used, especially in seasonal homes

10) Recycling Systems

Used	• Braddock Community Center, Fairfax County, Virginia • Wilson - Finley Company, Gainesville, Virginia • Thetford Corporation, Dexter, Michigan • Highway Department Weigh Station, U.S. Route 460 Suffolk, Virginia

11) Sand Filter, Disinfection, Discharge System

Researched

- Sauer, D.K., W.C. Boyle, and R.J. Otis "Intermittent Sand Filtration of Household Wastewater Under Field Conditions," J.Environ, Eng. Ar., ASCE 102, EE4 (1976).

Used

- Widely used throughout the United States

12) Evapotranspiration System

Used

- Extensively in the following states*
  - Colorado
  - Idaho
  - Montana
  - Nevada
  - New Mexico
  - New York
  - North Carolina
  - Ohio
  - Oregon
  - Rhode Island
  - Texas
  - Washington
  - West Virginia
  - Wyoming

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*Source: Bennett, Edwin R., and K. Daniel Linstedt "Sewage Disposal by Evaporation - Transpiration" EPA-600/2-78-163 (September 1978).

APPENDIX E

Fecal Coliforms/100 ml

Household Wastewater

Olsson et al, 1968 - blackwater - 2,235,000
Wittet al, 1974 - bath, shower and laundry water - 646
Olsson et al, 1968 - bath, shower and kitchen water - 1,470,000
Representative Value Chosen - 1,000,000

Septic Tank Effluent

Brown et al, 1977 p. 14	1,100,000
Otis, Richard J. et al, Oct. 1977 Fig. 1-9	1,900,000
Otis, R.J., W.C. Boyle and D.K. Sauer, 1974	421,000
Beterson and Fritton, 1979	950,000
Brandes Marck,	960,000
Representative Value Chosen ----	1,000,000

Sand Filter, Mound, or Leachfield Effluent

Otis, Richard J. et al. Oct. 1977 Fig. 1-9	10-100
Petersen and Fritton	10
Otis, Richard J. et al. Oct. 1977 Fig. 1-9	200-700
Bouma, Converse, Otis, Waller & Ziebell, 1975	0-580
Representative Value Chosen for Leachfield --- after clogging zone has developed	25

New Jersey Pinelands Commission
Alternative/Innovative Technology
Assessment

APRIL 1980

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FINAL REPORT

A PROCEDURE FOR EVALUATING ENVIRONMENTAL IMPACTS OF ALTERNATIVE WASTEWATER TREATMENT TECHNOLOGIES

Prepared for the
NEW JERSEY PINELANDS COMMISSION

By
DSI ENVIRONMENTAL ENGINEERS
90 CANAL STREET
BOSTON, MA 02114

April, 1980

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1.0 INTRODUCTION

The report "Assessment of Innovative and Alternative Technologies for On-Site Wastewater Disposal" presented the pollutants that are of concern in the Pinelands and their sources in household wastewater. It also described the conventional, alternative, and innovative technologies and management options available to control and reduce the amount of pollutants that are discharged into the environment. These alternatives were described qualitatively, and their treatment performance evaluated quantitatively. Hereafter, this report will be referred to as Report A.

The methodology described in this report is basically a model of the natural and man-made transformations that will take place as certain wastewater pollutants travel from their sources within the home to the sinks in the natural environment. Using certain assumptions based on available information, the model allows calculations to be made on the various transformations that take place according to the treatment technologies chosen and the exisiting environmental conditions. Therefore, the model can be used to predict the environmental effects of choosing a certain on-site wastewater treatment and disposal system on a specific site location. It can also be used in reverse by setting a maximum environmental impact permitted, and then calculating the possible sites and treatment alternatives that will be able to meet that goal.

Not all possibilities and combinations of possibilities were calculated and listed due to time and space limitations, but since the methodology is general, other "factors" can be added and calculated easily. Nor were all the alternatives listed in the first report included in this model. Only alternatives discharging pollutants to subsurface soil absorption systems are considered here. Systems discharging directly to surface waters should be handled by the NPDES program and permitted or not permitted according to dilution and subsequent eutrophication and oxygen depletion possibilities.

Finally, many of the assumptions made and calculations performed were based on limited data and best engineering judgement. Much additional research will be necessary for the model to be accurate enough to make policy decisions. These research needs will be noted during the model description. When the correct information is known, it can be substituted and the predictions recalculated. At that point, if a specific groundwater quality if chosen, this procedure can be used to regulate development. Knowing the groundwater quality required, a developer can, with a specific development site, then choose the combination of treatment and disposal technologies necessary to meet the standard.

2.0 GENERAL MODEL DESCRIPTION

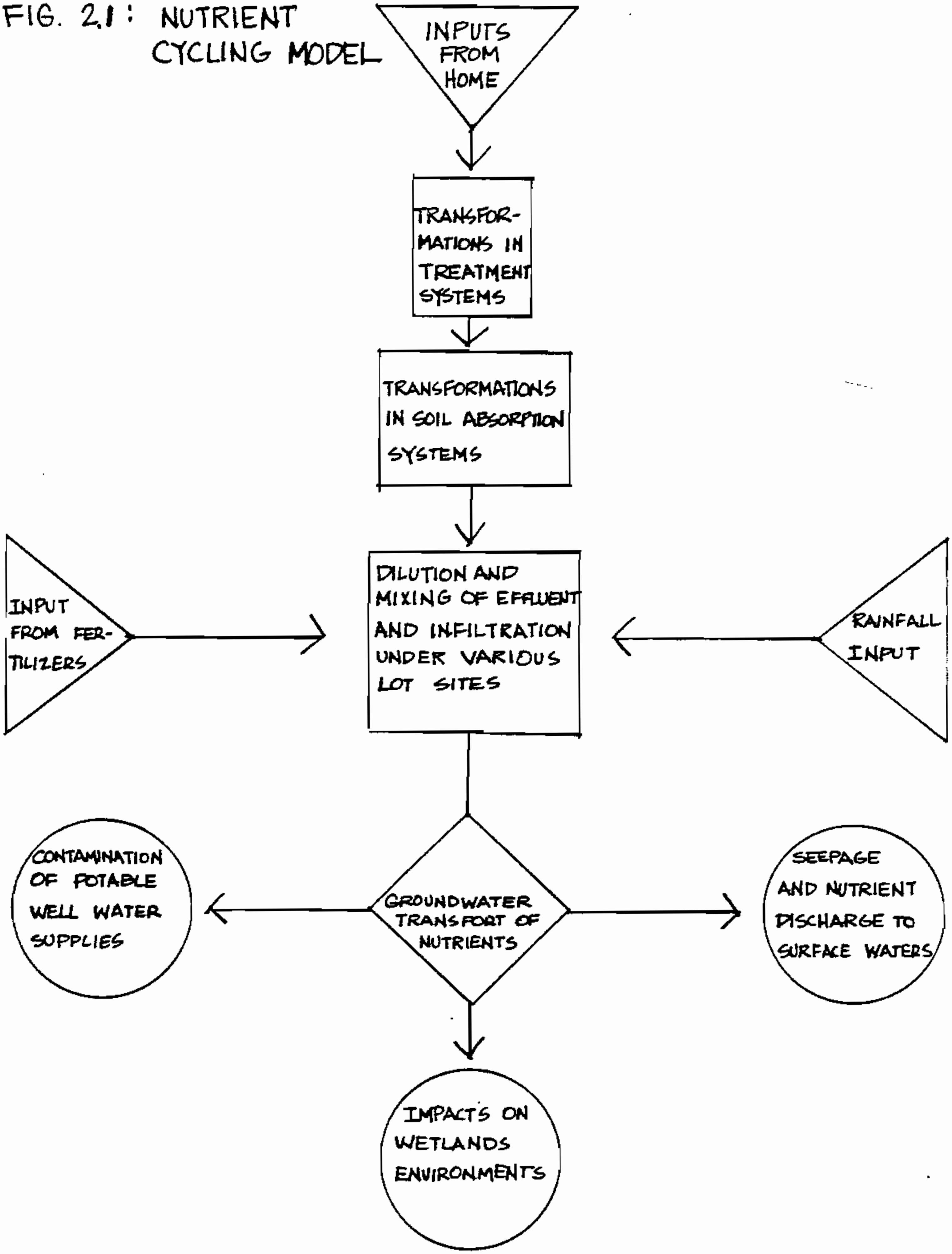
The authors of this report, in agreement with others, feel that pH, nitrogen and phosphorus are the pollutants of major concern from wastewater disposal in the Pinelands environment. It is believed that bacteria and virus removal can be assured by proper design of subsurface disposal systems and regulation of the separation distances from wells and surface waters. Most research seems to point out that four to five feet of unsaturated soil between the leaching lines and groundwater is sufficient to prevent any public health problems from bacteria contaminated groundwater.

Similarly, a properly designed, constructed, and maintained septic tank soil absorption system will remove BOD and Suspended Solids to levels that should not cause any groundwater pollution problems. Contamination of soils and groundwater by heavy metals will be discussed in the section on land application of sewage sludge and septage, since the amount of metals discharged from an on-site sewage disposal system should be of low concern.

The pH of the effluent from on-site systems is of concern because of possible changes in groundwater pH, but there isn't enough data to predict accurately the variations in final groundwater pH from different treatment technologies and soils. When this information is available, calculations such as in Appendix B of Report A can be made, and the result evaluated. If the pH changes and subsequent environmental effects are significant, pH adjustment units will have to be added to the treatment systems.

Therefore, only nitrogen and phosphorus have been carried through the model which is shown in Figure 2.1. This diagram is a mass and concentration balance for nitrogen and phosphorus from source to sink. The sources are the practices in the home that add nitrogen and phosphorus to the wastewater, as they are listed and quantified in Table 2.1 of Report A. The wastewater is then afforded some degree of treatment by the methods described in Report A and summarized in Table 10.1. These treatment units remove some of the nitrogen and phosphorus to be pumped as septage, and dispose of the effluent in subsufface soil absorption systems. It has been assumed in this report that the standard criteria for designing subsurface soil absorption systems will be adhered to in all cases, i.e. - depth to groundwater and bedrock, percolation rates, slopes, setback distances, etc.

FIG. 2.1: NUTRIENT CYCLING MODEL



Here in the soil, additional nitrogen and phosphorus is eliminated by denitrification and adsorption respectively before the effluent reaches the water table. At this point, nitrogen and phosphorus can also be added to the soil by the leaching of artificial fertilizers by infiltrating rainwater. It is this infiltrating rainwater and sewage effluent that dilutes and carries the nutrients down into the water table. Once in the sandy groundwater aquifiers, the nitrogen and phosphorus species are transported relatively unchanged except for dilution by diffusion (Brown, 1980 p. 4,7). Depending on the flow of the groundwater, the nitrogen and phosphorus will eventually be discharged to a public water supply well, a river or stream, a lake or pond, other forms of wetlands, or the ocean.

It is in these sinks that environmental impacts are of concern. Drinking water standards for nitrate have been set at 10 mg/l NO_3-N because of the dangers of methemoglobinemia. If nitrogen and phosphorus is added to rivers and streams, increased growth of algae and macrophytes can occur. When they die, the microbial decomposition processes can lower the dissolved oxygen content of the river water. The same process can occur in lakes and ponds, causing nuisance algae and plant growth, and increased eutrophication. The effect of nutrients on wetlands depends on the availability of the increased nitrogen and phosphorus concentrations to plant growth. Nutrients are in low supply in the Pinelands wetland environments, so the increased availability of a limiting nutrient could cause changes in species diversificaiton and distribution.

3.0 SPECIFIC DESCRIPTION OF METHODOLOGY AND ACCOMPANYING CHARTS

This section describes the procedure for calculating all the values in the Tables and the background information for the assumptions made. The formulas are not explicitly presented, but the procedure can be followed easily in order to input different data.

3.1 Sources of Nitrogen and Phosphorus

Tables 3.1 and 3.2 begin the model calculations with the column titled "Discharge to Treatment System" in grams per capita per day. These values of ammonia, nitrate, total nitrogen, total phosphorus and orthophosphate for total wastewater and greywater with and without the use of phosphate containing detergents are taken from Table 3.1 of Report A.

3.2 Alternative Technologies and Treatment Efficiences

The descriptions of each innovative and alternative technology and management practice can be found in sections 4.0, 5.0 and 6.0 of Report A. Not all of these alternatives are discussed in this report; only those that effect nitrogen and phosphorus removal. The alternatives have been presented in separate tables by nitrogen and phosphorus removal because many of the unit operations are different.

Table 3.1 lists the possible combinations of alternatives for nitrogen removal vertically and all the components horizontally. The results for septic tank treatment efficiencies are taken from Appendix C of Report A, while the aerobic tank removal rates are average of the findings from a number of references (EPA, 1978,; Otis et al., 1974, 1976, 1977). Ammonia Adsorption Units were assumed to operate at 85% ammonia removal effeciency. Sand filters were assumed to offer no net removal of nitrogen, but almost complete nitrification of ammonia and a breakdown of some organic nitrogen to ammonia. Finally, denitrification systems were assumed to denitrify 80% of the nitrate and breakdown more organic nitrogen to ammonia. The results for both total wastewater and greywater show that the amount of nitrogen discharged to the soil may vary by a factor of 30. Experimental studies in the field are needed to evaluate whether or not these alternatives will operate as well as shown in controlled conditions.

TABLE 3.1a: Nitrogen Loadings in Grams Per Capita Per Day from Alternative Wastewater* Treatment Systems in Various Soil Types

TREATMENT COMPONENTS ALTERNATIVES	Nitrogen Forms	Discharge to Treatment System	Septic Tank Effluent	Aerobic Tank Effluent	Ammonia Adsorption Unit Effluent	Sand Filter Effluent	Denitrification System Effluent	LEACHING AREA EFFLUENT Soils A + D 5% N Removal	Soil C 20% N Removal	Soils B + E 25% N Removal
A Septic Tank Soil Absorption System SAS	Nitrate TOTAL N Ammonia	.08 11.5 → 2.3	0.05 7.6 → 5.6	→	→	→	→	7.2	6.1	5.7
B Aerobic Tank Soil Absorption System	Nitrate TOTAL N Ammonia	.08 11.5 → 2.3	→	5.3 6.4 → .08	→	→	→	6.1	5.1	4.8
C Aerobic Tank Denitrification System SAS	Nitrate TOTAL N Ammonia	.08 11.5 → 2.3	→	5.3 6.4 → .08	→	→	1.1 2.2 → .54	2.1	1.8	1.7
D Septic Tank Sand Filter Denitrification System SAS	Nitrate TOTAL N Ammonia	.08 11.5 → 2.3	0.05 7.6 → 5.6	→	→	6.7 7.6 → .34	1.34 2.2 → .51	2.1	1.8	1.7
E Septic Tank Ammonia Adsorption Unit SAS	Nitrate TOTAL N Ammonia	.08 11.5 → 2.3	0.5 7.6 → 5.6	→	0.5 1.26 → .70	→	→	1.2	1.0	.95

*Assumes the Use of Phosphate Detergents and a Garbage Disposal

#In aerobic soils, most of the leachate nitrogen will be nitrate.

Notes The specific type of subsurface soil absorption system (conventional, mounded, fill) will depend on the actual soil and site conditions i.e., depth to groundwater or bedrock, percolation rate, slope, etc.

The amount of nitrogen removed by denitrification and plant uptake shown is only best engineering judgement; the actual removal rates must be measured in order to make accurate predictions.

TABLE 3.1b: Nitrogen Loadings in Grams Per Capita Per Day from Alternative Grey water* Treatment Systems in Various Soil Types

TREATMENT COMPONENTS ALTERNATIVES	Nitrogen Forms	Discharge to Treatment System	Septic Tank Effluent	Aerobic Tank Effluent	Ammonia Adsorption Unit Effluent	Sand Filter Effluent	Denitrification System Effluent	LEACHING AREA EFFLUENT #		
								Soils A + D 5% N Removal	Soil C 20% N Removal	Soils B + E 25% N Removal
F Septic Tank-Soil Absorption System SAS	Nitrate TOTAL N Ammonia	.05 1.8 .33	.01 1.5 1.1					1.4	1.2	1.1
G Aerobic Tank-Soil Absorption System	Nitrate TOTAL N Ammonia	.05 1.8 .33		1.1 1.3 .02				1.2	1.0	.98
H Aerobic Tank-Denitrification System- SAS	Nitrate TOTAL N Ammonia	.05 1.8 .33		1.1 1.3 .02			.21 .43 .11	.41	.34	.32
I Septic Tank-Sand Filter-Denitrification System- SAS	Nitrate TOTAL N Ammonia	.05 1.8 .33	.01 1.5 1.1			1.3 1.5 0.07	.26 .43 .10	.41	.34	.32
J Septic Tank-Ammonia Adsorption Unit SAS	Nitrate TOTAL N Ammonia	.05 1.8 .33	.01 1.5 1.1		.01 .25 .14			.24	.20	.19

*Assumes the use of non-discharge toilets and no garbage disposal. Treatment systems loadings calculated at 20% of total wastewater values since greywater contains only 16% as much nitrogen as total wastewater.

#In aerobic soils, most of the leachate nitrogen will be nitrate.

Notes: The specific type of soil absorption system (conventional, mounded fill) will depend on the actual soil and site conditions, i.e. depth to groundwater or bedrock, percolation rate, slope, etc.

The amount of nitrogen removed by denitrification and plant uptake shown is only best engineering judgement; the actual removal rates must be experimentally measured in order to make accurate predictions.

Table 3.2 lists the possible combinations of alternatives for phosphorus removal vertically, and all the components horizontally. The results for septic tank treatment efficiencies are taken from Appendix C of Report A, while the aerobic tank removal rates are averages of the findings from the same references listed in the last paragraph. It was assumed that 80% of the phosphorus could be removed by either adding alum to the treatment tank, adding alum in a settling tank following the treatment tank, or by passing the treatment tank effluent through a filter bed containing material that will adsorb and/or precipitate phosphate. The results for both total wastewater and greywater (and whether or not phosphate containing detergents are used) show that the amount of phosphorus discharged to the soil can vary by a factor of 33.

3.3 Various Soil Types and Renovation Capacities

Appendix A is a list of the most common soil series existing in the Pinelands, and the map symbols for all the variations found in each of the 7 Pinelands Counties. Table 3.3 summarizes the pertinent characteristics of all these soils and divides them into 7 groups (A-G) according to their nitrogen and phosphorus renovation performances and the type of subsurface disposal system that must be used. Appendix A also includes a column assigning each soil map symbol to one of these groups, while Table 3.4 condenses the Appendix into a matrix of soil grouping by county.

In the second row of Table 3.3, titled "Position in Landscape," it states whether the soil is generally found at High elevations in the xeric uplands of pine forests, at Intermediate levels of oak and swamp hardlands, or in the Low wetland areas of cedar swamps. The water table depths are shown because of their importance in the design and function of a subsurface soil absorption system. The next two rows present the amount of organic matter in the soil and whether or not there is a layer of slowly permeable clayey soil in the soil stratums that will limit percolation but help to induce denitrification and adsorb phosphorus. The natural drainage description is related to soil moisture conditions, that is, whether the soil remains wet or drains dry. All of these characteristics will determine if a subsurface soil absorption system can be built on a particular site, and what the actual design will be. For example, high groundwater conditions will require that a mounded system be built to insure enough unsaturated soil for bacterial removal. Due to the environmental sensitivity of the Pinelands, it may be desirable to limit development to only those soils that can easily accept conventional systems. However, this report investigates all the possible alternatives.

The next three rows present the permeability, texture, and clay content of the various horizons in the soil from the surface to 5 or 6 feet below. The second to last row states whether or not a mound is needed and how to size the leaching area for proper renovation. The last row is most important, for these conclusions are used in future charts to calculate how much nitrogen and phosphorus can be removed in the soils.

TABLE 3.2a: PHOSPHORUS LOADINGS AND REMOVAL PERIODS FROM ALTERNATIVE ON-SITE WASTEWATER* TREATMENT SYSTEMS IN VARIOUS SOIL TYPES

TREATMENT COMPONENT ALTERNATIVES	Phosphate Detergent Use or Ban	Discharge To Treatment Syst. Total P(ortho P) g/c/d	Septic Tank Effluent TP (ortho P) g/c/d	Aerobic Tank Effluent TP TP (ortho P) g/c/d	Effluent After Alum Addition or Sorption/Ppt. Filter Bed TP (ortho P)	Total Phosophate Dis-charged tô SAS	YEARS TO PHOSPHORUS BREAKTHROUGH#			
							Soils A&D	Soil C	Soil B&C	
							75 ug/g P 10 min/in 285 ft.^{2}	200 ug/g P 30 min/in 570 ft.^{2}	250 ug/g P 45 min/in 795 ft.^{2}	Rem. Cap. perc. rate leachfield
AEROBIC TANK--SOIL	Use	5.8 (1.64) →		5.3 (4.4) →		5.3	1.1	5.8	10	
ABSORPTION SYSTEM (S.A.S.)	Ban	3.5 (1.06) →		3.2 (2.7) →		3.2	1.8	9.5	17	
SEPTIC TANK- SOIL	Use	5.8 (1.64) →	2.5 (1.9) →			2.5	2.3	12	21	
ABSORPTION SYSTEM	Ban	3.5 (1.06) →	1.6 (1.2) →			1.6	3.8	20	35	
AEROBIC TANK WITH ALUM ADDITION OR SORPTION/PRECIPITA-TION FILTER BED - S.A.S.	Use	5.8 (1.64) →		5.3 (4.4) →	1.1 (.66) →	1.1	5.2	28	48	
	Ban	3.5 (1.06) →		3.2 (2.7) →	.64 (.4) →	.64	8.9	47	83	
SEPTIC TANK WITH ALUM ADDITION OR SORPTION/PRECIPITA-TION FILTER BED S.A.S.	Use	5.8 (1.64) →	2.5 (1.9) →		.50 (.29) →	0.50	11	61	106	
	Ban	3.5 (1.06) →	1.6 (1.2) →		.31 (.18) →	0.31	18	98	171	

* Assuming The Use of Phosphate Detergents and Garbage Disposals

\# Calculated assuming 4 feet of soil between leachfield and groundwater, the phosphorus fixing capacity shown, and an effecitve adsorption area twice the trench bottom area indicated. The trench bottom areas are taken from the New Jersey regulations according to the perc. rate listed.

Notes: The specific type of subsurface soil absorption system (conventional, mounded, fill) will depend on the actual soil and site conditions, i.e. depth to groundwater or bedrock, percolation rate, slope, etc.

The phosphorus absorption capacity shown is only best engineering judgement; the actual capacity must be experimentally measured in order to make accurate predictions.

TABLE 3.2b: PHOSPHORUS LOADINGS AND REMOVAL PERIODS FROM ALTERNATIVE ON-SITE GREYWATER* TREATMENT SYSTEMS IN VARIOUS SOIL TYPES

TREATMENT COMPONENT ALTERNATIVES	Phosphate Detergent Use or Ban	Discharge To Treatment Syst Total P(ortho P) g/c/d	Septic Tank Effluent TP (ortho P) g/c/d	Aerobic Tank Effluent TP TP (ortho P) g/c/d	Effluent After Alum Addition or Sorption/Ppt. Filter Bed TP (ortho P) g/c/d	Total Phosophate Dis-charged to SAS	YEARS TO PHOSPHORUS BREAKTHROUGH#			
							Soils A&D	Soil C	Soil B&C	
							75 ug/g 10 min/in 285 ft.^{2}	200 ug/g 30 min/in 570 ft.^{2}	250 ug/g 45 min/in 795 ft.^{2}	P Rem.Cap. perc.rate leachfield
AEROBIC TANK--SOIL ABSORPTION SYSTEM (S.A.S.)	Use	3.7 (1.2) →	→	3.4 (2.9) →	→	3.4	1.5	8.9	16	
	Ban	1.4 (.66) →	→	1.3 (1.2) →	→	1.3	4.4	23	41	
SEPTIC TANK- SOIL ABSORPTION SYSTEM	Use	3.7 (1.2) →	1.8 (1.4) →	→	→	1.8	3.2	17	29	
	Ban	1.4 (.66) →	.8 (1.7) →	→	→	0.8	7.1	38	66	
AEROBIC TANK WITH ALUM ADDITION OR SORPTION/PRECIPITATION FILTER BED - S.A.S.	Use	3.7 (1.2) →	→	3.4 (2.9) →	.68 (.43) →	0.68	8.4	45	78	
	Ban	1.4 (.66) →	→	1.3 (1.2) →	.26 (.17) →	0.26	22	117	203	
SEPTIC TANK WITH ALUM ADDITION OR SORPTION/PRECIPITATION FILTER BED S.A.S.	Use	3.7 (1.2) →	1.8 (1.4) →	→	.35 (.21) →	0.35	16	87	151	
	Ban	1.4 (.66) →	.8 (.7) →	→	.16 (.11) →	0.16	36	190	330	

* Assuming The Use of Non-Discharge Toilets and No Garbage Disposal

\# Calculated assuming 4 Feet of Soil Between Leachfield and Groundwater, The Phosphorus Fixing Capacity shown, and an Effective Adsorption Area Twice the Trench Bottom Area Indicated. The Trench Bottom Areas are Taken from the New Jersey Regulations According To the Perc. Rate Listed.

Note: The specific type of subsurface soil absorption system (conventional, mounded, fill) will depend on the actual soil and site conditions, i.e. depth to groundwater or bedrock, percolation rate, slope, etc.

The phosphorus absorption capacity shown is only best engineering judgment; the actual capacity must be experimentally measured in order to make accurate predictions.

Table 3.3a: Classification of Pinelands Soils According to Wastewater Treatment Capability

SOIL GROUPING	TYPE A			TYPE B					TYPE C	
POSITION IN LANDSCAPE	High			High					High	
WATER TABLE DEPTH Spring Summer	Greater than 5 ft. Greater than 6 ft.			Greater than 5 ft. Greater than 6 ft.					Greater than 5 ft. Greater than 6 ft.	
SURFACE SOIL Organic Matter Content	Low (Less than 1%)			Low (<1%)	Moderate (.5-2%)				Moderate (.5-2%)	
SLOWLY PERMEABLE SUBSTRATUMS	NO			YES - CLAYEY SUBSTRATUMS					NO	
REPRESENTATIVE SOIL TYPE	Lakewood	Evesboro	Woodmansie	Evesboro	Woodmansie	Sassafras	Downer	Aura	Sassafras	Downer
NATURAL DRAINABLE	Excessive		Well Drained	Excessive	Well Drained		Well Drained		Well Drained	
PERMEABILITY in Inches per hour — Soil Horizons from Surface to Substratum	6-20 2-20	6-20 0.6-20	6-20 0.6-6 0.6-20	6-20 0.6-20 0.2	76.3 2-6.3 0.2-2	0.2- 6.3 0.6-2 2- 6.3 0.2-2	0.6-6 0.6-2 0.2	0.2-6 0.2-2 0.2-2	0.6-6 0.6-2 0.6-20	0.6-6 0.6-2 2- 6
PREDOMINANT SOIL TEXTURES — Surface to Substratum	Sand Fine Sand or Sandy Loam	Sand Loamy-Sand	Sand or Loamy Sand Sandy Loam Gravelly Sand & Loamy Sand	Sand Loamy Sand Sandy Clay	Sand Sandy Loam Sandy Clay	Sandy Loam f.s.l or s.c.l. l.s. or g.l.s. sandy c.l.	Loamy Sand Sandy Loam Sandy Clay	Sandy Loam Sandy c.l. Sandy Loam	Sandy Loam Sandy c.l. loamy sand	Loamy Sand Sandy Loam Loamy Sand and g. Sand
CLAY CONTENT — Surface to Substratum	0-15% 0-10%	0-5% 0.24%	0-5% 5-10% 0-10%	0-5% 0.25% 30-45%	0-5% 5-10% #	3-20% 5-30% 5-10% #	0-10% 5-15% 20-50%	#	3-20% 15-30% 5-10%	0-10% 5-15% 0-10%
SUBSURFACE WASTE-WATER DISPOSAL SYSTEM CONSIDERATIONS	Due To Rapid Permeability, Infiltration Area Should Be Based On Renovation Capacity and Crust Conductivity			Existence Of Slowly Permeable Substratum Will Necessitate The Use Of A Mounded Subsurface Absorption System For Proper Renovation Of Effluent Before Reaching Clayey Layer That Will Dictate The Leaching Area Size.					Least Permeable Soil Stratum Will Determine Leaching Area Size And At Some Sites Prohibit Use For Subsurface Absorption Systems.	
PERFORMANCE ASSUMPTIONS MADE:	Denitrification Insignificant, 5% N Uptake by plants Average P Removal Capacity Thru 4' Soil = 75 ug/g Soil.			Denitrification In Sandy Clay Layer, Possibly 20%. Plant Uptake of Nitrogen - 5%. Average Phosphorus Removal Capacity Through 4 Feet Of Soil - 250 ug/g.					Denitrification - Possibly 10% Nitrogen Plant Uptake - 10% Average P Removal Capacity Through 4' Of Soil - 200 ug/g	

#= Not Reported by Douglas & Walker (1979), f.s.l.=fine sandy loam, s.c.l.=sandy clay loam, l.s.=loamy sand, g.l.s.=gravelly loamy sand, c.l.=clayey loam

Table 3.3b: Classification of Pinelands Soils According to Wastewater Treatment Capabilility

SOIL GROUPING	TYPE D			TYPE E		TYPE F	TYPE G		
POSITION IN LANDSCAPE	Intermediate			Intermediate		Low	Low		
WATER TABLE DEPTH Spring Summer	1 1/2'-4' Greater than 5'			1 1/2'-4' Greater than 5'		0-1' 2 1/2'	0' 1-2'		
ORGANIC MATTER CONTENT OF SERVICE SOIL	Low(Less than 1%)			Low-Moderate (0-2%)		Mod.(3-8%)	High (20-80%)		
SLOWLY PERMEABLE SUBSTRATUMS	NO			YES- CLAYEY SUBSTRATUMS		NO	NO		
REPRESENTATIVE SOIL TYPE	Lakehurst	Hammonton	Klej	Hammonton	Klej	Atsion	Berryland	Pocomoke	Muck
NATURAL DRAINAGE	Moderately Well Drained To Somewhat Poorly Drained			Moderately Well To Somewhat Poorly Drained		Poorly Drained	Very Poorly Drained		
PERMEABILITY in Inches per Hour — Soil Horizons Surface to Substratum	6-20 (2-6, some)	2-6 .6-6 2- >6	6-20 2- >6	2-6 .6-6 .2	>6 >6 <.2	6-20 2-20 .6-20	6-20 2-6 6-20	.6-2 .6-6	6-20 6-20
PERDOMINANT SOIL TEXTURES — Surface to Substratum	sand (sandy loam-some series)	loamy sand sandy loam sand	loamy sand sand	loamy sand sandy loam sandy clay	loamy sand sand sandy clay	sand sand or l.s. s.l. or s.c.l.	sand loamy sand s.+ grav.sand	sandy loam gravelly sand + sand	muck sand
CLAY CONTENT — Surface to Substratum	0-15%	#	#	#	#	0-8% 0-8% 0-20%	#	#	0=10%
SUBSURFACE WASTEWATER DISPOSAL SYSTEM CONDIDERATIONS	Mound May Be Necessary Due To High Water Table. Due To Rapid Permeability, Infiltration Area Should Be Based On Renovation Capacity.			Mound Necessary Above Groundwater Table And Slowly Permeable Layer.		Due To The Groundwater Being At The Surface Periodically, And The Possibility Of Flooding, These Soils Should Not Be Used For Subsurface Sewage Disposal.			
PERFORMANCE ASSUMPTIONS MADE:	Denitrification Insignificant, 5% N Removal By Plant Uptake. Average Phosphorus Removal Capacity Through 4' Soil = 75 ug/g Soil.			5% N Plant Uptake. 20% Denitrification in Saturated Sandy Clay. Average P Removal Capacity in 4" Soil = 250 ug/g					

Not reported by Douglas & Walker(1979). l.s.-loamy sand, s.l.=sandy loam, s.c.l.=sandy clay loam, grav.=gravelly

TABLE 3.4 : Map Symbols for Soil Series from County Soil Surveys Indexed by County and Wastewater Renovation Capacity Groupings

Soil Groupings County	A	B	C	D	E	F	G
ATLANTIC	LeB LeC		SaA SaB DoA DsA	LaA HaA HmA KmA	KnA HcA HnA	Ac	Bp Bs Mu Po
BURLINGTON	WeB WeC LtB LtC LtD LvB LuB LwB LyA	WgC WhB Sm ShA ShB	DoB SfB SgA DoC SgB SgC DrA DoA Sk DsB DoB	LaA LlA KmA LmA LrA KoA LnA LsA	KnA	At Au Av Aw	Bp Bt Bu Mu Pv
CAMDEN	LgB LgC LfB LfC LfD LhE	AmA DrA AmB ArA ArB AtB AvB	DoA DsA DsB DtC	LaA LbA KmA			Mo Mu Ps
CAPE MAY		ArB	DrA SaA SaB SbA DoA DpA DrA DrB	HaA HbA KmA			Bp Mu Ps
CUMBERLAND	LeB	AmB ArA ArB AgA AgB	DoB DoC DrA SrA DrB SrC2 SrB SgA SgB	LaA HaA HbA HbB KmA		Ac	Bp Ms Ps
GLOUCESTER	LeB	AmB AuB ArB AuC AsB AsC AuC3	DoB DsA DsB AsC SfB SfC SsE SrA SrB SsD	LaA			Mu Ps Po
OCEAN	WoB WoC LwB LwC	AxB	SaB DoA DpA DpB DrB	LhA LmA HaA	HcA KlA	At Aw	Be Bf

Soils A & D have the most rapid permeability and lowest organic matter content, and with the help of a mound for soil D, should have aerobic, unsaturated conditions in the subsurface absorption system. Therefore, it has been assumed that denitrification will be insignificant in soils A and D. However, Brown (1980) has estimated that approximatedly 5% of the nitrogen will be removed by plant uptake in soils of type A, B, C, and E (rapid permeability in the top horizons). The soils with slower surface permeabilities such as Type C are assumed to allow about 10% nitrogen removal by plant uptake. Soil C is less permeable and has a higher clay and organic matter content; therefore, we have assumed a denitrification rate of 10%. Soils B and E have slowly permeable sandy clay layers that are thought to be inducive to developing anaerobic conditions and denitrification. Therefore, soils B and E were assigned a denitrification rate of 20% of the percolating nitrate. As with Soil D, Soil E will require a mounded subsurface absorption system because of high groundwater. Table 3.1 uses these soil denitrification and plant uptake rates and the treatment discharge values to calculate the nitrogen loading in grams per capita per day that flows from the bottom of the soil absorption field to the groundwater. Depending on the alternative and the soil, the nitrogen discharged can vary from 7.2 to .19 grams per capita per day, a factor of 38 to 1.

This phenomenon of denitrification in soil is controversial with regard to the conditions that are necessary and to the degree with which it will occur. The values used in this model are only best judgement; extensive research is needed to verify how much denitrification of sewage effluent will actually take place in the different Pinelands soils. These experimentally determined values can then be substituted into the model. The results may also lead to a design of subsurface soil absorption systems that induce denitrification (see Report A).

The phosphorus fixing abilities of soils are also not wholely agreed upon. Some research has reported that almost all the phosphorus in an effluent is removed by a few feet of soil while others find phosphate removed only to a limited degree. Most agree though that phosphate is removed in soils by adsorption onto tiny clay particles, and by precipitation with iron and aluminum. Whichever mechanisms are responsible, soils have a finite capacity to fix a certain amount of phosphorus, and the capacity appears to be related to clay content. Therefore, as time goes on the depth of phosphorus saturated soil will increase until all the soil beneath the leaching lines is saturated, and phosphorus begins to enter the groundwater. The length of time before the phosphorus front reaches the water table will depend on the concentration of phosphate in the treatment system effluent, the phosphorus adsorption capacity of the soil, the area of the soil absorption system and the depth of soil above the water table.

Table 3.3 in the last row makes assumptions for the phosphorus removal capacity of different soil groupings according to the amount of clay in the various soil horizons. These assumptions were based on the summary of values reported in the literature listed in Table 3.5. They vary from 75 ug P/g soil for the very sandy soils to 150 ug/g and 200 ug/g for loamy sand soils that contain some clay, to an average of 250 ug/g for the soils with a significant layer of slowly permeable sandy clay. In reality, the situation is not such that all

TABLE 3.5: Phosphorus Adsorption Capacities For Soils Reported In The Literature

Reference	Soil Type	Capacity (ug P/g Soil)
Reddy et al, 1980	Coastal Lomay Sand and Sandy Loam (at 15 ppm in solution)	180
EPA 625/1-77-008	Sandy Dune (bulk density = 1.6 g/	18
	Clay Loam	436
Walker et al, 1973	Low Hydraulic Conductivity Soil In Soil Absorption field	100
EPA-600/3-77-129, p.27	Wisconsin Sand	10-50
Magdoff et al, 1974	Soil Column With Low Hydraulic Conductivity	121
Ellis and Child, 1973	Rifle Peat	30
	Newton Loam Sand	100
	Berland Loam	138
	Nester Loam	138
	Rubicon Sand	169
Harlukowicz & Ahlert, 1978	Evesboro Sand Horizon A	626
	B	744
	C	347
	Lakewood Sand Horizon A	1.9
	B	47
	C	347
Sawhney and Hill, 1975	Merrimac Sandy Loam	90
	Charlton Fine Sandy Loam	219
	Paxton Fine Sandy Loam	290
Sawhney, 1977	Merrimac Fine Sandy Loam	140
	Buxton Silt Loam	280

phosphorus is removed for a period of years, and suddenly it all breaks through. Rather, the adsorption equilibria and phosphorus concentration dictate that a percentage of phosphorus will always be leaching to the groundwater. This percentage will begin low and then gradually increase with time until the concentration reaching the groundwater equals that leaving the treatment system. At this point, the phosphorus fixing capacity of the soil should be exhausted. However, some investigators (Jones, R.A., and Lee, G. Fred. EPA-600/3-77-129) feel that there is infinite capacity for phosphorus removal via precipitation reactions.

Table 3.2 shows in column seven the amount of phosphorus that will be discharged to the soil absorption system from all the alternative treatment systems and management options. Using the assumed phosphorus fixing capacities, the trench bottom area shown according to percolation rates,the phosphorus loading rates, 4 feet of soil to the water table for adsorption and 3.5 inhabitants per house, the number of years until breakthrough can be calculated. The results are listed in Table 3.2. (In this simple calculation, an unrealistic discontinuous breakthrough curve is assumed, i.e. - the concentration of phosphate reaching the water table increases instantaneously from 0 to the effluent concentration at some point in time.) Due to all these variables, the time to breakthrough can vary from 1 year to 33 years, depending on which alternative is chosen and which soil is present. To calculate these breakthrough periods more accurately and realistically, it will be necessary to experimentally analyse the phosphorus fixing capacity of the soil and measure the depth between the leaching lines and the water table through different times of the year. It will then be possible to control phosphate contamination of groundwaters by regulating how long a soil absorption can be used before being exhausted and requiring abandonment.

3.4 Dilution of Nutrients by Infiltrating Groundwater

The Pinelands is really a giant groundwater recharge area. Almost half (50.8cm/114.3cm) of the rainfall in the area infiltrates the soil to reach the water table (Forman, 1979 p. 163). Since the Pinelands do not receive any surface or groundwater from outside, we can consider the entire Pinelands area as one hydrological system. As we are concerned with the environmental impact from on-site discharges of nitrate and phosphate, it is necessary to calculate the concentration of these nutrients in the water being recharged from developed areas. Dilution models used by Brown (1977, 1980) and Trela and Douglas (1980) assume complete mixing of infiltrating rainwater and effluent from subsurface absorption systems. Similar calculations will be performed here to calculate the concentration of this nitrate and phosphate after being diluted by 20 inches of infiltrating rainwater falling over the entire house lot. Since mixing is not complete in reality, there can be plumes of groundwater with higher and lower concentrations than shown here.

Table 3.6 presents the concentrations of nitrogen leaving house lots of various acreage due to the various treatment and management alternatives. This nitrogen will be predominantly in the nitrate form. This chart shows only the values calculated from Table 3.1 data for sandy type A and D soils because these are the most likely types of soils to be developed. Also, the value of 5% nitrogen removal rate is the most conservative to use in predictions. The denitrification rates have not been proven yet for other soil types, but similar predictive calculations can be made when the information is available. It has also been assumed that 3.5 people occupy each house lot. As expected, the concentration of nitrogen increases with small lots, from a low of 0.025 mg/l to 12.6 mg/l depending on the alternative.

Table 3.7 is a matrix that displays the alternative wastewater treatment systems that can meet certain groundwater nitrogen concentration standards on various lot sizes. The abscissa lists five different nitrogen concentrations that may be chosen as maximum limits not to be exceeded in the groundwater. The ordinate is the six different lot acreages used in Table 3.6. Alternatives were assigned that would not increase the natural concentration of nitrogen by more than the abscissa limits. The letters refer to the treatment system alternative as listed in Table 3.1. The actual groundwater concentration will depend on the naturally existing concentration and other inputs such as fertilizers which is discussed in the next section. As Table 3.7 shows, two combinations of lot size and concentration limit will not allow any type of system to be built, thirteen choices will allow the use of a conventional septic tank-soil absorption system, and the remainder will require an alternative or innovative system.

As discussed previously, phosphorus will be absorbed onto soil particles for some period of time depending on many factors. However, it would be beneficial to know the concentration of phosphorus in the groundwater that subsurface soil absorption systems could produce. Therefore, calculations were performed on the mixing of leachfield effluent and infiltrating groundwater. Since the leaching phosphorus concentration will probably require a very long period of time to breakthrough to the treatment effluent concentration, it would be appropriate to choose a time when, say, 80% of the phosphorus leaches to the groundwater. The remaining 20% is assumed to be absorbed in the soil or taken up by plants. The result should approximate a long term loading rate of phosphorus to the groundwater, and occur after about the number of years shown in Table 3.2. So Table 3.8 reports the concentration of phosphorus in the groundwater from all the wastewater treatment alternatives after being diluted by infiltrating rainwater. At this point in time, when 20% of the phosphorus is still absorbed into the soil, the diluted concentration ranges from 0.015 mg/l to 7.4 mg/l. Similar calculations can be done for other points in the breakthrough curve.

Table 3.6 Incremental Increase over Natural Conditions in the Concentration of Nitrogen Leaving House Lots Assuming Steady-State Dilution of Effluent from Subsurface Absorption Systems by Infiltrating Precipitation

Management and Treatment Alternatives	10 Acre Lot	5 Acre Lot	2 Acre Lot	1 Acre Lot	½ Acre Lot	¼ Acre Lot
Total Wastewater - Septic Tank (S.T.) Soil Absorption System (S.A.S.)	0.44 mg/l	0.88 mg/l	2.1 mg/l	4.2 mg/l	7.4 mg/l	12.6 mg/l
Total Wastewater - Aerobic Tank (A.T.) Soil Absorption System (S.A.A.)	0.37 mg/l	0.74 mg/l	1.8 mg/l	3.4 mg/l	6.3 mg/l	10.9 mg/l
Total Wastewater - S.T. - Sand Filter - Denitrification System (D.S.)-S.A.S. or Total Wastewater -A.T. - D.S. -S.A.S.	0.13 mg/l	0.26 mg/l	0.63 mg/l	1.2 mg/l	2.2 mg/l	3.9 mg/l
Total Wastewater - Septic Tank - Ammonia Adsorption Unit - S.A.S. or Greywater - Septic Tank - S.A.S. or Greywater - Aerobic Tank - S.A.S.	0.08 mg/l	0.15 mg/l	0.35 mg/l	0.67 mg/l	1.2 mg/l	2.1 mg/l
Greywater - A.T. - Denitrification Syst. - S.A.S. or Greywater - S.T. - Sand Filter - Denitrification - S.A.S.	0.025 mg/l	0.046 mg/l	0.11 mg/l	0.21 mg/l	0.39 mg/l	0.63 mg/l
Greywater - Septic Tank - Ammonia Adsorption Unit - S.A.S.	0.015 mg/l	0.025 mg/l	0.063 mg/l	0.12 mg/l	0.22 mg/l	0.35 mg/l

Note: Nitrogen Loading rates from Table 3.1 assuming 3.5 inhabitants per household, 51 cm. of infiltrating rainfall per year and sandy soils A & D

TABLE 3.7 Wastewater Treatment and Disposal Alternatives that Meet Various Limits for the Increase in Groundwater Nitrogen Concentrations from Subsurface Absorption System Leachates

Lot Size	Nitrogen Concentration Limit in Groundwater Leaving House Lot				
	0.2 mg/l	1 mg/l	2 mg/l	5 mg/l	10 mg/l
¼ Acre	LIMIT WILL BE EXCEEDED	Alternatives H I J	Alternatives H I J	Alternatives C D E F G H I J	Alternatives C D E F G H I J
½ Acre	LIMIT WILL BE EXCEEDED	Alternatives H I J	Alternatives E F G H I J	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM
1 Acre	Alternative J	Alternatives E F G H I J	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM
2 Acre	Alternatives H I J	Alternatives C D E F G H I J	Alternatives B C D E F G H I J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM
5 Acre	Alternatives E F G H I J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM
10 Acre	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM

Notes:
1. Letters refer to the alternatives listed in Table 3.1
2. Does not take into account nitrogen from natural sources, fertilizers, and other non-point sources
3. Same assumptions as with Table 3.6

TABLE 3.8: Concentration of Phosphorus (in mg/l) Leaving House Lot Assuming Steady State Dilution of Effluent from Subsurface Absorption Systems by Infiltrating Precipitation and 20% Long Term Phosphorus Removal Rate by Soil.

MANAGEMENT & TREATMENT ALTERNATIVES	HOUSE LOT SIZE				
Wastewater w/Phosphate Detergent	5 Acres	2 Acres	1 Acre	½ Acre	¼ Acre
Aerobic Tank- Soil Abs. Syst.	.52	1.3	2.4	4.3	7.4
Septic Tank - Soil Abs. Syst.	.25	.59	1.1	2.1	3.5
Aerobic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.10	.26	.50	.88	1.5
Septic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.049	.12	.22	.41	.70
Wastewater w/o Phosphate Detergent					
Aerobic Tank - Soil Abs. Syst.	.31	.75	1.4	2.6	4.5
Septic Tank - Soil Abs. Syst.	.16	.38	.72	1.3	2.2
Aerobic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.064	.15	.29	.53	.88
Septic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.030	.073	.14	.26	.43
Greywater w/Phosphate Detergent					
Aerobic Tank - Soil Abs. Syst.	.33	.80	1.5	2.8	4.7
Septic Tank - Soil Abs. Syst.	.18	.42	.81	1.4	2.5
Aerobic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.066	.16	.30	.56	.96
Septic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.034	.08	.16	.29	.49
Greywater w/o Phosphate Detergent					
Aerobic Tank - Soil Abs. Syst.	.13	.30	.58	1.0	1.8
Septic Tank - Soil Abs. Syst.	.08	.19	.36	.66	1.1
Aerobic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.026	.062	.12	.22	.36
Septic Tank - Alum Addition or Sorption/Ppt. Filter Bed - S.A.S.	.015	.038	.072	.13	.22

3.5 Nutrient Loadings from Lawn Fertilization

In addition to nutrients entering the groundwater from wastewater disposal systems, there are non-point sources that make contributions to the overall loading. Rainwater itself contains small amounts of nitrogen and phosphorus, but we are concerned here only with the increases due to development.

Fertilizers used on residential lawns add nitrogen, phosphorus and potassium to the soil for better growth. Although the amount of fertilizer applied is calculated according to growth requirements over the entire growing season, homeowners usually spread it in only one or two applications. Therefore, the nutrients after application are in excess of what can be taken up by the plants, and instead can be leached into the soil by infiltrating rainwater.

Phosphorus is the least mobile of the nutrients as much of the excess phosphate should be adsorbed and precipitated in the top few feet of soil depending on the amount of clay and aluminum. While the phosphorus is fixed in the soil it can be continually withdrawn by the plants for growth. Therefore, we are assuming that all the phosphorus is consumed by plants while fixed in the soil, and that insignificant amounts will be transported to the groundwater.

Potassium is a highly mobile cation that can be transported by infiltration to groundwater supplies if not completely removed by plant roots. Some potassium may be removed by ion exchange with the soil, but most of the excess will only be attenuated by rainwater dilution. However, it doesn't appear that an increase in the potassium concentration in the groundwater will have any environmental or health effects other than increasing the dissolved solids content and conductivity of the water.

So nitrogen is the nutrient of major concern from home fertilization. If inorganic nitrate fertilizers are applied in excess of demand, nitrate can be transported downwards with percolating rainwater, and attenuated only by denitrification in lower anaerobic soils and by dilution. If organic nitrogen fertilizers are used, they can be decomposed to ammonia which may be leached downwards if in excess or if first oxidized to nitrate in aerobic soils.

Brown (1980) states that research has shown that one-third to one-half of the applied nitrogen can be leached from soils to groundwater from organic and inorganic fertilizers, respectively. An average value of 40% was chosen for our calculations as the amount of nitrogen that will leach to the groundwater from the applied fertilizer.

The literature (Brown, 1980; Nassau-Suffolk Regional Planning Board, 1978) reports that most homeowners apply from 1-4 lbs Nitrogen/1000 ft^2 (5-20kg/1000m^2) of lawn per year. An average value of 2 lbs N per year will be used in the following calculations and tables.

The degree to which the nitrogen concentration in the groundwater leaving the house lot will be increased is dependent on how much land area is fertilized and how much dilution by rainwater there is. Therefore, the ratio of total lot size to fertilized land area is the determining factor. For the following example, the same lot sizes will be used as in Table 3.6 which shows the dilution of nitrogen from subsurface sewage disposal sources. It was further assumed that homeowners with 1/4 and 1/2 acre lots will fertilize 5,000 ft^2 of lawn, while 1,2, and 5 acre lots will have 10,000 ft^2 fertilized.

Table 3.9 shows the average concentration of nitrogen in the groundwater leaving the lot boundaries from fertilizer leachate with the aforementioned assumptions and 20 inches of infiltrating rainwater per year. The actual concentrations will be very variable depending on application rates and frequency as well as rainfall frequency and duration. There is likely to be large plugs of nitrogen entering the groundwater with the first rainfall after heavy fertilizer applications.

TABLE 3.9

GROUNDWATER CONTAMINATION BY NITROGEN FROM HOME FERTILIZER SOURCES

Lot Size in Acres	Infiltration and SAS effluent (l/d)	Nitrogen leached from Fertilizer (g/d)	Incremental Increase in Concentration of Nitrogen in Groundwater - mg/l
10	56,935	10	0.18
5	28,763	10	0.35
2	11,862	10	0.84
1	6,229	10	1.6
1/2	3,412	5	1.5
1/4	2,003	5	2.5

As Table 3.9 indicates, home fertilization can add more nitrogen to the groundwater than three-quarters of the alternative treatment and management systems. If additional research shows that these application and leaching rates are typical for the Pinelands, it may be economically beneficial and/or necessary to prohibit lawn fertilization or institute some Best Management Practices (BMP) in order to meet certain groundwater nitrogen concentrations limits.

Table 3.10 uses the data from Table 3.9 and Table 3.6 to evaluate which alternatives can be used to meet certain groundwater nitrogen limits if fertilizer leachate is also accounted for. Since fertilizer will add an appreciable amount of nitrogen to groundwater, the subsurface soil absorption system will have to discharge less nitrogen to meet the same standards as shown in Table 3.7. Therefore, lower discharge alternatives will have to be used. As seen in Table 3.10, nine combinations will not allow development because fertilizer leachate alone will exceed the concentration limit, only eleven cases will allow standard septic systems, and the remaining possibilities will require stricter alternatives than when fertilizer was not considered in Table 3.7.

Another matter of potential concern might arise if lime is used in addition to fertilizers and it is shown that the leachate is alkaline and has the ability to increase the groundwater pH, hardness and alkalinity.

TABLE 3.10 Wastewater Treatment and Disposal Alternatives Whose Subsurface Absorption System Discharges, Together with Nitrogen Leaching From Fertilizers, Will Meet Various Limits on Groundwater Nitrogen Concentrations

Lot	Nitrogen Concentration Limit in Groundwater Leaving House Lot				
Size	0.2 mg/l	1 mg/l	2 mg/l	5 mg/l	10 mg/l
¼ Acre	LIMIT WILL BE EXCEEDED*	LIMIT WILL BE EXCEEDED*	LIMIT WILL BE EXCEEDED*	Alternatives E F G H I J	Alternatives C D E F G H I J
½ Acre	LIMIT WILL BE EXCEEDED*	LIMIT WILL BE EXCEEDED*	Alternatives H I J	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM
1 Acre	LIMIT WILL BE EXCEEDED*	LIMIT WILL BE EXCEEDED*	Alternatives H I J	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM
2 Acre	LIMIT WILL BE EXCEEDED*	Alternatives H I J	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM
5 Acre	LIMIT WILL BE EXCEEDED*	Alternatives C D E F G H I J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM
10 Acre	Alternative J	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM	STANDARD SEPTIC SYSTEM

* The limits are exceeded by the fertilizer leachate itself.

Note:
1. Letters refer to the alternatives listed on Table 3.1
2. Includes fertilizer leachate according to Table 3.9
3. Same infiltration assumptions as with Table 3.6

4.0 DESCRIPTION OF THE PINELANDS WETLAND ECOLOGY AND THE POTENTIAL ENVIRONMENTAL IMPACTS FROM WASTEWATER DISPOSAL

Whittaker (1979) describes the Pine Barrens as a vegetation pattern characterized by open forests of Pitch Pine (*Pinus rigida*) with an understory of shrubby oak and heath species. Upon closer examination, the Pinelands region is not a homogeneous stand of pine and oak but rather a complex of plant communities in which formation is determined by the topography such as variation in slope and soil substrate; the hydrology such as local drainage patterns and soil moisture; the complex interaction of the soil and water nutrient chemistry; fire frequency and man, namely, forest and agricultural practices as well as urban development.

The most critical determining factor of vegetation formation in the Pine Barrens is soil moisture and so vegetative communities have been most often recognized from this critierion (Harshbarger 1916; McCormic 1979; Olsson 1979; and Whittaker 1979). Another important characteristic of the Pine Barren region is its geology and respective soil complexes which the vegetative communities inhabit in the region. Soil substrate together with soil moisture largely determines the nutrients that will become available to plants and therefore, determines where plants will become established.

Much of the Pine Barren vegetation overlies what are known as the Kirkwood and Cohansey sand formations. The principle formation, the Cohansey Sand formation, underlies the major portion of the Pine Barren region. It consists of coarse sand, it is 1.2 million acres in size and approximately 37 ft. deep. Together with the kirkwood formation, a depth of 600 ft. of sand may be reached. Due to the water holding capacity of these coarse sands, the Cohansey Sand formation is the principle aquifer of the region. Because this formation is not usually more than 20 ft. from the surface, it has been classified as a freshwater/water table aquifer (Rhodehamel 1979). Most streams and rivers flow above this aquifer and may discharge to local streams or move very slowly (130-160 ft/year) to lower reaches of the Pine Barren drainages (Rhodehamel 1979). Water flow in the Cohansey Sand aquifer is principally south and each of the geological strata in which water flow is neither linear or laminar and rapid movement of groundwater to the ocean does not occur (Boerner 1980), personal communication).

The characteristic soils of the Pine Barrens have been described as being extremely sandy and xeric, having inadequate nutrient supply and being highly acidic with toxic levels of Aluminum (Tedrow 1979). The soil characteristics do change however, along a moisture gradient from xeric, excessively well drained upland soils to very poorly drained hydric conditions in the lowlying regions. Soil drainage conditions typically go directly from xeric to hydric conditons (Tedrow 1979; Douglas 1980, personal communication). The sandy soil substrate does not change much along this gradient.

On the basis of soil moisture, vegetative communities have been classified into two major floristic complexes, the lowland complex and the upland complex (McCormick 1970; 1979). The classification of the vegetation into distinct plant communities based upon plant composition within both complexes varies between 9 (Harshbarger 1916; Whittaker 1979) and 12 (McCormick 1979) distinct community types. A synthesis of the classifications of McCormick's and Whittaker's Classifications will be used here. It is important to note that discrete boundaries between community types often differ from one site to the next indicating the potential influence of adjacent community types on those communities proximate to them.

Lowland vegetation occupy sites which range from soil conditions of continuous water saturation to those areas where water covers the area only during a few periods during most years (McCormick 1979). McCormick lists 6 community types of the lowlands:

Herbaceous Wetland Communities
Shrubby Wetland Communities
Southern White Cedar Swamp
Broadleaf Swamp
Pine Transition
Pitch Pine Lowland

The lowlands of the Pine Barrens contain many of the critical habitats of the region (Fairbrothers et al., 1980) and within the lowland complex, the bogs and herbaceous wetland communities contain the greatest species diversity (Fairbrothers 1979; McCormick 1979). Very little has been worked to completion with regard to the ecology of the various wetland communities of the Pine Barrens (Boerner 1980; Ehrenfeld 1980; Douglas 1980 personal communication) therefore, only a rough sketch may be given at this time. Table 4.1 summarizes the general soil characteristics of the major community types. All unlimed soils of the wetlands have a surface pH range of 3.6 to 4 and a subsurface pH range of 4.2 to 5. Table 4.2 summarizes the chemical conditions that may likely be found in wetlands of the Pine Barrens, however, much is drawn from other wetland regions. Chemical characteristics for wetlands is generally lacking in the literature (Richardson 1978) so general comparisons are made between waterlogged, anaerobic soils and waterlogged soils that are mostly oxygenated. Table 4.3 lists the main vegetative components of the principle wetland communities found in the Pine Barrens.

The work of Richardson et al (1976) revealed that peat soils with leatherleaf - Bog Birch species composition and sandy soils containing a sedge - willow composition responded similarily to low levels of added N (18 kg/ha) and P (6 kg/ha) in that there were no differences in net seasonal production and growth rates. In the peat soils in contrast, N and P were found to concentrate in litter and

TABLE 4.1 Pineland Wetland Soil Types Found Under Principle Plant Communities

Soil Characteristics	Bog Marsh	Swamp Forest	Swamp Transitional
	Shrubby - Herbaceous	White Cedar Broadleaf Pitch Pine	Pitch Pine
Soil Moisture	Waterlogged	Waterlogged to very poorly drained	Moderate to poorly drained.
Composition	Muck/Sand	Muck and sand organic layer 10" deep	Organic layer 10" deep and sand
pH	Strongly Acid	Strongly Acid	Acid
Depth to Water Table	0 winter spring 30 - 60 cm Summer	0 winter spring 30 - 60 cm Summer	45 - 120 cm winter spring 150 cm Summer
Fertility (Cation Exchange capacity in m equiv. per 100 g)	5 - 10 in muck soils	10	5

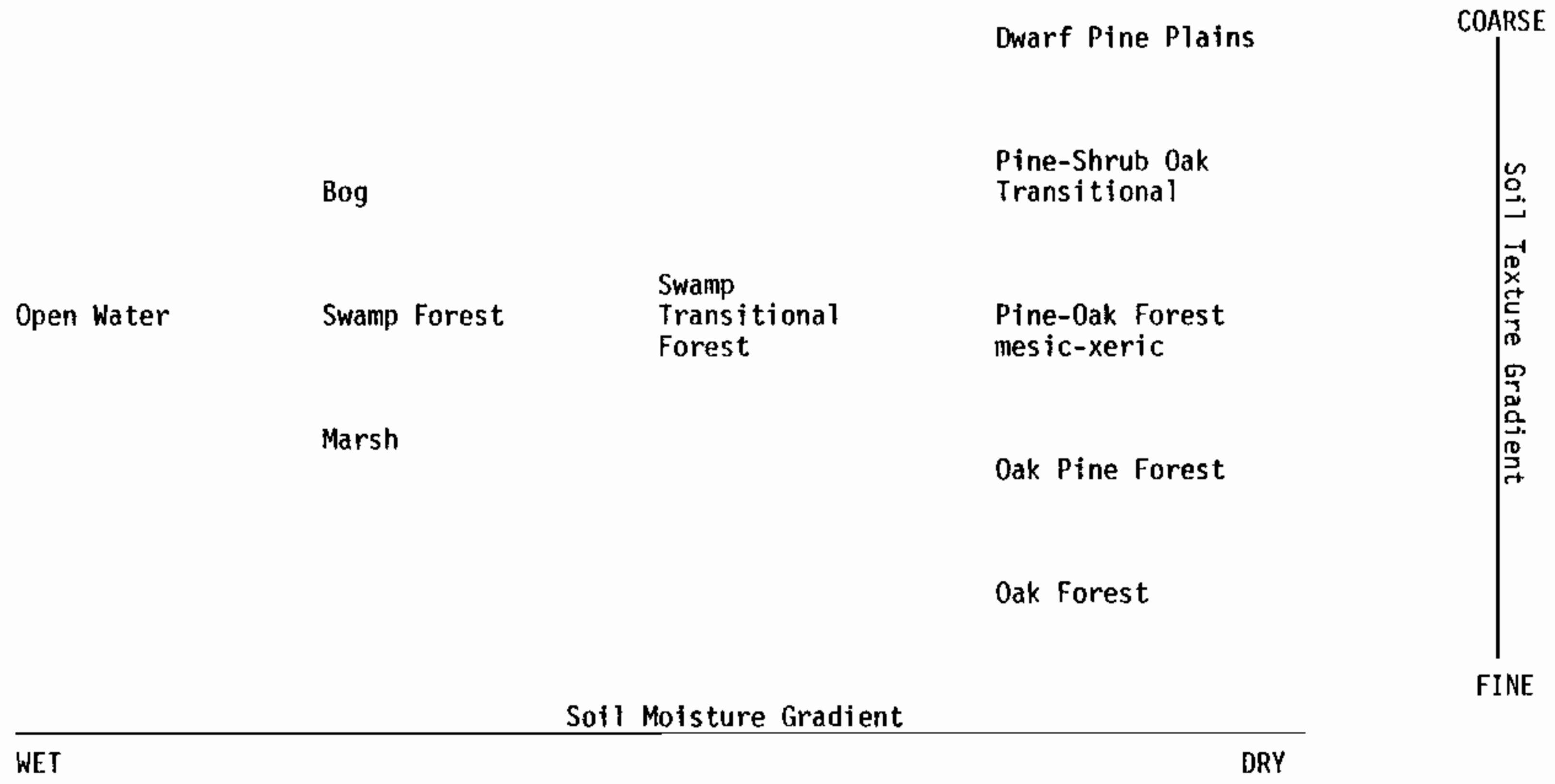
TABLE 4.2 Chemical Conditions Found in Anaerobic and Aerobic Water Saturated Soils Applied to Soils Found in the Pinelands

Nutrient	Bog Marsh	Swamp Forest	Swamp Transitional
Oxygen	Mostly anaerobic, depending upon location of water table.	Anaerobic-Aerobic depending on the location of the water table.	Aerobic, sometimes anaerobic when inundated with water.
Nitrogen	Characteristically not available to plants (as NO_3) for uptake[9]. Nitrogen lost via denitrification. NH_4 principle N form in water logged soils. Organic soils and litter sink but may not function as such in marshland and sedge swamp.[c]	Nitrogen likely not available as NO_3 but unknown for Pinelands environment. NH_4 may be principle nitrogen form.	Unknown. NO_3 (nitrate) may be present during aerobic soil conditions.
Phosphorus	In anaerobic soils, phosphate becomes solubilized as iron phosphate precipitates are released into solution.[b] Plant roots cannot survive in anaerobic soils so phosphorus is unavailable for uptake. Peat is the major sink.[c]	In aerobic and very acid soils, iron becomes insoluble and creates a binding surface for phosphate[b] and consequently immobilizes phosphate; making it unavailable to plants.	-----

TABLE 4.3 Principle Vegetative Species Found in the Pinelands Wetlands Communities

Bog Marsh	Swamp Forests	Swamp Transitional
Spatterdocks (Nupher Variagartum) Bladdernorts (Utricularia Spp.) Sphagnum Moss Sedge (Carrex) Rush (Juncus) Chauferns (Woodwardia spp.) and in areas of fluctuating water tables: Lowland Broomsedge (Andropogon virginicus abbreviatus). Bullsedge Encods: Leatherbed (Aamaedaphnia colyculata) Blueberry Sheep Laurel (Kalivia argustifolia) Stagga bush (Lyoniamarianna)	White Cedar in Pine stands or mixed with Red Maple Forests. Red Maple Pitchpine Blackgum Understory: Dangleberry (Gaylussauva Frondosa) Clammy Azalia (Rhododendren Vigism) Sweet Pepperbush (Clethra Almifotia) Letterbush (Leucothoe Raumosa) Bayberry (Myrica Pensylvanica) Herbaceous Plants: Carnivorous Species Swamp Pink (Helonias Bullata) Partridge Berry (Mitchella Repens) Sphagnum is 10% cover in pitch pine areas and continuous under white cedar.	Pitch Pine Red Maple Blackgum Sheep Laurel Dangelberry 1% covered by Sphagnum Moss

FIGURE 4.1 Pattern of Vegetation in the Pinelands (From Whittaker 1979)



peat, becoming unavailable for plant uptake. While first year litter decomposition rates or elemental losses were not significantly different, they did become significantly different through time (Richardson 1976). A similar study in Michigan peatland (Kadlec 1976) showed that with low (6.3 l/m^2/wk) and even high (12.5 l/m^2/wk) nutrient loads there were no increases in productivity the first year. However, increases did begin to result the second year, suggesting that continued application on a large scale, enough to reduce the dilution effect, would produce significant changes in the nutrient status of peatland (Kadlec 1976). This conclusion is supported by the work of Burke (1975), where nutrient losses over a 2 year period were 19% and 23%.

The question of peatland decomposition rate was addressed by Coulson and Butterfield (1978). They found decomposition rates of peatland in the United Kingdom increased with N enriched litter.

The effect of nutrient loading on individual plant species has been studied to a greater extent than has the effect of nutrient loadings on entire wetlands communities (Good et al 1978). Data is available for the absorbtion of N and P by highly productive emergent monodominant macrophhte communities such as for *Typha latifolia* (Wetzel 1975; Linsley et al 1976); Phragmites (Wetzel 1975) and *Scrupus validus*, *Sparganium eurycarpon*, and *Sagittaria latifolia* (Linsley et al 1976) and other species (Klopatek, 1978). Patterns in productivity rates and nutrients tend to concentrate in each plant (Linsley 1976, Klopetk 1978).

In *Typha*, productivity increases over the entire growing season (Linsley et al 1976) and the plant continues to take up nutrients over the winter (Prentki 1978). In contrast, nutrient uptake by *Phragmites* increases at the beginning of the growing season and then begins to decline by August. It can be seen that seasonal changes in nutrient concentration of these plants likely occurs. This has been demonstrated for the species mentioned above as well as in the work of Klopatek (1978) who attempted to correlate monthly changes in soil nutrients with those in emergent macrophytes.

Due to the highly diverse nature of the wetlands in the Pine Barrens, it is obviously difficult to quantify the response of a given plant community to a given nutrient load. Research needed for the interpretation of nutrient loading in the Pine Barren reigon has only begun (Boerner 1980, personal communication). What may be inferred from the literature indicates that continuous nutrient loading of N and P on the wetland communities may have detrimental effects through time.

These adverse impacts may include:

- the decomposition of the peat substrate in saturated peatbog wetlands
- accelerated growth of certain wetland species, particularly those growing in aerobic soil environments
- the accumulation and release of nutrients on a seasonal basis by certain wetland plants.

The impact that a given nutrient loading will have on wetlands depends both on the sensitivity of the wetland species and on the method of nutrient application. In areas with saturated, anaerobic soils, for example, nitrogen and phosphorus applied subsurfacely would be largely immobilized due to the sorption processes within the soil. However, the surface application of the same nutrients would make them available for plant uptake or peat decomposition. In wetlands with aerobic soils, nutrients would be available under either surface or subsurface application conditions. Thus, local groundwater flow conditions and wetlands flooding patterns may have a large infludence on the impact caused to a wetland by the discharge of nutrients in adjacent areas.

5.0 LAND APPLICATIONS OF WASTEWATER AND SLUDGES

Up to this point, we have only discussed the environmental impacts of the effluent from individual on-site treatment and disposal systems. However, there are two other issues that must be contended with. The first is the environmental impacts of treating and disposing of the septage or other sludges that on-site treatment systems generate. The second is the alternative of centralized sewage collection and treatment, and the environmental impacts of the effluent discharges and sludge disposal on the land.

If centralized sewage treatment facilities with surface discharges are constructed in villages and towns, one environmental concern is the effect of treated effluent discharges on surface waters. The degree of impact that must be evaluated depends on the concentration of BOD, suspended solid, and nutrients in the effluent; the flow rate of the effluent, the quality and flow rate of the river water, and other site specific conditions. Discharge of BOD can cause depletion of dissolved oxygen in rivers depending on quantities, dilution, and reaeration. Suspended solids can cause the water quality to become more turbid. Nutrients like nitrogen and phosphorus can stimulate the growth of aquatic plants, thereby changing the productivity of the riverine ecosystem.

An alternative to discharging sewage effluent to surface waters that is receiving increased attention today is the application of sewage to land for uptake by plant growth and treatment by soil. This may involve applying primary or secondary treated sewage to agricultural land by spray irrigation, overland flow or subsurface injection. In addition, sludges from sewage treatment facilities, and septage from individual on-site treatment systems can also be disposed of by various land application methods.

The treatment and design principles are basically the same for whichever type of waste is applied to the land. Organic matter is filtered out by the soil and gradually oxidized by soil micro-organisms. Suspended solids are filtered out and incorporated into the soil. Nutrients like nitrogen and phosphorus are taken up by plant roots, incorporated into the crop and harvested. Metals in the wastewater and sludges are held in the soil by keeping the soil pH alkaline so that metals are precipitated as hydroxides. By affording these pollutant removals, the treated leachate can then be collected by underdrains for surface water discharge, or allowed to continue percolating and recharge the groundwater tables.

There are guidelines for these land application techniques that have been developed by the U.S.E.P.A. The application rates are based on crop production and are calculated in the same manner as commercial fertilizer rates. At these rates, sludges can be considered a low grade fertilizer.

Annual application rate recommendations for agricultural soils are presently based on the nitrogen and cadmium contents of a sludge or wastewater and the nitrogen demand of the crop being grown. This is because nitrogen will be easily leached to the ground water if in excess of crop requirements, and cadmium is the most toxic heavy metal to be allowed to accumulate in the soil. The total amount of wastewater or sludge applied to soils over time is limited by the heavy metal additions of zinc, copper, nickel and cadmium. The amount of nitrogen applied will also vary depending on the nitrogen forms in the sludge. The annual cadmium loading rate has been set at 2 lbs/acre/year for food chain crops, and the maximum amount of other metals is based on the soil cation exchange capacity. Tables 5.1 and 5.2 are from EPA's "Application of sludges and Wastewaters on Agricultural Land: A Planning and Educational Guide," MCD 35. These are used with this guide to calculated application rates and periods.

Table 5.1 Annual Nitrogen, Phosphorus, and Potassium Utilization by Selected Crops.*

Crop	Yield	Nitrogen	Phosphorus	Potassium
		Lb. per Acre		
Corn	150 bu.	185	35	178
	180 bu.	240	44	199
Corn silage	32 tons	200	35	203
Soybeans	50 bu.	257†	21	100
	60 bu.	336†	29	120
Grain sorghum	8,000 lb.	250	40	166
Wheat	60 bu.	125	22	91
	80 bu.	186	24	134
Oats	100 bu.	150	24	125
Barley	100 bu.	150	24	125
Alfalfa	8 tons	450+	35	398
Orchard grass	6 tons	300	44	311
Brome grass	5 tons	166	29	211
Tall fescue	3.5 tons	135	29	154
Bluegrass	3 tons	200	24	149

*Values reported above are from reports by the Potash Institute of America and are for the total above-ground portion of the plants. Where only grain is removed from the field, a significant proportion of the nutrients is left in the residues. However, since most of these nutrients are temporarily tied up in the residues, they are not readily available for crop use. Therefore, for the purpose of estimating nutrient requirements for any particular crop year, complete crop removal can be assumed.

†Legumes get most of their nitrogen from the air, so additional nitrogen sources are not normally needed.

TABLE 5.2 Total Amount of Sludge Metals Allowed on Agricultural Land.

Metal	Soil Cation Exchange Capacity (meq/100 g)* 0 - 5	5 - 15	> 15
	Maximum Amount of Metal (Lb/Acre)		
Pb	500	1000	2000
Zn	250	500	1000
Cu	125	250	500
Ni	125	250	500
Cd	5	10	20

*Determined by the pH 7 ammonium acetate procedure.

In the sandy Pinelands soils there should be concern over the amount of nitrogen that may reach the groundwater from land application of sludge, septage, and wastewater. Also, the sandy, acidic Pinelands soils might limit sludge application because the heavy metals may not be held sufficiently in the soil. The mobility of metals may be determined by subjecting sludge to the metals extraction procedure outlined in the regulation of the Resource Conservation and Recovery Act, (Federal Register 12/18/78). The usual solution of liming the soil to make it alkaline may not be satisfactory because of the concern for not changing the acidic soil and groundwater nature. Fortunately, though, the lack of industrial wastes now and probably in the future should insure that the heavy metal content of the sludges should remain low.

One final wastewater disposal proposal to consider is deep injection. When this disposal technique is used, the effluent must be treated prior to injection. The degree of treatment must be determined based upon EPA's Best Practicable Treatment regulations. These regulations generally require that the groundwater leaving a wastewater treatment/disposal site must meet drinking water standards. The major issues in the land application of wastewater, sludge or septage can be summarized as follows:

- large land areas (determined by the volume and strength of the waste) are required. Nitrogen and heavy metal loadings are the usual design parameters

- retention of metals in the soil will require the raising of the soil pH and consequently the pH of the infiltrating water.

- storage facilities must be provided to hold wastes generated during winter months.

- the useful life of a land application site may be limited by the accumulation of heavy metals.

- localized changes in groundwater flow may result from the application of large waste flows
- nutrients that might otherwise be discharged to surface or groundwaters are reused for plant growth
- water may be reused to provide groundwater recharge
- metals become concentrated in one geographic location

REFERENCES:

1. Brown, K.W. and Associates. "An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization and Agricultural Activities on Groundwater Quality". Prepared for the New Jersey Pinelands Commission. February 25, 1980.

2. Brown, K.W., et al, June 1977. "Accumulation and Passage of Pollutants in Domestic Septic Tank Disposal Fields". Texas A&M Research Foundation, College Station, Texas. Project # R801955-01-2.

3. Burke, W. (1975) "Fertilizer and Other Chemical Losses in Drainage Water from Blanket Bog". IR. J. Agric. Res. 14,163-178.

4. Coulson, D.C., Butterfield J., 1978. " An investigation of a Blanket Bog", J. of Ecology, 66, 631-650.

5. Douglas, Lowell A. and Walker, Raymond. "Non-Point Sources of Pollution and Soils of the Pine Barrens of New Jersey", N.J. Agricultural Experiment Station. Rutgers, New Brunswick, N.J., January, 1979.

6. Ellis, B.G., Childs, K.E., 1973. " Nutrient Movement from Septic Tanks and Lawn Fertilization. Water quality protection project, Houghton Lake, Michigan. An Inland Lake Water Quality Management Project Report", Dept. of Natural Res. Tech. Bull. No. 73-5. Michigan Water Resources Comm., Lansing.

7. EPA, "Process Design Manual for Land Treatment of Municipal Wastewater " Technology Transfer, October, 1977. EPA 625/1-77-008. P. B-6.

8. EPA, "Septic Tank Disposal Systems as Phosphorus Sources for Surface Waters" Robert Kerr Env. Res. Lab, Ada, OK. November 1977. EPA-600/3-77-129.

9. EPA, "Management of Small Waste Flows" by Small Scale Waste Management Project." University of Wisconsin, Madison. September 1978 EPA-600/2-78-173. Table A-114.

10. Fairbrothers, D. 1979. "Endangered, Threatened and Rare Vascular Plants of the Pine Barren and Their Biogeography". R. T. Freeman (Ed) Pine Barrens, Acemedic Press 395-404.

11. Fairbrothers, D., and Caiazza, N., 1980. "Threatened and Endangered Vascular Plant Species in the New Jersey Pinelands and Their Habitats". Prepared for the New Jersey Pinelands Commission - Unpublished, January 15, 38 pages.

12. Forman, Richard T.T. Pine Barrens: Ecosystem and Landscape, Academic Press., New York, 1979.

13. Harlukowicz, Thomas J., and Ahlert, R.E., November. 1978. "Effects of Septic Tank Effluent on Groundwater Quality in the New Jersey Pine Barrens". Rutgers, The State University of New Jersey, Bureau of Engineering Research, Piscataway, N.J.

14. Harshberger, J.W., 1916. "The Vegetation of the New Jersey Pine Barrens". Dover Publ. 339 pp.

15. Kadlec, D.A., 1976. "Dissolved Nutrients in a Peatland Near Houghton Lake, Michigan" in "Freshwater Wetlands and Sewage Effluent Disposal" (D.L. Tilton, E.H. Kadlec, C.J. Richardson (ed) pp 25-50 University of Michigan, Ann Arbor, Michigan.

16. Klopatck, J.M. 1978. "Nutrient Dynamics of Freshwater Riverine Marshes the the Role of Emergent Macrophytes". R. Good, D.F. Whigham, R. Simpson (Eds) 1978. Freshwater Wetlands, Academic Press.

17. Linsley, D.J., Schuck, T. Stearns, F., 1976. "Productivity and Nutrient Content of Emergent Macrophytes in Two Wisconsin Marshes." In Freshwater Wetlands and Effluent Sewage Disposal (D.L. Tilton, R.H. Kadler, C.J. Richardson (ed) P. 51-76.

18. Magdoff, F.R. et al, 1974. "Columns Representing Mound-Type Disposal System for Septic Tank Effluent: II Nutrient Transformation and Bacterial Populations." J. of Environmental Quality, 3:228-234.

19. McCormick, J. 1979. "The Vegetation of the New Jersey Pine Barrens", In R. T. Foreman (Ed.) 1979. Pine Barrens Academic Press, 229-242.

20. Nassau-Suffolk County Regional Planning Board. "The Long Island Comprehensive Wastewater Treatment Management Plan". Vol. II, July 1978, Hauppauge, New York, P. 193.

21. Olsson, H. 1979. "Vegetation of the New Jersey Pine Barrens: A Phytosociological Classification". In R.T. Foreman (Ed) 1979 Pine Barrens. Academic Press 245-261

22. Otis, R.J. Boyle, W.C., Converse, J.C., and Tyler, E.J. 1977. "On-Site Disposal of Small Wastewater Flows". Small Scale Waste Management Project, Univ. of Wisconsin, Madison. P. 64.

23. Otis, R.J. Boyle, and D.K. Sauer, "Performance of Household Wastewater Treatment Units under Field Conditions", Home Sewage Disposal, Proc. AM. Ag. Eng., 175, Dec. 1974.

24. Otis, R.J., Boyle, W.C., 1976,"Performance of Single Household Treatment Units", J. of Environmental Engin., 102 (EEI): 175-189.

25. Patrick, W.H., and R.A. Kahlid 1974 "Phosphate Release and Sorption by Soils and Sediments: Effects of Aerobic and Anaerobic Conditions". Science 186: 53-55.

26. Preutki, R.T., T.D. Gustafson and M.S. Adams, 1978. "Nutrient Movements in Lakeshore Marshes in Freshwater Wetland" (R. Good, D.F.Whigham and R.L. Simpson Eds.) Academic Press 169-194 p.

27. Reddy, Overcash, Khaleel and Westerman. J. Env. Qual. 9(1), 1980 "Phosphorus Adsorption-Desorption Characteristics of Two Soils for Disposal of Animal Wastes".

28. Richardson, C.J., Tilton, D.L., Kadlec, J.A., Channing, J.P. and Wentz, W.A., 1978. Nutrient Dynamics of Northen Wetlands Ecosystems. In. R.E. Good, D.F. Whigham, R.L. Simpson (Eds) 1978. Freshwater Wetlands. Academic Press. 217-242. p.

29. Richardson, C.J., Wentz, N.A., Channing, J.P., Kadlec, A.J., and D.L. Tilton. "Plant Growth Nutrient Accumulation and Decomposition in a Central Michigan Peatland Used for Effluent Treatment in Freshwater Wetlands and Effluent Disposal, 77-118. University of Michigan, Ann Arbor, Michigan.

30. Rhodehamel, E. 1979. "Hydrology of the New Jersey Pine Barrens". In R.T. Foreman (Ed) 1979 Pine Barrens 147-165.

31. Tedrow, J.C. 1979, "Development of Pine Barren Soils." In R.T. Foreman (Ed) 1979. Pine Barrens 61-78.

32. Trela, John J. and Douglas, Lowell A. "Soils, Septic Systems and Carrying Capacity in the Pine Barrens". New Jersey Agricultural Experimental Station, 1978.

33. Walker, W.G. Bouma, J., Keenery, Dr.R. and Magdoff, F.R. 1973a. "Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluents in Sands: 1. Soil Transformations." J. of Environ. Quality, 2: 475-480.

34. Whittaker, Robert, 1979. "Vegetational Relationships of the Pine Barrens". In R. T. Foreman, (Ed) 1979. Pine Barrens Acemedic Press 315-329 p.

35. Wetzel, R.G. 1975 Limnology, W. B. Saunders Co., Philadelphia, p. 743.

36. Sawhney and Hill, "Phosphorus Removal in Soils," J.Env. Qual. 4(3) 342-346, 1975.

37. Sawhney and Starr, "Phosphorus Movement in Soils," J.W.P.C.F., 49(11), 2238-2242, 1977.

APPENDIX A : PINELANDS SOILS (UNITED STATES SOIL CONSERVATION SERVICE SOILS SERIES)

SOIL SERIES	SOIL GROUPING	ATLANTIC	BURLINGTON	CAMDEN	CAPE MAY	CUMBERLAND	GLOUCESTER	OCEAN
ATSION								
Sand	F	Ac	At			Ac		At
Sand, loamy substratum	F		Au					
Fine Sand	F		Av					
Fine sand, loamy substratum	F		Aw					
Sand, tide flooded	F							Aw
AURA								
Loamy sand, 0-2% slopes	B			AmA				
Loamy sand, 0-5% & 2-5% slopes	B	AmB		AmB		AmB	AmB	
Sandy loam, 0-2% slopes	B	ArA		ArA		ArA		
Sandy loam, 0-5% & 2-5% slopes	B	ArB		ArB	ArB	ArB	ArB	AxB
Gravelly sandy loam, 0-2% slopes	B					AgA		
Gravelly sandy loam, 2-5% slopes	B					AgB		
Aura-Downer loamy sand, 0-5% slopes	B			AtB				
Aura Downer sandy laom, 0-5% slopes	B			AvB				
Aura-Sassafras loamy sands, 0-5% slopes	B						AsB	
Aura-Sassafras loamy sands, 5-10% slopes	B						AsC	
Aura-Sassafras sandy loams, 0-5% slopes	B						AuB	
Aura-Sassafras sandy loams, 5-10% slopes	B						AuC	
Aura-Sassafras sandy loams, 5-10% slopes severly eroded	B						AuC3	
Aura-Urban land complex	B			Ax				
BERRYLAND								
Sand	G	Bp	Bp		Bp	Bp		Be
Sand, flooded or frequently flooded	G	BS						BF
Fine sand	G		Bt					
Mucky sand	G		Bu					
WOODMANSIE								
Sand, 0-5% slopes	A		WeB					WoB
Sand, 5-10% slopes	A		WeC					WoC
Sand, firm substratum, 2-5% slopes	B		WgB					
Sand, loamy substratum, 0-5% slopes	B		WhB					

APPENDIX A - continued: PINELANDS SOILS (UNITED STATES SOIL CONSERVATION SERVICE SOILS SERIES)

SOIL SERIES	SOIL GROUPING	ATLANTIC	BURLINGTON	CAMDEN	CAPE MAY	CUMBERLAND	GLOUCESTER	OCEAN
DOWNER								
Loamy sand, 0-2% & 0-3% slopes	C		DoA	DoA	DoA			DoA
Loamy sand, 0-5% & 2-5% slopes	C	DoA	DoB			DoB	DoB	
Loamy sand, 5-10% slopes	C		DoC			DoC		
Loamy sand, loamy substratum, 0-2% slopes	C		DrA					
Loamy sand, gravelly substratum, 0-5% slopes	C		DpB					
Loamy sand, clayey substratum, 0-5% slopes	B			DrA				
Loamy sand, water table, 0-2% slopes	C				DpA			
Sandy loam, 0-2% slopes	C	DsA		DsA	DrA	DrA	DsA	DpA
Sandy loam, 2-5% slopes	C			DsB	DrB	DrB	DsB	DpB
Sandy loam, gravelly substratum, 2-5% slopes	C							DrB
Sandy loam, truncated, 0-5% slopes	C		DsB					
Soils, 5-10% slopes	C			DtC				
Downer-Aura complex, 5-10% slopes	C			DxC				
EVESBORO								
Sand, 0-5% slopes	A	EvB	EvB		EvB	EvB		EvB
Sand, 5-10% slopes	A		EvC			EvC		EvC
Sand, 10-15% slopes	A					EvD		EvD
Sand, loamy substratum, 0-5% slopes	A		EwB					
Sand, clayey substratum, 0-5% slopes	B	EwB						
Fine sand, 0-5% slopes	A		EyB					
HAMMONTON								
Loamy sand, 0-3% & 0-5% slopes	E	HaA			HaA	HaA		HaA
Loamy sand, clayey substratum, 0-2% slopes	E	HcA						
Sandy loam, 0-2% & 0-3% slopes	E	HmA			HbA	HbA		HcA
Sandy loam, 2-5% slopes	E					HbB		
Sandy laom, clayey substratum, 0-2% slopes	E	HnA						
KLEJ								
Sand, 0-4% slopes	D		KmA					
Sand, loamy substratum, 0-2% slopes	E		KnA					
Fine sand, 0-2% slopes	D		KoA					
Loamy sand, 0-2% & 0-3% slopes	D	KmA		KmA	KmA	KmA		KlA
Loamy sand, clayey substratum, 0-3% slopes	E	KnA						

APPENDIX A - continued: PINELANDS SOILS (UNITED STATES SOIL CONSERVATION SERVICE SOILS SERIES)

SOIL SERIES	Soil Grouping	Atlantic	Burlington	Camden	Cape May	Cumberland	Gloucester	Ocean
LAKEHURST								
Sand, 0-3% or 0-5% slopes	D	LaA	LaA	LaA		LaA	LaA	LhA
Sand, loamy substratum, 0-3% slopes	D		LmA					
Sand, clayey substratum, 0-3% slopes	D							LmA
Fine sand, 0-3% slopes	D		LnA					
Fine sand, loamy substratum, 0-3% slopes	D		LoA					
Sand, thick surface, 0-3% slopes	D		LlA					
Lakehurst-Lakewood association, 0-5% slopes	D			LbA				
Lakehurst-Lakewood sands, 0-5% slopes	D		LrA					
Lakehurst-Lakewood sands, loamy substratum, 0-5% slopes	D		LsA					
LAKEWOOD								
Sand, 0-5% slopes	A	LeB	LtB	LgB		LeB	LeB	LwB
Sand, 5-10% slopes	A	LeC	LtC	LgC				LwC
Sand, 10-15% slopes	A		LtD					
Sand, loamy substratum, 0-5% slopes	A		LvB					
Sand, thick surface, 0-5% slopes	A		LuB					
Fine sand, 0-5% slopes	A		LwB	LfB				
Fine sand, 5-10% slopes	A			LfC				
Fine sand, 10-25% slopes	A			LfD				
Fine sand, loamy substratum, 0-5% slopes	A		LyA					
Lakewood-Lakeland sands, 10-30% slopes	A			LhE				

APPENDIX A- continued : PINELANDS SOILS (UNITED STATES SOIL CONSERVATION SERVICE SOILS SERIES)

SOIL SERIES	SOIL GROUPING	ATLANTIC	BURLINGTON	CAMDEN	CAPE MAY	CUMBERLAND	GLOUCESTER	OCEAN
SASSAFRAS								
Loamy sand, 0-5% slopes	C		SfB				SfB	
Loamy sand, 5-10% slopes	C						SfC	
Sandy loam, 0-2%	C	SaA			SaA	SrA	SrA	
Sandy loam, 2-5% slopes	C	SaB			SaB	SrB	SrB	SaB
Sandy loam, 5-10% slopes	C						SrC	
Sandy loam, 5-10% slopes, eroded	C					SrC2		
Sandy loam, 10-15% slopes, severly eroded	C						SrD3	
Sandy loam, water table, 0-2% slopes	C				SbA			
Gravelly sandy loam, 0-2% slopes	C					SgA		
Gravelly sandy loam, 2-5% slopes	C					SgB		
Fine sandy loam, 0-2% slopes	C		SgA					
Fine sandy loam, 2-5% slopes	C		SgB					
Fine sandy loam, 5-10% slopes	C		SgC					
Fine sandy loam, clayey substratum, 0-2% slopes	B		ShA					
Fine sandy loam, clayey substratum, 2-5% slopes	B		ShB					
Soils, 10-15% slopes	C						SsD	
Soils, 15-40% slopes	C						SsE	
Sassafras-urban land complex	C		Sk					
Sassafras-urban land complex, clayey substratum	B		Sm					
POCOMOKE								
Sandy loam	G	Po		Ps	Ps	Ps	Ps	
Fine sandy loam	G		Pv					
Loam	G						Po	

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FINAL REPORT

STANDARDS AND CRITERIA FOR THE DESIGN AND MAINTENANCE OF ON-SITE WASTEWATER TREATMENT SYSTEMS

Prepared for the
NEW JERSEY PINELANDS COMMISSION

by
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March, 1980

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1.0 INTRODUCTION

Septic Systems have long been the standard means of wastewater disposal in unsewered areas. Their continued use in ever increasing densities is now coming into question, however, due to potential surface and groundwater pollution problems. Even with properly operating systems, undesireable levels of nitrogen and phosphorus may be released.

A variety of technical options are available for the treatment of household wastewater that can reduce the amount of nutrients released to the environment. None of these treatment systems have enjoyed the widespread use that septic systems have. As a result, comparatively little data is avaialble concerning system design and operation. The following sections of this report describe the available technologies and provide guidance concerning the design and maintenance of such systems.

The appropriateness of each option to a particular situation depends on several factors. The cost and management implications of each technology are discussed in the previous DSI report entitled "Assessment of Innovative and Alternative Technologies for On-Site Wastewater Disposal" (February, 1980). The water quality impacts associated with each treatment option are described in the accompanying DSI Report entitled "A Procedure for Evaluating Environmental Impacts of Alternative Technologies" (March, 1980).

2.0 SAND FILTERS

2.1 Treatment Objective

Traditionally the value of sand filters has been their ability to significantly reduce the BOD, suspended solids and bacteria levels of applied wastewaters. However, for use in individual on-lot treatment systems where effluent will ultimately be discharged to the ground, the value of sand filters lies in their ability to produce a nitrified effluent. This nitrification is a necessary conditioning step prior to nitrogen removal through anaerobic dentrification.

In addition to the essentially complete nitrification of the effluent, sand filters loaded with septic tank effluent are typically capable of reducing coliform levels by 95% (1,2,3), and reducing BOD and suspended solids concentrations to 10 mg/l or less (4,5). With specially selected filter media, phosphorus removals of 75-90% may also be achieved. During initial system start-up, effluent quality may be somewhat poorer due to short circuiting through the filter media. Once biological growth becomes established within the filter, however, effluent characteristics remain quite constant despite normal variations in influent flow rate or quality.

2.2 Treatment Process Description

A sand filter consists basically of an underdrained bed of sand through which wastewater is made to percolate. Treatment is provided by a combination of physical and biological processes which take place within the bed. The system functions essentially like a traditonal leaching system which has been constructed in a controlled environment.

When a sand filter is initially put into operation, the sand bed has uniform characteristics throughout its depth. Once the unit begins to receive wastewater, however, a stratified profile develops. At the surface of the soil where the wastewater is applied, suspended particles are strained out forming an organic mat. This layer, which develops to a depth of 3/4" to 1-1/2", tends to clog the soil pores and greatly reduce the permeability.

Below this clogging layer the sand remains quite permeable. Biological growth which develops in this portion of the filter acts to remove dissolved BOD and to nitrify the waste stream.

In a mature sandfilter, the applied wastewater ponds on top of the clogging mat and infiltrates slowly into the much more permeable underlying sand; as a result, the soil below the organic mat remain in an unsaturated, aerobic condition.

The thickness, permeability and rate of build-up of the clogging layer in sand filter depends on the volume and quality of the applied wastewater. For example, when aerobic treatment unit effluent (which has a low dissolved BOD) is applied, the clogging layer only develops to a depth of 3/4" to 1-1/2" (4,5).

At the loading rate that most sand filters are designed for, the clogging mat builds up at a faster rate than the microbial population can decompose it; as a result the mat becomes increasingly impermeable. Once the filter becomes clogged to point where wastewater is continuously ponded, the clogging mat grows quite rapidly (4,6). At this point, the infiltration rate may drop from a start up rate of over 500 gallons per day, per square foot, to less than 0.12 gallons per day, per square foot (4).

In sand filters designed for phosphorus removal, a combination of precipitation and adsorption reactions act to remove phosphorus from solution. The filter medias which can be used for this purpose include granular limestone, a sand mixture containing 10% alumina red mud, and a sand mixture containing 50% Clayer silt.

2.3 Design Considerations

As Figure 1 shows, a sand filter consists of a water tight container which holds an underdrained bed of sand.

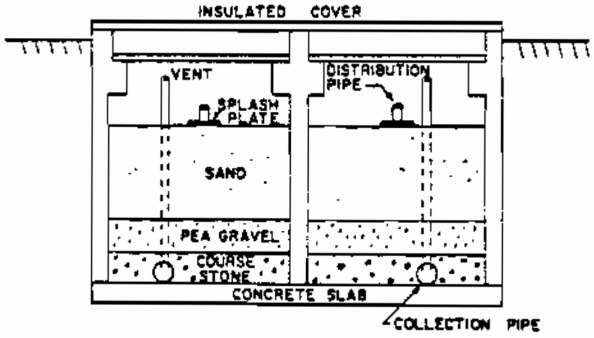


Fig. 1. Profile of Intermittent Sand Filter

The primary consideration in the design of a sand filter involves a trade off between the rate at which wastwater is applied to the surface of the sand, and the length of time that the filter can be expected to operate before cleaning is needed. In general, for wastewater of a given BOD and suspended solids concentration, the heavier the loading rate, the shorter the filter run will be. Typical loading rates fall in the range of 1-32 gallons per day, per square foot (gpd/ft^2) with resultant filter runs of from 30 to 150 days (4,5,7). The most commonly recommeded loading rate is 5 gpd/ft^2 (4,5,9,10).

As table 1 illustrates, the length of filter runs also depends on the effective grain size of the fitler sand. With effective sizes below 1.5 mm, effluent quality is reportedly not significantly affected once a clogging layer begins to form. Figure 2 illustrates the relationship among sand size, loading rate and length of filter run.

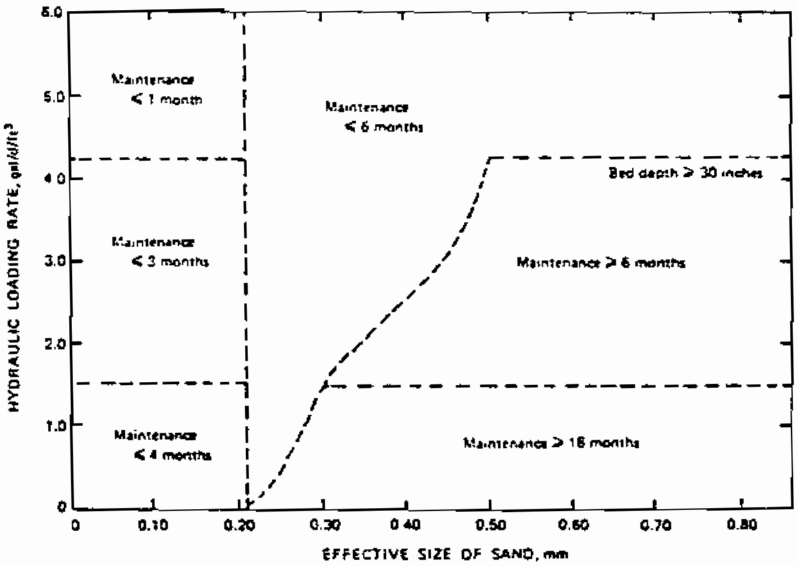
Table 1. Filter Run Lengths as a Function of Sand Size

Effective Size (mm)	Uniformity Coefficient	Filter Run Length (Days)
0.2	3-4	30
0.4	3	90
0.6	1.4	150

Source: Reference 4.

Figure 2

Trends in required maintenance of intermittent sand filters treating septic tank wastewater (avg. BOD,94 mg/l).



Source: Reference 9

The quality of the filter sand is an important consideration. Uniform grain size provides a media with a maximum amount of void space. For this reason highly uniform sand (coefficient of uniformity less than 3.5) has been recommended (8). McGauhey, however, suggests that the use of a graded filter (with particles ranging from pea gravel at the loading surface to medium sand within the fitler) will produce "clogging in depth" (11). This is a condition in which the clogging layer forms throughout the bed resulting in a higher infiltration rate for a given hydraulic and organic load. Sand depth of 24 to 36 inches have been shown to be effective at providing the expected level of treatment. The underlying 9 to 12 inches of gravel functions primarily as a drainage media rather than a site for further treatment. The underdrainage is generally collected by 4" diameter perforated drainage pipes. To ensure that aerobic conditions are maintained below the clogging layer, these drainage pipes are vented above the filter.

Since the filter sand eventually clogs to the point where infiltration rates fall below the wastewater loading rate, provision must be made for removing the clogging mat and resting the filter. For this reason, two identical filters are installed, so that one unit can be in operation while the second unit is resting. To permit maintenance access to the filter sand, the units must be equipped with large, removable covers. Insulation of the covers is necessary since wastewater may remain ponded above the filter for periods up to several hours. To accomodate surge flows, a storage space should be provided above the surface of the sand. A clear space of 12 inches will provide storage for about 150% of the daily design flow.

2.4 Maintenance Requirements

Sand filter maintenance is limited essentially to measures required to maintain acceptable infiltration rates. Generally, a filter is left in service until it becomes clogged to the point where it can no longer accept the applied waste load. The flow is then diverted to the second filter and the first filter is cleaned. Cleaning consists of the removal of the organic mat and replacing or raking the top 4-6 inches of sand. The cleaned unit must then be allowed to rest for 30-60 days to allow the sand to recover a sufficient infiltration capacity. Figure 3 illustrates the effect of maintenance on infiltration capacity.

Maintenance can be provided based on a calendar schedule (3 months service, 3 months rest for each filter unit) or on an as needed basis. Need for maintenance can be determined either through frequent visual inspection or through an automatic alarm system. Such an alarm system could consist of a flow detector installed in an overflow line connecting the two filter units at a height of 12 inches above the sand surface.

In sand filters designed for phosphorus removal, treatment effectiveness declines as the filter media becomes coated with organic matter. As a result, the media must be replace annually if phosphorus removal rates are to be maintained. (1,5).

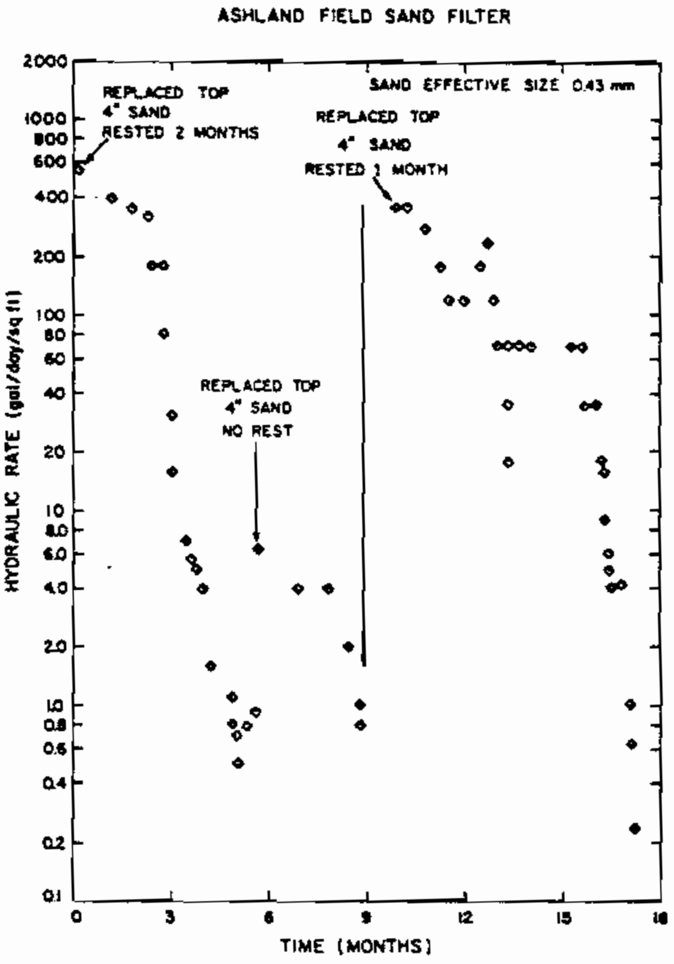


Figure 3 Effect of maintenance on sands loaded with septic tank effluent.

Source: Reference 5

2.5 Design Guidelines

The following guidelines are suggested for the design of sand filters as depicted in Figure 1.

A. The system should consist of identical dual filters each sized on a loading rate of 5 gallons per day, per square foot of surface area or 50 square feet per bedroom.

B. Filter media should consist of a 30" layer of washed sand with an effective grain size 1.0 to 1.5 mm with a coefficient of uniformity of less than 3.5.

C. The filter sand should be underlain by a 6" layer of washed pea gravel overlying a 6" layer of 1-1½" washed stone.

D. Underdrainage pipes should consist of 4" diameter perforated pipe vented above the filter surface.

E. The storage area above the surface of the sand should provide for 12" of liquid storage

F. The filter units should be burried to protect against freezing and equipped with insulated, removable covers.

G. The influent line should be equipped with a diversion valve and piping capable of delivering flow to either filter bed independently. A splash plate or similar energy disipation device should be provided at the loading surface to prevent erosion of the filter sand.

3.0 AEROBIC TREATMENT UNITS

3.1 Treatment Objective

Aerobic Treatment units have generally been used to treat household wastewater prior to discharge to a soil absorption system. When operating properly, such systems are capable of producing effluent with much lower BOD and suspended solids levels than are septic tanks. Effluent BOD less than 20 mg/l and suspended solids concentration below 40 mg/l are generally possible (5,12,13). The most important aspect of aerobic treatment from a groundwater quality perspective, however, is the essentially complete nitrification which takes place. This nitrification is a necessary pretreatment step prior to anaerobic denitrification. In addition to nitrification, certain aerobic units which employ cycled aeration can achieve 50% nitrogen removal through denitrification (5).

3.2 Process Description

Unlike conventional septic systems which are assembled on the site from stock components, aerobic treatment units are factory built units. The design of these units varies from one manufacturer to another, but they all rely on the same basic process - aerobic treatment.

Wastewater entering an aerobic unit flows first into an aeration chamber. Here, constant aeration maintains the aerobic environment necessary for aerobic decomposition. The waste then flows into a clarification chamber where the sludge is allowed to settle out. This sludge is then returned to the aeration chamber to keep the microbial population in this treatment chamber high.

A modification of this process involves cycled aeration in the treatment chamber rather than continuous aeration. In this type of unit, the wastewater is initially aerated to a point where nitrification is achieved. When the aeration cycle ends, anaerobic conditions develop and denitrification takes place.

3.3 Design Considerations

Aerobic treatment units are by nature much more complex treatment systems than homeowners are used to operating. They essentially duplicate the treatment processes employed at municipal treatment plants on a small scale. Unlike municipal facilities, however, trained operators are not always available to oversee aerobic treatment units. For this reason, the major design considerations focus on methods of protecting the system from upsets and of permitting long periods of unattended operation.

Each aerobic treatment unit manufacturer employs a slightly different design for the various components which make up the whole treatment system. This makes it difficult to evaluate the units in any way other than overall treatment performance. Fortunately, the treatment capabilities of a wide range of aerobic units have been tested under identical conditions and their performance judged according to set standards. This work has been performed by the National Sanitation Foundation (NSF). Their evaluation of each unit covers such items as structural integrity, servicability, performance under load, safety and effluent quality. Units are approved as meeting Class I or Class II standards based on the effluent characteristics in Table 2 (14).

TABLE 2

AEROBIC TREATMENT UNIT CLASSIFICATIONS

Effluent Quality	Class 1 Maximum Value*	Class II Maximum Value*
BOD, mg./l	20	60
Suspended Solids, mg./l	40	100

* Maximum value not to be exceeded more than 10% of the time.

In addition to the basic items covered in the NSF evaluation, several other design features have been found to be desirable. Use of a septic tank to pretreat the wastewater has been found to be useful in preventing grease and non-degradable solids from entering the treatment unit. The tank can also be used to store sludge wasted from the aerobic unit. Use of a heating element has helped prevent the problem of sludge bulking which can severely impede winter treatment capabilities. (5)

The electrical controls and alarm devices comprise an essential part of the treatment system. All electrical connections should be waterproof to prevent deterioration from the corrosive environment in which they operate. In addition, the main control panel should be located such that a maintenance person can gain access to it without the homeowner having to be home. (5,13)

3.4 Maintenance Requirements

Aerobic treatment units demand a substantially higher level of maintenance than do conventional septic systems. This maintenance is generally beyond the capability of the typical homeowner, and is often performed under contract by the manufacturer's service representative. Specific annual maintenance tasks typically include:

- measuring the mixed liquor suspended solids concentration
- pumping out the accumulated sludge
- cleaning the tank treatment chambers
- inspecting and lubricating the aeration unit, sludge return pump and other mechanical components
- inspecting and testing electrical and alarm systems.

Maintenance will be required both on a regular schedule (annual or semiannual) and as problems arise. Unscheduled maintenance may be called for when the treatment process is upset (due to overloading, introduction of toxics or sludge bulking) or when mechanical breakdowns occur (pump burn out, blown fuse etc.).

3.5 Design Guidelines

The following guidelines are suggested for the use of aerobic treatment units:

a. Treatment Units should be capable of meeting the design and performance criteria described in Standard No. 40 of the National Sanitation Foundation.

b. Treatment units should be installed in conformance with the manufacturers specifications. The installation should be inspected within 10 days after initial start up to verify proper installation.

c. Aerobic treatment units should be preceeded by a septic tank with a capacity of at least 50% of the daily design flow unless such pretreatment is contrary to the manufacturer's recommendation.

d. All electrical connections should be waterproof and easily accessible by service personnel.

e. The owner of an aerobic treatment unit should have a signed service contract with someone authorized by the manufacturer to perform routine and emergency maintenance.

4.0 DENITRIFICATION SYSTEMS

4.1 Treatment Objective

Denitrification systems are designed to remove nitrogen from a waste stream through the reduction of nitrate to nitrogen gas. Field demonstrations show that the concentrations of nitrite and nitrate can be reduced by 90% by this anaerobic, biological process (15).

4.2 Process Description

During denitrification, facultative heterotrophic bacteria reduce nitrites and nitrates to nitrogen gas. The process takes place under anaerobic conditions in an environment where carbon is available to be oxydized. Since the process only removes nitrogen that is introduced into the system in the nitrite or nitrate forms, it is essential that the influent wastewater be nitrified. The most likely sources of such a wastewater flow are the effluent from an intermittent sand filter or from an aerobic treatment unit. Since these effluents generally do not contain a sufficient amount of carbon to support the process, additional carbon in the form of methanol (CH_3OH) is often added.

The weight of methanol which must be added to a carbon deficient waste stream is determined by the following stoichiometric equation:

$$6\ NO_3- + 5CH_3OH \longrightarrow 3\ N_2 + 5\ CO_2 + 7\ H_2O + 6\ OH^-$$

This weight can be estimated based upon the characteristics of the wastewater being treated as shown in Table 3.

TABLE 3

METHANOL REQUIRED FOR DENITRIFICATION

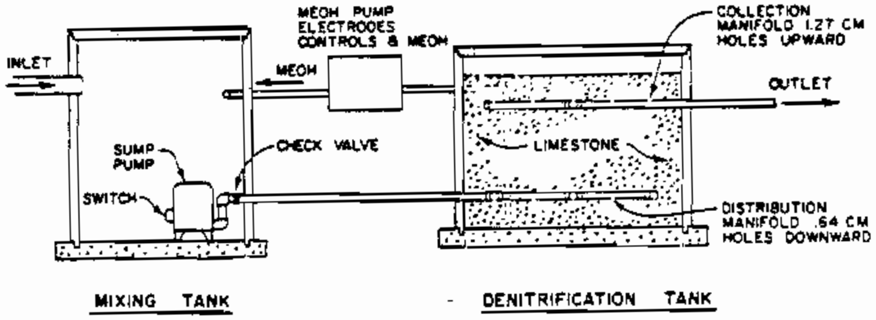
mg/l CH_3OH	per	mg/l of
2.47		NO_3-N
1.53		NO_2-N
0.87		D.O.

SOURCE: Innovative and Alternative Technology Assessment Manual, EPA, 1978

4.3 Design Considerations

The basic configuration of a denitrification system as depicted in Figure 4 consists of a methanol feed pump, a mixing tank/pump chamber, and an attached growth, upflow denitrification tank.

FIGURE 4



DENITRIFICATION SYSTEM

Operation of the system is controlled by a series of automatic timers and pumps. Wastewater entering the mixing tank triggers the methanol feed pump. This unit then injects a measured dose methanol into the mixing tank. The sump pump then pumps a mixture of nitrified wastewater and methanol into the denitrification tank. An equal volume of denitrified wastewater is displaced from the system and flows out of the denitrification tank through the collection manifold.

The hydraulic design for the system is based primarily on the detention time within the denitrification tank. The effect of residence time on nitrogen removal can be seen in Sikora's data (15) from a system in Wisconsin presented in Table 4. Here it can be seen that significant nitrogen removals were achieved with both 24 and 12 hour residence times.

TABLE 4. Nitrogen Concentrations (mg/l) for Influent into and Effluent from the Denitrification Unit.

	Influent			Effluent		
Date	Org N	NH_4^+-N	NO_3^- + NO_2^--N	Org N	NH_4^+-N	NO_3^- + NO_2^--N
8/28/75[a]	1.2	0.1	33.1	<0.1	0.1	25.8
8/04/75	21.7	0.1	35.3	3.9	0.1	12.7
8/11/75	0.8	0.6	56.2	0.1	0.2	6.9
11/07/75	0.1	0.1	16.4	<0.1	0.1	<0.1
12/06/75	0.2	3.6	9.2	1.5	<0.1	<0.1
6/03/76[b]	2.7	2.9	18.4	1.0	0.1	0.1
6/30/76	<0.1	0.1	26.0	0.7	0.1	0.6
7/02/76	<0.1	0.1	29.2	0.7	0.1	2.8
7/07/76	---	0.1	28.8	1.9	0.1	2.8
7/27/76	---	<0.1	36.4	1.0	<0.1	6.4
7/28/76	---	<0.1	32.7	1.4	<0.1	6.3
8/10/76	---	<0.1	29.6	1.0	<0.1	2.2
8/17/76	---	<0.1	34.8	1.4	<0.1	5.9

[a] 24 h residence time used in 1975
[b] 12 h residence time used in 1976

The media upon which the denitrifying growth develops is a gravel with a minimum diameter of 15 mm. This size permits adequate surface area without problems of clogging.

Methanol requirements can be estimated from the data in Table 3. Assuming that the unit is loaded with the effluent from a septic tank sand filter system which has a nitrate concentration of 40 mg/l and 3 mg/l of dissolved oxygen, approximately 45 ml of 30% methanol solution must be added per 100 liters of wastewater.

As with other wastewater treatment systems, the denitrification system must be buried to prevent freezing. Other considerations include the fact that the denitrification media must be kept anaerobic to maintain the microbial population. To ensure this, the denitrification tank must be watertight and the distribution manifold must be equipped with a check valve to prevent liquid from draining back into the pump chamber.

4.4 Maintenance Requirements

Maintenance requirements for a denitrification system include replenishment of the methanol supply, and inspection and maintenance of the pumps and check valve. A typical four member household discharging effluent of the quality described above would use approximately 25-30 gallons of 30% methanol.

If effluent from an aerobic treatment unit is discharged into the system, the added BOD and suspended solids loading can be expected to cause an accumulation of sludge within the denitrification tank. While experimental data on this possible problem is lacking, sludge removal and possibly backwashing of the filter media may be required.

4.5 Design Guidelines

Based on the system configuration depicted in Figure 4, the following guidelines are suggested for the design of denitrification systems:

a. Methanol feed equipment should be designed in accordance with Table 3. For typical sand filter effluent this would be a rate of 45 ml of 30% methanol per 100 liters of the daily loading rate.

b. Mixing tank volume should be between 50% and 100% the daily loading rate.

c. The denitrification tank should be a watertight container with a volume at least 300% of the daily loading. The tank should be filled with washed stone of 15-30 mm size.

d. The system should be equipped with alarms to signal pump failure or exhaustion of the methanol supply.

5.0 AMMONIA ADSORPTION

5.1 Treatment Objective

The ammonia adsorption process is designed to reduce the total nitrogen concentration of wastewater by removing ammonia through ion exchange. When wastewater containing ammonia nitrogen is passed through a bed of clinoptilolite, a naturally occuring zeolite, over 90% of the ammonia may be removed (10,17).

5.2 Process Description

Ion exchange is a process in which ions in solution are physically exchanged for ions of a like charge which are in a solid phase. The process is reversible in that once the solid exchange media has lost most of its exchangeable ions, it can be regenerated through treatment with a concentrated solution containing exchangeable ions. Thus the ion exchange media can be regenerated and reused in a cyclical treatment process.

For the removal of ammonia from wastewater, the most attractive ion exchange resin is clinoptilolite. This naturally occuring material has a preference for ammonium ions over most other ions commonly found in wastewater including calcium and sodium. Nitrogen in forms other than ammonia are unaffected by the material. Once the resin has reached its ammonia soption capacity, it can be regenerated by treatment with a lime slurry or salt brine. In this process, the calcium or sodium ions in solution are exchanged for the ammonium ions held by the resin. When the resin is reused, the calcium or sodium ions will enter into solution in the wastewater stream as ammonia is removed. (18)

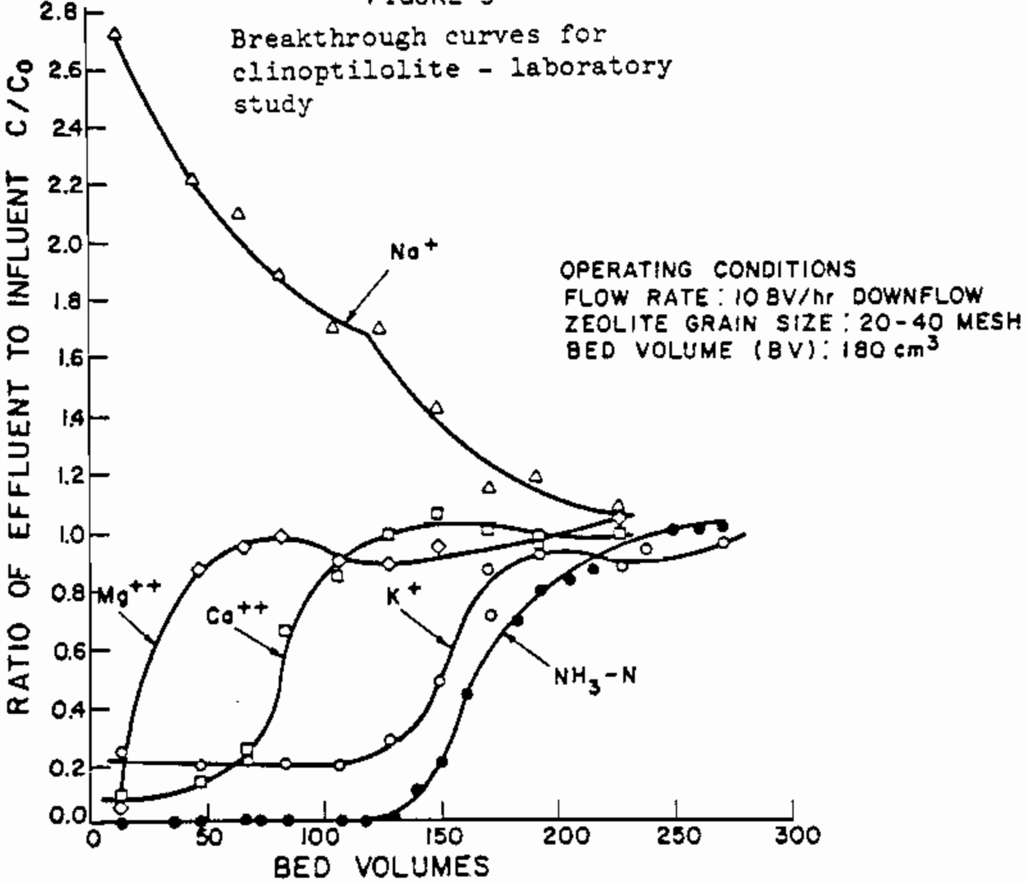
By removing ammonia from the regenerating solution (by ammonia stripping or other processes), the solution can be reused. Thus a cyclical process of ion exchange and regeneration can be established.

5.3 Design Considerations

To date, most field demonstrations of ammonia removal using clinoptilolite have been large (100,000 gpd) municipal scale applications in which ammonia is removed from secondary treatment plant effluent (18). Laboratory experiments, however, have demonstrated the technical feasibility of treating septic tank effluent (5, page A - 237).

The ion exchange unit consists simply of a filter bed packed with granular clinoptilolite (20 x 40 mesh) through which wastewater is passed. When loaded with septic tank effluent (33 mg /l of NH_4-N) at a rate of ten bed volumes per hour, nearly complete ammonia removal is achieved over a total loading of approximately 150 bed volumes. At this point, breakthrough develops rapidly (5,17). Figure 5 shows the breakthrough curves for ammonia and the other ions contained in septic tank effluent.

FIGURE 5



Breakthrough curves for clinoptilolite - laboratory study

SOURCE: Management of Small Waste Flows
EPA - 600/2-78-173, September, 1978

Clogging of the exchange media with organic matter was observed to coincide with ammonia breakthrough. When the resin was regenerated with a salt solution, the organic material was effectively washed off.

Based on an average household wastewater flow of 200 gallons per day and a treatment capacity of 150 bed volumes prior to breakthrough, a total bed volume of approximately 500 gallons of clinoptilolite would be required to provide one year of treatment.

5.4 Maintenance Requirements

The primary maintenance requirement for an ion exchange unit is the periodic regeneration of the resin. This involves the circulation of approximately 30 bed volumes of salt or lime solution through the exchange media. No practical, on-lot regeneration systems have been demonstrated. Centralized regeneration facilities and the use of modular exchange columns, however, have been proposed (5).

5.5 Design Guidelines

Sufficient operational data on home scale ammonia removal systems treating septic tank effluent is not available to allow the setting of design standards. Any such systems should be considered experimental. However, the following general rules appear reasonable in light of existing data:

a. The wastewater should be applied evenly to the ion exchange column or bed at a rate of not more than 10 bed volumes per hour.

b. The column or bed should be packed with granular clinoptilolite (20 x 40 mesh)

c. Provision should be made for replacement or regeneration of the resin after approximately 150 bed volumes of treatment.

6.0 ALUM ADDITION

6.1 Treatment Objective

The addition of alum to household wastewater is designed to remove dissolved phosphorus through the formation of an insoluble precipitate. Depending on the amount of alum added, 90% of the phosphorus may be removed. In addition, the removals of coliform bacteria, BOD and suspended solids are higher in septic systems to which alum is added than in conventional septic tanks (19).

6.2 Treatment Process

Phosphorus removal through alum addition consists simply of the injection of a solution of alum (aluminum sulfate) into the household wastewater prior to its entry into a conventional septic tank leaching field system. The alum combines with phosphate in the wastewater to form aluminum phosphate, a solid precipitate which settles to the bottom of the septic tank. This reaction is described by the following stoichiometric equation:

$$Al_2\,(SO_4)_3 + 2PO_4 \longrightarrow 2\,AlPO_4 + 3SO_4$$

This indicates that 0.87 g of aluminum must be added to precipitate 1.0 g of phosphorus. In practice, however, the reaction depends upon the ratio of aluminum to phosphorus. Experience has shown that a ratio of 2.0 is necessary to achieve good phosphorus removal. This is equivalent to an alum concentration of approximately 430 mg/l (19).

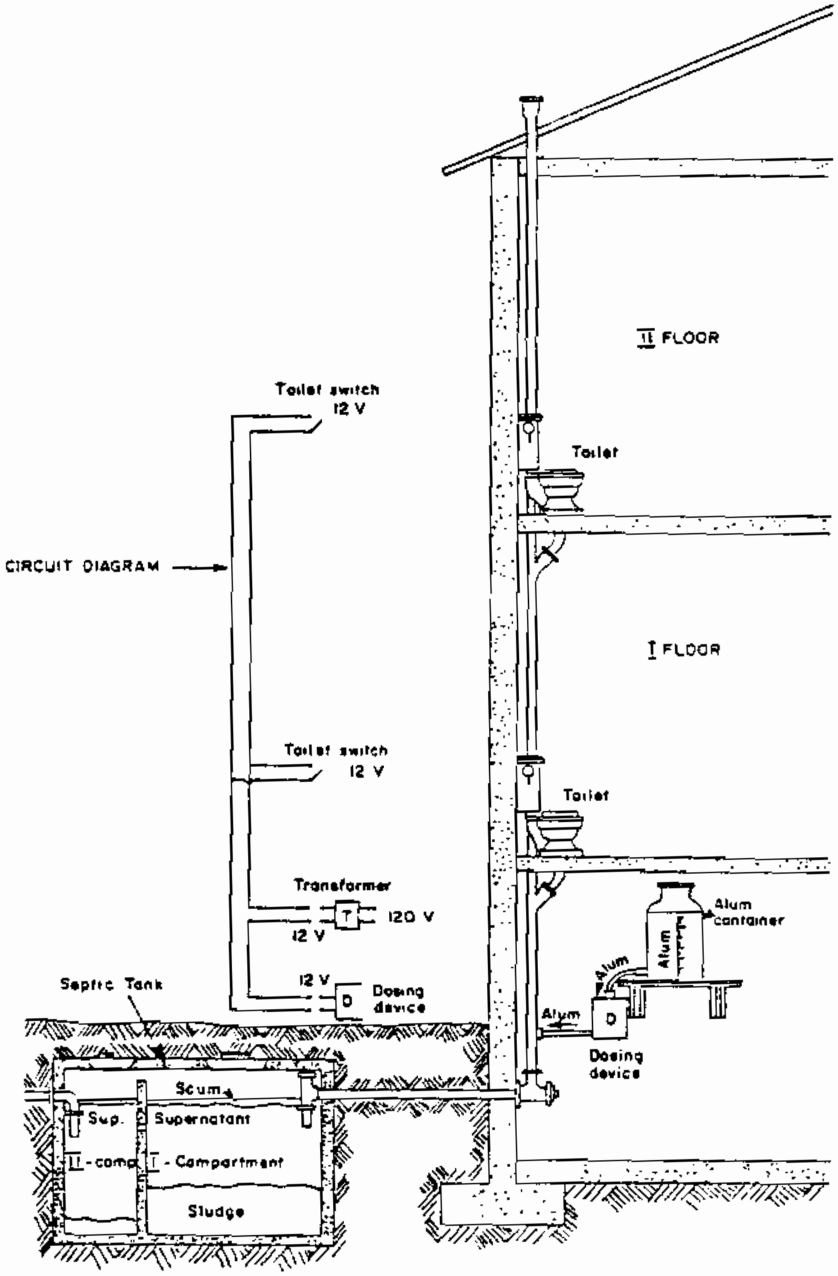
In addition to aluminum phosphate, the addition of alum to wastewater causes the formation of other precipitates including iron and calcium containing compounds. These materials also settle out into the septic tank and add to the accumulating sludge. The addition of alum also leads to an increase in sulfate concentration in both the sludge and the septic tank effluent.

6.3 Design Considerations

The alum addition system evaluated by Brandes (19) is shown in Figure 6. It consists simply of a chemical feed pump which discharges a measured dose of alum into the house sewer each time a toilet is flushed. Ideally, it would be desirable to add alum in proportion to the amount of phosphate being discharged. In practice, however, it is much simpler to add the alum in proportion to the wastewater flow assuming an average phosphate concentration. A single daily dose of alum flushed down the toilet was found to provide a lower level of phosphorus removal due to a lack of mixing with the septic tank contents. For this

Figure 6

ALUM ADDITION SYSTEM



7.0 COMPOST TOILETS

7.1 Treatment Objective

Compost toilets, like other non-discharge toilets, do not produce any liquid effluent. As a result, the wastewater leaving a household has substantially lower levels of BOD, suspended solids, backteria, phosphorus and nitrogen. The substitution of compost toilets for conventional flush toilets can be expected to reduce the flow by 30-40%, BOD by 25%, total nitrogen by 75-80%, total phosphorus by 30-35% and suspended solids by 35-40%.

7.2 Treatment Process

The compost or humus toilet allows for the aerobic biological decomposition of wastes deposited in a chamber to produce a humus-like material. Compost toilets work on the principle of optimizing the aerobic biological decomposition process that occurs when manure is plowed into soil. Two types of compost toilets exist - the small electrically assisted unit and the larger non-electrically assisted unit. The smaller units attempt to operate in the thermophilic composting process temperature range while the larger units operate in the lower mesophilic composting process temperature range. The smaller units fit easily in the space required for a conventional toilet, while the larger units usually have a collection chamber in the basement where kitchen scraps (replacing a garbage grinder) and lawn clippings can also be added. The smaller units require a heat source (usually electric heating coils) for maintenance of the 140° - 160° thermophilic compost temperature and evaporation of excess liquids. After one year a family of four will produce about 3 - 10 gallons of stabilized compost, removed quarterly, which can be used as a garden mulch or soil additive, although it is recommended that the compost be buried as a public health precaution and for further breakdown. The larger compost toilet requires about a year to stabilize and the resulting compost product needs to be removed annually.

7.3 Design Considerations

Compost toilets are complete, factory built units. As a result, the factors related to proper performance which can be controlled are limited to system installation and operation. These factors, however, can make a great deal of difference in how well the unit operates.

As with all wastewater treatment systems it is important that compost toilets be sized according to the expected loading. Manufacturer's recommendations concerning the number of people to be served by each unit must be observed if overloading problems are to be avoided.

reason, smaller, more frequent doses keyed to toilet flushing was employed.

The addition of alum to a septic system approximately doubles the rate of sludge accumulation. As a result a larger sludge storage volume is required if the interval between tank pumpouts is to remain constant.

6.4 Required Maintenance

Maintenance of the alum addition system consists of inspecting lubricating and cleaning the dosing pump, inspecting the wiring, replenishing the alum supply and pumping out the septic tank as needed. Based on a 96% phosphorus removal target, a typical four member household can expect to use about 175 pounds of dry alum per year. The long term impacts (if any) of alum addition on leach field performance and maintenance requirements are unknown.

6.5 Design Guidelines

The following guidelines are suggested for the design of alum addition systems for phosphorus removal:

a. Alum should be added to the wastewater at a rate of approximately 430 mg/l.

b. The system should provide for adequate mixing of the alum and wastewater either through the injection of small doses into the house sewer or the use of a mixing tank.

c. Provision should be made for regular replenishment of the alum supply and removal of the septic tank sludge.

8.0 GREYWATER TREATMENT

8.1 Treatment Process and System Design

Greywater may be treated by essentially any of the techniques appropriate for treatment of normal household wastewater. The simplest and most common technique is the use of a conventional septic system sized in proportion to the expected greywater flow.

A modification of the standard septic system is to replace the septic tank with an aerobic rock filter. This unit which is similar to a trickling filter, consists of a gravel filled column through which the greywater is allowed to percolate. Filter clogging and sludge buildup may occur if the unit treats greywater containing garbage grinder waste.

The suggested method for basic greywater treatment is the use of a conventional septic system. The septic tank should be the same size as required for normal wastewater. This will provide for some attenuation of surge flows associated with such greywater sources as washing machines, bathtubs and dishwashers. The soil absorption system may be reduced in size by 40% due to the decreased hydraulic and organic load that the system must handle.

Commercial greywater treatment and reuse for toilet flushing systems exist which utilize cartridge filters and chlorine disinfection. Such systems can also be custom designed and built.

Two important concerns related to the installation of compost toilets are the provision of adequate venting and liquid drainage. Venting is necessary to maintain the aerobic composting environment, to prevent odors from entering the home, and to increase the evaporation of liquids. A liquid drainage system should also be provided to remove excess liquids from the unit should they accumulate.

7.4 Maintenance Requirements

The maintenance required by a compost toilet is generally minimal. It consists of the inspection (and repair as needed) of mechanical components such as ventilation fans and the periodic removal of the compost product. Some units also require the regular addition of bulking materials such as kitchen scraps or lawn clippings for optimal performance.

7.5 Design Guidelines

a. Compost toilets should be installed in conformance with manufacturers recommendations concerning the number of people to be served by each unit.

b. Each compost toilet should be installed with ventilation to the outdoors and a system for liquid drainage, unless alternate measures are recommended by the manufacturer.

c. Provision should be made for the periodic removal and burial of compost product.

9.0 SOIL TESTS FOR EFFLUENT DISPOSAL

9.1 Soil Test Objectives

The percolation test and similar methods of soil evaluation have been developed in an attempt to judge the ability of a particular soil to accept effluent applied through a leaching system. The basic assumption underlying these test procedures is that the ability of a soil to conduct clean water during a short testing period can be used to predict the soil's behavior when loaded with septic tank effluent over long periods of time.

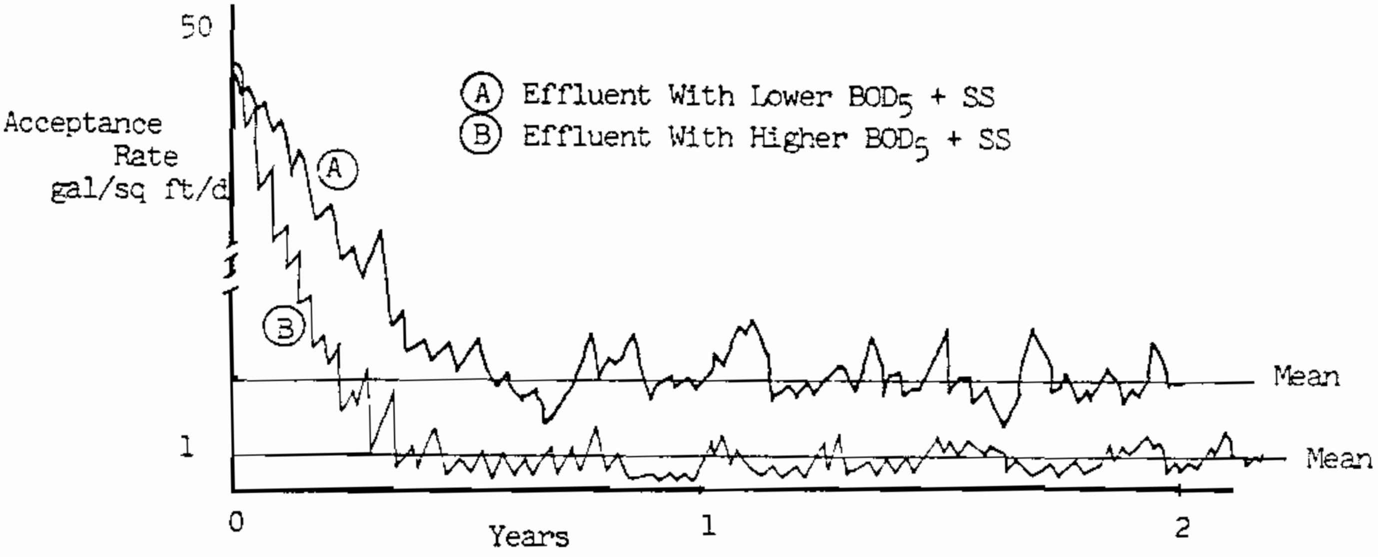
The value of a valid method for sizing soil absorption systems is clear. It would allow such systems to be designed with confidence that they would not fail du to soil clogging. Needless oversizing of leaching facilities could also be avoided.

9.2 Percolation Tests

Since its development in New York State in 1926, the percolation test has been widely adopted as the best method of sizing soil absorption systems. The test consists basically of measuring the rate at which water soaks into the soil from a one foot diameter hole. Since the water seeps into the soil laterally through the sides of the hole as well as vertically down through the bottom of the hole, the observed perc rate is a combined measure of horizontal and vertical infiltration rates. In most soils, the horizontal and vertical permeabilities are not equal. In these cases, a perc rate will not accurately reflect either value.

It was originally believed that the behavior of a given soil when loaded with clean water could be used to predict that soil's behavior when loaded with wastewater effluent. This belief has come into serious question, however, in light of recent research on leach field and sand filter clogging. It has been determined that the mechanisms of wastewater infiltration into soil absorption system are significantly different from the infiltration of clean water into the soil. While the rate of infiltration of clean water into the soil is controlled by the physical characteristics of the soil (grain size distribution, etc.) the rate of infiltration of wastewater into the soil soon becomes limited by the permeability of the organic mat that develops (11,20,21,22). The infiltration rate through this clogging layer appears to be relatively independent of the infiltration rate through the underlying soil. The permeability of the clogging layer seems to depend on the organic loading rate applied to the soil (4,5,23). Thus the long term rate at which a soil will allow the infiltration of wastewater will depend at least in part on the quality of the liquid applied. (This characteristic is illustrated in figure 7 (23.). Any equilibrium infiltration rate of 1.0 to 1.5 cm per day through natural clogging layers has been widely reported (5,11,20).

Figure 7



ACCEPTANCE RATE OF CLOGGING SOILS

In addition to the perc test's inability to predict infiltration rates following the development of a clogging layer, the test can also give highly variable results under apparently similar conditions. This variability can result from many factors including the following:

- natural soil variations
- variations in geometry among perc holes
- compaction of the soil infiltrative surface during preparation of the test hole
- variations in the depth of water in the test hole
- variations in the pre-soaking routine followed prior to the perc test

The highly variable nature of perc tests was demonstrated by Winneberger. He selected nine locations within a 4,700 square foot plot and had three engineering companies perform perc tests at each location in test holes located 20 to 33 inches apart. The results of this demonstration are presented in Table 5.

TABLE 5
COMPARATIVE PERCOLATION RATES AT NINE SITES
(minutes/inch)

SITE	FIRM #1	FIRM #2	Firm #3
1	23	118	37
2	15	59	172
3	2	15	32
4	130	91	161
5	5	59	73
6	2	12	24
7	3	39	229
8	4	22	34
9	19	63	259

9.3 Alternatives to Percolation Tests

Acknowledging the limitations of perc tests, investigators have suggested a wide range of alternative methods for evaluating the suitability of soils for effluent absorption. These methods generally fall into one of two categories - field measurement techniques or soil classification techniques.

Field measurement techniques include both the refinement of standard perc test procedures in an attempt to standardize results as proposed by Peterson (25), and techniques designed to directly measure soil properties in different ways. This second group of measures includes simple procedures which could replace perc tests in common usage and very sophisticated procedures requiring trained specialists.

The shallow well pump-in method, the double-ring infiltrometer method and the auger-hole method are three techniques suggested by Fritton (26) as possible replacements for the perc test in every day use. Each of these methods provides a measure of the hydraulic conductivity of the soil. Like the perc test, however, they do not predict how an organic clogging layer may change the soil's characteristics.

More sophisticated methods of measuring soil properties include crust tests and soil tensiometry. The purpose of such tests is to simulate the clogging layer and measure the reaction of the soil directly. While such tests may provide much more directly useful information than do perc tests, their complexity precludes their widescale use.

It has been suggested that because of the major effect that organic clogging has on soil behavior, detailed knowledge of soils is not always necessary. Kropf for example suggests that an infiltration rate of 0.2 to 0.5 gpd/ft^2 is appropriate for the design of soil absorption systems in a wide range of soils (27). Bouma proposes the division of soils into four basic groups based on in situ measurements of their performance under clogging conditions (28). An infiltration rate would then be specified for each group. Such a classification system would greatly simplify the design of soil absorption systems if it were available.

9.4 Discussion

It is clear that the standard percolation test leaves much to be desired both in terms of its ability to produce consistent results under similar conditions and in terms of its ability to predict soil characteristics after loading with wastewater begins. The fact that the perc test ignores the dominant role which the organic clogging layer assumes in the infiltration of effluent into the soil would appear to be a major limitation of the technique.

The precise nature of clogging layers is much in question. The extent to which the infiltration rates of these layers depends on effluent quality, hydraulic loading, soil texture, and absorption trench design is not well known. Thus it may be possible to develop clogging layers with various equilibrium infiltration rates depending on the design criteria used. However, presently available data suggests that clogging layers commonly have infiltration rates in the range of 0.5 to 1.5 gpd/ft^2.

If leach field failures are occuring due to underdesign, the problems would be expected to be most pronounced in sandy soils where present regulations permit the use of smaller systems. For systems built on the most permeable soils (5 minutes per inch or less percolation rate), these regulations require only 70 square feet of trench bottom area per bedroom. If the trench design provides one square foot of sidewall for each square foot of bottom area, a total of 140 square feet of infiltrative surface will be provided per bedroom. At the design flow of 200 gallons per day, per bedroom, an infiltration rate of at least 1.4 gpd/ft^2 would be required. This rate is marginally within the range of reported values. It is possible therefore, that certain heavily loaded absorption systems located in sandy soils are failing due to the limited infiltration capacity of the clogging layer. A survey of failures located on sandy soils would be required, however, to determine if such problems are actually the result of underdesign due to perc test results.

REFERENCES

1. Brandes, M. Chowdhry, N.A., and Cheng, W.W., "Experimental Study on Removal of Pollutants from Domestic Sewage by Underdrained Soil Filters" in Proceedings, National Home Sewage Disposal Symposium, ASAE, December, 1974.

2. Ziebell, W.A. et al, "Use of Bacteria in Assessing Waste Treatment and Soil Disposal Systems" in Proceedings, National Home Sewage Disposal Symposium, ASAE, December, 1974.

3. Converse, J.C., Et al, "Pressure Distribution to Improve Soil Absorption Systems" in Proceedings, National Home Sewage Disposal Symposium, ASAE, December, 1974.

4. Sauer, D.K., Boyle, W.C., "Intermittent Sand Filtration and Disinfection of Small Wastewater Flows" in Proceedings, National Home Sewage Disposal Symposium, ASAE, December, 1974.

5. University of Wisconsin, Management of Small Waste Flows, EPA-600/2-78-173, September, 1978.

6. Otis, R.J., Et al, "Effluent Distribution" in Proceedings, Second National Home Sewage Treatment Symposium, ASAE, December 1977.

7. Otis, R.J., Boyle W.C., and Sauer, D.K., "The Performance of Household Wastewater Treatment Units Under Field Conditions" in Proceedings, National Home Sewage Disposal Symposium, ASAE, December, 1975.

8. Hines, M.W. B ennett, E.R. and Hoehne, J.A., "Alternate Systems for Effluent Treatment and Disposal" in Proceedings, Second National Home Sewage Treatment Symposium, ASAE, December, 1977.

9. U.S. EPA Technology Transfer, "Alternatives for Small Wastewater Treatment Systems", EPA-625/4-77-011, October, 1977.

10. U.S. EPA Municipal Environmental Research Laboratory, "Innovative and Alternative Technology Assessment Manual", EPA-430/9-78-009, 1978.

11. McGauhery, P.H. and Krone, R.B., Soil Mantle as Wastewater Treatment System, University of California, Berkeley - SERL Report No. 67-11, December, 1967.

12. Krebs, Robert J., "Sizing, Design and Application Factors in Home Sewage Treatment Systems" in Proceedings, National Home Sewage Disposal Symposium, ASAE, December, 1974.

13. Hutzler, N.J., "Performance of Aerobic Treatment Units" in Proceedings, Second National Home Sewage Treatment Symposium, ASAE, December, 1977.