DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Water Supply and Wastewater Management

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TITLE:	Impact of the Use of Subsurface Disposal Systems on Groundwater Nitrate Nitrogen Levels
EFFECTIVE DATE:	December 29, 1997 Minor edits were made throughout (August 27, 2002) Minor edits were made on pages i, 6, 8, and 9 (March 31, 2003)
AUTHORITY:	Pennsylvania Sewage Facilities Act, Section 3(6) and Section 10(6) 35 P.S. §§705.3(6) and 750.10(6)
POLICY:	The Department of Environmental Protection (DEP) shall publish technical guidance and cooperate in studying and evaluating new methods of sewage disposal in continuing support of the policy goals set by the Pennsylvania Sewage Facilities Act 537.
PURPOSE:	The Department of Environmental Protection (DEP) shall supplement the information incorporated into Title 25 Pennsylvania Code Chapter 71, as needed.
APPLICABILITY:	This guidance applies to consideration of onlot wastewater disposal systems and consideration of the use of denitrifying technologies, as and where they apply.
DISCLAIMER:	The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements. The policies and procedures herein are not an adjudication or regulation. There is no intent on the part of DEP to give these rules that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.
PAGE LENGTH:	15 pages
LOCATION:	Volume 33 Tab 26

I. GENERAL

A. Use of onlot subsurface disposal systems and community onlot subsurface disposal systems requires extensive site evaluation. These systems are dependent upon a very sensitive system of physical, chemical and biological processes in the soil and groundwater to renovate and dispose of sewage.

A number of onlot system proposals anticipate flows in excess of 10,000 gallons per day or have a density of more than one EDU per acre. These proposals may be located in areas where existing groundwater contamination levels or the geology would preclude the use of such systems. Additional planning information relating to siting these systems may be required including:

1. site specific soil profiles and percolation testing;

2. additional permeability testing; and

3. hydrogeologic studies

B. The use of high individual onlot system density or high volume community onlot occurs in Pennsylvania because these systems may be more cost-effective than other conventional treatment technologies in many situations. Additionally, the cost of operating and maintaining these systems can be lower and less energy demanding than conventional sewered collection and treatment systems.

C. This use has caused continued concern about a problem inherent in these systems. The systems release high volumes of treated effluent to local groundwater. This effluent can cause nitrate nitrogen (NO_3-N) concentrations in groundwater which exceed the upper limit of 10 ppm established for drinking water supplies.

D. This fact limits the use of subsurface system technology unless specific procedures are understood and implemented. The purpose of this paper is to discuss the nitrate nitrogen problem and the DEP policies and procedures which have been developed to protect water supplies from the potentially detrimental groundwater effects generated by subsurface disposal systems. Supporting documents pertaining to specific issues in this paper are listed in the bibliography.

II. PUBLIC HEALTH SIGNIFICANCE OF NITRATES IN DRINKING WATER

A. The U.S. Public Health Service first proposed nitrate limitations as part of drinking water standards in 1962. The EPA's National Primary Drinking Water Regulations, published in 1997, continues to set 10 parts per million (ppm)[1] nitrate nitrogen as the upper limit for drinking water. The documents base this limit on studies conducted from 1945 through 1975, as well as later confirming studies, in which infant cyanosis caused by methemoglobinemia was linked with high concentrations of nitrate nitrogen in potable water supplies.

B. Three factors make infants less than 6 months of age more susceptible to cyanosis than adults:

1. Liquid intake is three times higher than adults per unit of body weight.

2. Gastric pH is 5-7. This is a range at which nitrate reducing bacteria thrive.

[1] For purposes of this discussion, 1 ppm is equivalent to 1 milligram per liter (mg/l)

3. Fetal hemoglobin F is more susceptible to the formation of methemoglobin than is adult hemoglobin A.

C. In infants drinking water having greater than 10 ppm nitrate nitrogen, the nitrate reducing bacteria in the intestine can convert nitrates to nitrites. These nitrites change the hemoglobin in the infant's blood stream to methemoglobin. Hemoglobin carries oxygen to the cells of the infant's body. Methemoglobin cannot carry oxygen. If enough hemoglobin is converted to methemoglobin, cyanosis and oxygen deprivation occurs. Death has been attributed to nitrate concentration in water of less than 40 ppm. The existence of this process is supported by studies that have shown elevated levels of methemoglobin in the blood stream of infants experiencing cyanosis after consuming water containing high nitrate levels (10 ppm).

D. As a result of this potential public health problem, the EPA has retained the limit of 10 ppm for nitrate nitrogen in drinking water. Public water supplies having concentrations in excess of this amount may be required to seek alternative water sources, treat water to remove excess nitrates and notify the public of the health hazards associated with such nitrate levels. These National Primary Drinking Water Regulations do, however, allow noncommunity water supplies to be used with up to 20 ppm nitrate nitrogen if the state provides control measures (notification of physicians and public notice).

III. SUBSURFACE DISPOSAL SYSTEMS AND NITRATE GENERATION

A. The sequence of events that releases nitrates in a subsurface disposal system is shown in figure 1. It is as follows:

1. Toilet wastes which contribute 78 to 90 percent of the nitrogen generated by a household, enter the septic tank as urea, uric acid, ammonia, proteinaceious food stuff, and bacterial cells. In the septic tank, these materials undergo anoxic microbial decomposition with the aid of enzymes such as protease and urease. As a result, these materials are broken down to more basic products. About 75% becomes dissolved ammonia (NH_3) and ammonium (NH_4^+) and 25% becomes dissolved organic nitrogen. The effluent liquid leaves the septic tank to enter the subsurface absorption area

2. Upon entering the soil the remaining organic nitrogen is converted to ammonia. Some of the ammonia and ammonium, in a water solution, undergoes adsorption on soil particles through anion/cation exchange until equilibrium occurs. Excess ammonium ions remain in an available form for continued aerobic nitrification as these leach through the soil. Through the action of bacterial agents, such as Nitrosomonas, the ammonium ion is broken down to nitrite nitrogen:

   $$2\ NH_4^+ + 3\ O_22 \rightarrow 2\ NO_2 + 4H^+ + 2H_2O$$

   Nitrite nitrogen is further broken down through the action of Nitrobacter bacterium to nitrate nitrogen:

   $$2\ NO_2 + O_2 \rightarrow 2\ NO_3$$

3. If the soil and groundwater have the normal presence of oxygen this nitrate nitrogen remains unchanged in the groundwater aquifer.

B. Nitrate nitrogen loading of groundwater is more critical than such loading for surface water for several reasons:

1. Rapid dilution and mixing occurs in surface waters. Dilution and mixing of groundwater occurs more slower. The rate of this mixing is more difficult to estimate.

2. Use of nitrates as food by aquatic plants occurs rapidly in surface waters. Assimilation of nitrates does not occur in groundwater.

3. Essentially all nitrogenous materials entering subsurface disposal systems ultimately converts into nitrate nitrogen. This nitrate nitrogen does not break down in normal groundwater.

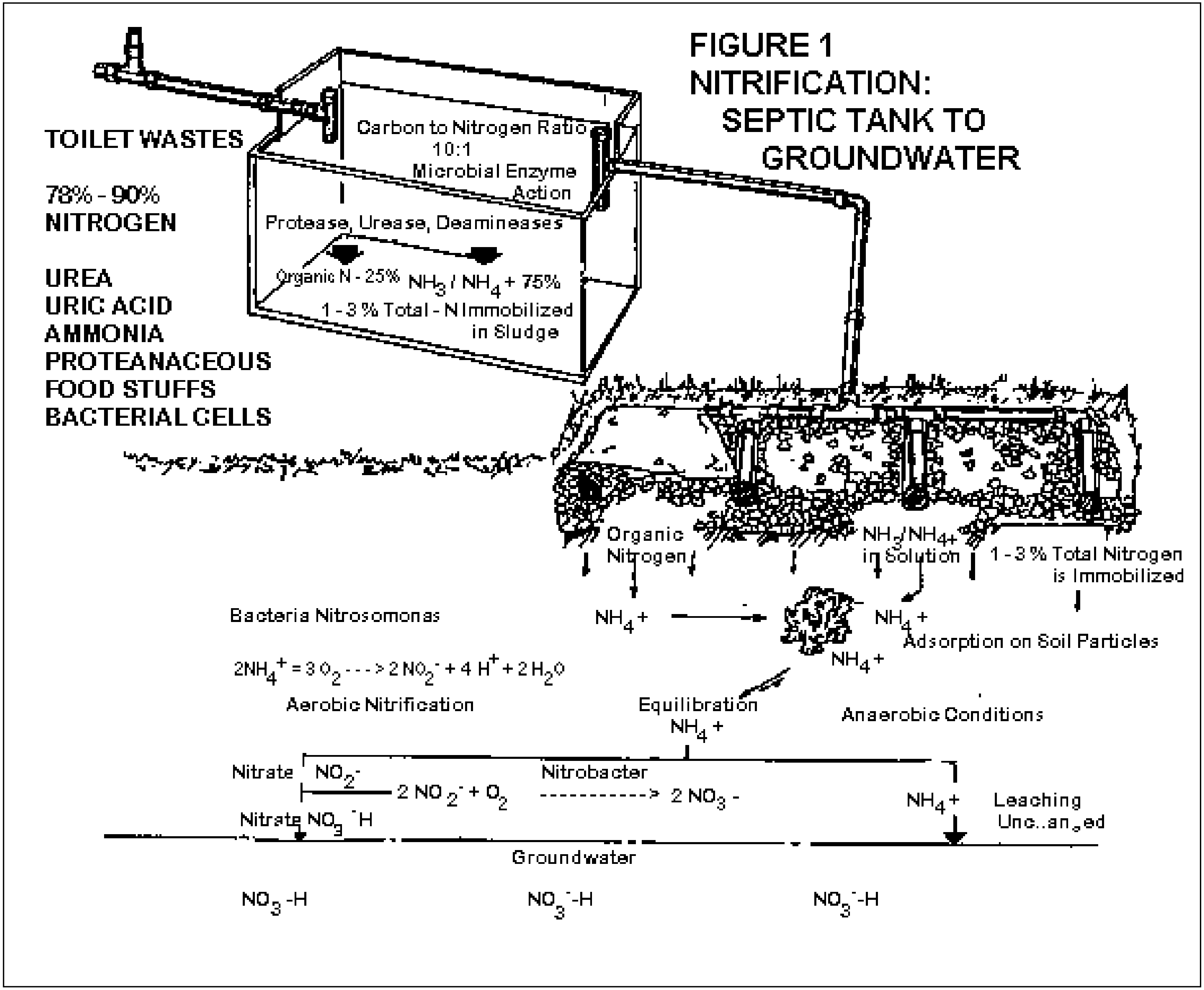
FIGURE 1
NITRIFICATION:
SEPTIC TANK TO
GROUNDWATER
TOILET WASTES
78% - 90%
NITROGEN
UREA
URIC ACID
AMMONIA
PROTEANACEOUS
FOOD STUFFS
BACTERIAL CELLS
Carbon to Nitrogen Ratio
10:1
Microbial Enzyme
Action
Protease, Urease, Deamineases
Organic N - 25%
NH_3 / NH_4 + 75%
1 - 3 % Total - N Immobilized
in Sludge
Organic
Nitrogen
NH_3/NH_4+
in Solution
1 - 3 % Total Nitrogen
is Immobilized
Bacteria Nitrosomonas
NH_4+
NH_4+
Adsorption on Soil Particles
NH_4+
$2NH_4^+ = 3 O_2 ---> 2 NO_2^- + 4 H^+ + 2 H_2O$
Aerobic Nitrification
Equilibration
NH_4+
Anaerobic Conditions
Nitrate
NO_2^-
$2 NO_2^- + O_2$
Nitrobacter
------------> $2 NO_3$ -
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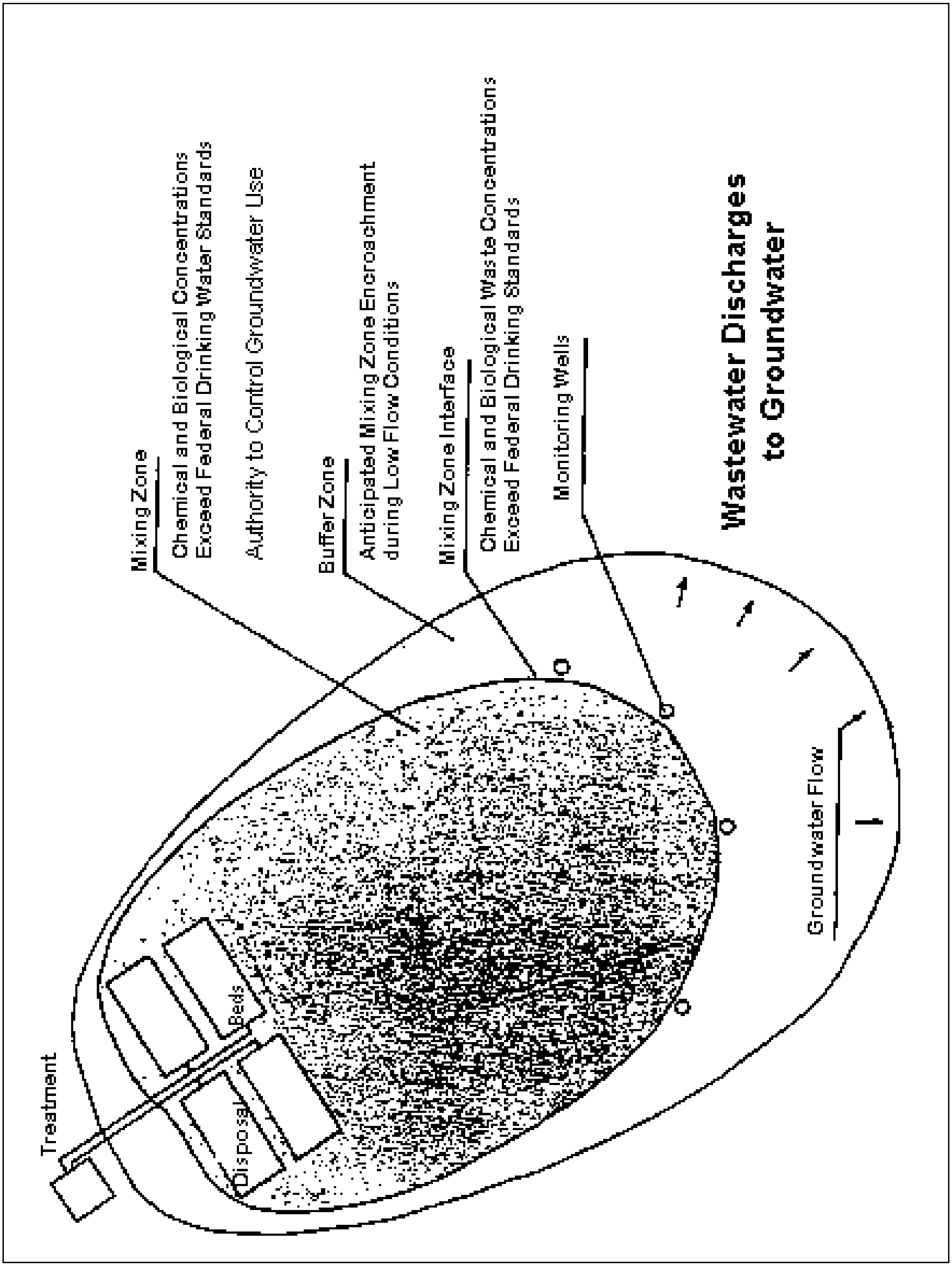
Nitrate NO_3^-H
Groundwater
NO_3 -H
NO_3^--H
NO_3^--H


Mixing Zone
Chemical and Biological Concentrations
Exceed Federal Drinking Water Standards
Authority to Control Groundwater Use
Buffer Zone
Anticipated Mixing Zone Encroachment
during Low Flow Conditions
Mixing Zone Interface
Chemical and Biological Waste Concentrations
Exceed Federal Drinking Standards
Monitoring Wells
Wastewater Discharges
to Groundwater
Treatment
Disposal
Beds
Groundwater Flow

IV. TREATMENT TO REDUCE NITRATE NITROGEN CONCENTRATIONS

A. Biological Denitrification

Water can be treated to reduce concentrations of nitrate nitrogen. The process is called denitrification. Denitrification involves the biological reduction of nitrate to nitrite and finally to nitrogen gas. Such biological denitrification requires:

1. Bacteria - Pseudomonas, Micrococcus, Bacillus and Acomobacter;

2. No available oxygen (anoxic conditions) and,

3. A source of organic carbon compounds

Biological denitrification occurs as the bacteria use nitrate to oxidize organic carbon to obtain energy. This can only occur if oxygen is not present (anoxic conditions).

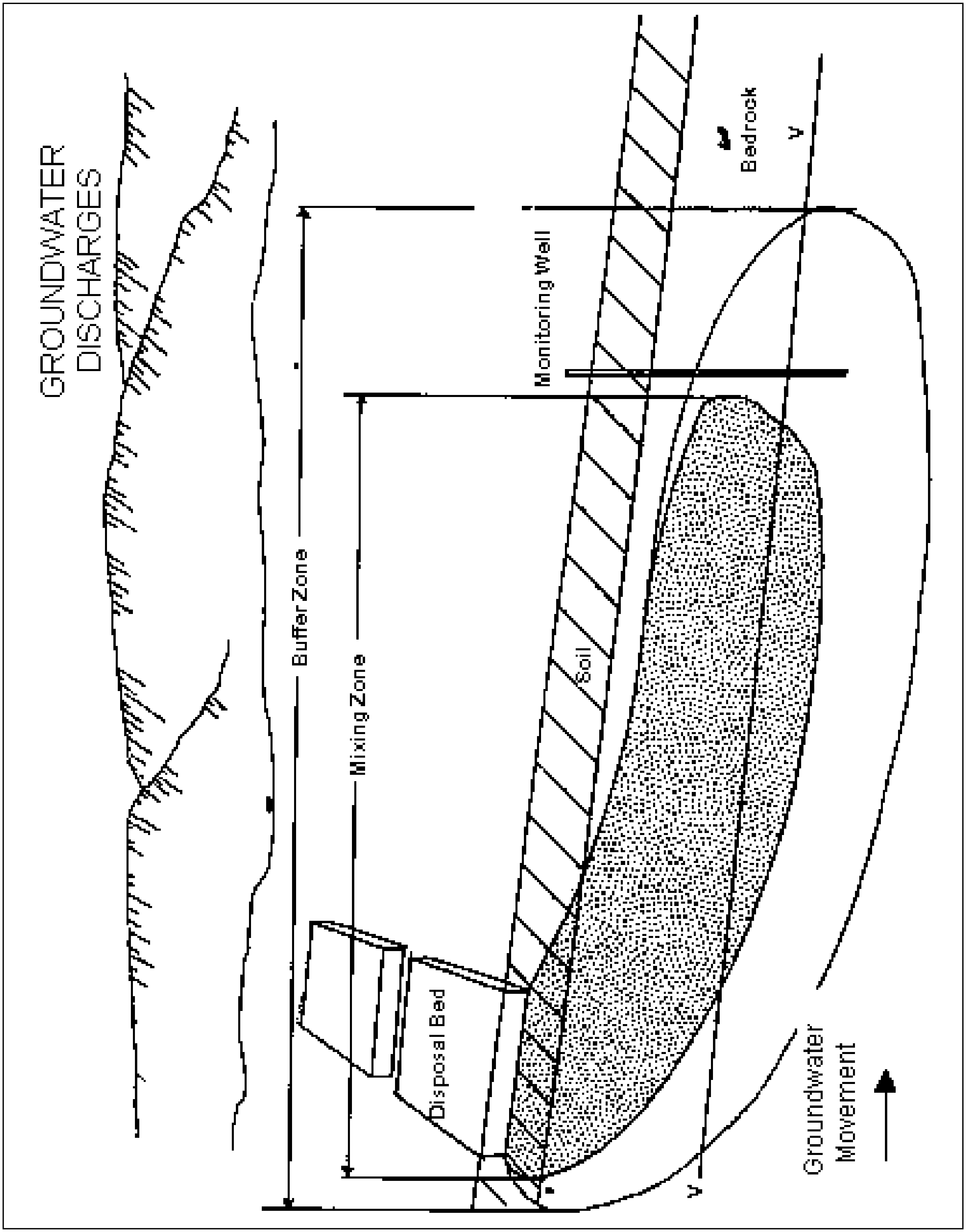
B. Denitrification by System Components

A number of treatment methods based on the denitrification process have been developed. These eliminate nitrates from sewage prior to disposal by subsurface absorption systems. Most treatment methods require operation and maintenance activities. Most methods which have been utilized and evaluated are components of treatment plant systems. Such systems have been utilized to provide necessary nitrate removal before a subsurface discharge proposed to recharge groundwater in areas where maintaining groundwater supply is critical.

C. Dilution and Dispersion of Contaminants in Groundwater

Subsurface disposal systems depend upon soil activity for proper treatment of sewage. They depend on groundwater for dispersion and dilution of contaminants that have not been completely treated. Nitrates generated in subsurface disposal systems enter the groundwater at levels of approximately 45 ppm directly under the absorption field. The groundwater concentration is reduced through dilution and dispersion in a zone of attenuation (mixing zone).

1. The water supply for a single family dwelling served by an onlot subsurface disposal system is protected by nitrate concentration reduction through regulatory control of isolation distances (100 feet) between the sewage system and well. Dilution and dispersion reduce the nitrate nitrogen concentration from sewage effluent as groundwater travels through the soil. The 100 foot distance, however, may not provide sufficient isolation to allow for nitrate nitrogen dilution to less than 10 ppm before reaching a water supply due to the presence of additional systems in the area. These systems also release nitrate nitrogen to the local groundwater. Theoretically, approximately 1.4 acres is necessary to isolate each sewage system serving a single family dwelling in a subdivision so that sufficient dilution of nitrate can occur. The existing 100 foot well/sewage system isolation distance requirement can be met on 1/4 acre lots. The potential for nitrate nitrogen contamination increases as the density of the subdivision (number of single family dwellings/acre) increases.


GROUNDWATER DISCHARGES
Buffer Zone
Mixing Zone
Monitoring Well
Soil
Bedrock
Disposal Bed
Groundwater Movement

2. A significant concern about nitrate nitrogen loading of groundwater arises with single large volume effluent discharges or high density discharges from multiple subsurface disposal systems. Because of the large volume of effluent being discharged in relation to the area for disposal, nitrate nitrogen loading is increased relative to the dilution/dispersion capabilities of the groundwater system. Therefore, the capability of the local groundwater system to dilute and disperse these increased nitrate loads must be determined before the approval of these discharges.

V. DETERMINATION OF THE IMPACT OF NITRATES ON DRINKING WATER SUPPLIES

A hydrogeologic study evaluates the existing and proposed nitrate loading of the groundwater. It estimates the velocity and direction of groundwater movement. It projects the area of potential contamination above 10 ppm that can be anticipated in the local aquifer and its impact on water uses in the local area.

A. Hydrogeologic studies are site specific. Final determination as to the final content of such studies should be made by groundwater geologists working for the Department. Their judgment rests on an evaluation of specific geological characteristics of the area proposed for subsurface disposal systems.

B. Hydrogeologic studies should delineate a:

1. Dispersion Plume - Volume of effluent and groundwater flowing away from a treatment disposal site.

2. Mixing Zone - Portion of the dispersion plume in which groundwater quality does not meet Federal Drinking Water Standards.

3. Buffer Zone - The groundwater surrounding the mixing zone. It is provided for containment and restoration activities should groundwater which exceeds Federal Drinking Water Standards leave the mixing zone.

C. General guidelines for such studies are included in DEP Policy, and Procedures and Modules.

VI. USE OF ACT 537 PLANNING TO CONTROL THE IMPACT OF NITRATES ON DRINKING WATER

A. DEP does not approve or disapprove permits for onlot or small community onlot subsurface disposal systems (treating less than 10,000 gal/day). This approval or disapproval power is given to the individual municipalities administering the provisions of Section 7 of the Pennsylvania Sewage Facilities Act. Any requirements for such safeguards as hydrogeologic studies must, therefore, be required as part of the Act 537 planning process over which DEP has approval power.

B. Pennsylvania does have principles to guide groundwater protection and remediation. DEP currently does not require any discharge limitations where subsurface sewage disposal systems are discharging to groundwater and groundwater nitrate concentrations are less than 5 ppm. Existing DEP regulations on subsurface disposal systems do not establish effluent limitations for specific types of sewage disposal systems. Effluent limitations for surface waters do not apply to subsurface discharges to groundwater.

C. The Environmental Protection Agency’s drinking water regulations define the concentrations and chemical characteristic parameters that are harmful to public health. These regulations state that water containing nitrate nitrogen levels in excess of 10 ppm should not be used for drinking water. Further, nitrite nitrogen may not exceed 1 ppm. This regulation, when linked with the language of the Clean Streams Law which defines pollution in part as "contamination…that renders…waters harmful…to public health," thereby provides the basis for requiring hydrogeologic studies.

D The Act 537 planning process can be used to require site specific testing and hydrogeologic studies to determine the extent of groundwater contamination expected from subsurface systems. Such studies can also identify existing and potential water supplies that will be affected by nitrate nitrogen levels in excess of 10 ppm. The Act 537 Plan can require that the methods of preventing use of this water for drinking water purposes be evaluated. A method can be chosen and implemented, as part of the plan, to prevent creation of a public health hazard.

E. Evaluations of possible methods of prohibiting the present and potential use of contaminated groundwater within the mixing and buffer zones for drinking water purposes include:

1. Sewage Facilities Planning that limits the installation of treatment facilities in high nitrate nitrogen zones.

2. Land use zoning established by local government agencies which prohibits development using on-site wells in high nitrate nitrogen zones (this would eliminate drinking water use).

3. Use of alternative water supplies.

4. Deed restrictions, easements, or other legal mechanism limiting use of affected groundwater areas.

5. Ownership of all property impacted.

F. Act 537 Planning can also be used to require evaluation and implementation of groundwater monitoring activities which will detect nitrate nitrogen levels and movement outside the mixing zone defined by the hydrogeologic study. Such monitoring can be used to initiate action to stop nitrate nitrogen from reaching 10 ppm in drinking water supplies. The planning can require an evaluation of contingencies to stop such unpredicted contamination including:

1. Abandonment of the onlot system (replacement with another type of system, connection to public sewers).

2. Adding Nitrate Nitrogen treatment components to the onlot system.

3. Groundwater diversion.

4. Temporary water supply treatment in conjunction with 1, 2, or 3 above.

VII. SUMMARY OF ISSUES

The following summary identifies major issues discussed in this paper and provides DEP's position on each issue along with support for each position:

<u>Issue No. 1</u>

Subsurface sewage disposal systems can cause nitrate nitrogen pollution of groundwater. Large volume or high density discharges from subsurface systems increase the potential impact of nitrate nitrogen introduction into potable water supplies.

<u>Position</u>

DEP recognizes the fact that subsurface sewage disposal systems rely upon the soil and hydrogeologic treatment systems to renovate sewage and that dilution and dispersion through the groundwater flow system reduces the concentration of nitrate nitrogen generated from subsurface systems. Such systems can only be allowed if the concentration of nitrate nitrogen reaches safe levels prior to <u>use</u> of the groundwater as a potable water supply source

<u>Support</u>

Chapter 73 of DEP's Rules and Regulations

Clean Stream Law Sec. 5(a)(2) & Sec. 402(a)

<u>Issue No. 2</u>

Opinion varies as to the public health significance of nitrate nitrogen and the concentration which poses a public health hazard in drinking water.

<u>Position</u>

DEP accepts 10 ppm as the maximum allowable level of nitrate nitrogen in drinking water systems. The siting of subsurface sewage disposal systems must protect existing and potential potable water supplies from nitrate nitrogen loadings in excess of this limit. Scientific opinion seems solidified that the 10 ppm limit for nitrate in drinking water is valid. <u>National Primary Drinking Water Regulations</u>, 40 CFR 141.11(d), were finalized in 1997 using this limit.

<u>Support</u>

Bibliography References #1, #2, #3, #7, #8, and #9.

PA Sewage Facilities Act 537 Sec. 5(d)(3) and (5).

Clean Streams Law Sec. 5(a)(2)

Eagles View Lake Inc. v. DER Environmental Hearing Board Docket No. 76-086-W, April 4, 1978

<u>Issue No. 3</u>

The level of nitrate nitrogen leaving a subsurface sewage disposal system is important in determining the impact of this effluent on the groundwater. The treatment capabilities of subsurface disposal systems have been claimed to be from 0% to 44% removal of nitrate nitrogen.

Position

Unless DEP accepted components of a subsurface sewage disposal system have been demonstrated to consistently reduce nitrate nitrogen loading of the groundwater directly under the subsurface absorption area, all nitrogen entering the system will be assumed to be converted to nitrate nitrogen and loaded to the groundwater. The accepted figure for this loading from household waste is 45 ppm nitrate nitrogen.

Support

References #10, #11, #12, #13, #14,#15

Issue No. 4

A number of treatment methods are now available that claim to reduce nitrate nitrogen levels prior to treatment in the subsurface sewage disposal system components.

Position

Only treatment facilities shown to have a consistent nitrogen removal capability, as documented by in-field testing, can be employed as a means of reducing nitrogen loading levels prior to sewage disposal by a subsurface system.

Support

References #14, #15

Issue No. 5

The permitting of subsurface sewage disposal systems is controlled by Chapter 73 of DEP's regulations. The 100 foot isolation distance between subsurface systems and drinking water supplies established by these regulations may not be adequate to provide for nitrate concentration reductions in effluent from large systems before reaching a water supply.

Position

Act 537 planning for community onlot disposal systems utilizing subsurface disposal for wastewater flows in excess of 10,000 gallons per day; high density developments (lot less than 1 acre in size) utilizing individual onlot systems for a subdivision of more than 50 lots; onlot system proposed in areas documented by DEP as having existing nitrate nitrogen levels in excess of 5 ppm, or areas with critical geology must evaluate the impact of nitrate nitrogen on the groundwater. A preliminary hydrogeologic study will estimate the extent of the potential problems. A detailed hydrogeologic study will be required where DEP concludes there is a need for more detailed information. This information is included as supporting documentation to sewage facilities planning module components. Permit exempt systems must be installed 200 feet horizontal distance from potential water supplies of all types.

Support

Chapter 71, Sec. 71.62(c)

Chapter 72, Sec. 71.23(g)

Clean Streams Law, Sec. 5(a)(2), 5(b)(2), 402(a)

Eagles View Lake Inc. v. DER Environmental Hearing Board Docket No. 7 6-086-W, April 4, 1978

Issue No. 6

Once a hydrogeologic study delineates a mixing zone and it has been established that the water in that zone will be in excess of 10 parts per million, the water in that zone cannot be used for drinking water purposes. Sufficient measures must be taken to prevent a public health hazard (consumption of the water) from occurring in such cases.

Position

Act 537 planning must evaluate and establish the legal or institutional measures to control both present and potential water usages within the mixing and buffer zones. Usage controls must prevent human consumption of water with nitrate concentrations in excess of levels associated with specific health hazards. Adverse impacts on existing or potential public or private water supplies that may be caused by a proposed sewage disposal system must be mitigated to the satisfaction of DEP by measures approved through the Act 537 planning process. Act 537 planning proposals must also establish groundwater monitoring requirements to confirm the validity of the original hydrogeologic study. Measures to prevent hazardous groundwater nitrate-nitrogen levels in the mixing zone from migrating beyond the buffer zone must be evaluated. Plans must evaluate and establish remedial actions that can be taken before hazardous concentrations of nitrate-nitrogen leave control of the established zone of attenuation.

Support

Ref. 1, 2, 12

Chapter 71, Sec. 71.3, 71.62(c)(2)-(4)

Clean Streams Law Sec. 4 and Sec. 5

Eagles View Lake Inc., v. DER Environmental Hearing Board Docket No. 76-086-W, April 4, 1978

Sewage Facilities Act Sec. 5

DEP Document Number 383-0800-001, December 1, 1996, Principles for Groundwater Pollution Prevention and Remediation.

BIBLIOGRAPHY

1. U.S. Department of Health, Education and Welfare, Public Health Services, 1962, *Public Health Service Drinking Water Standards*, Page 47-57. Establishes 10 ppm nitrate limit for potable water supplies based upon support from ten studies showing the public health impact of nitrogen. Replaced by 40 CFR 141.11(d).

2. Code of Federal Regulations, 1997, *National Primary Drinking Water Regulations*, 40 CFR 141.11(d). Continues the use of 10 ppm nitrate nitrogen limit for potable water supplies based upon nine more recent studies showing the public health impact of nitrogen.

3. National Academy of Sciences, 1977, *Drinking Water and Health*, pages 411-439. This report supports the 10 ppm nitrate nitrogen limit stating that: "Epidemiological investigation on the occurrence of methemoglobinemia in infants tends to confirm the value near 10 mg/L nitrate as nitrogen as a maximum concentration level for water with no adverse health effect, but there is little margin of safety in the value." The same report questions the 10 ppm limit stating that; "The highly sporadic incidence of methemoglobinemia when drinking water that contains much greater concentration of nitrate is used suggested, however, that factors other than nitrate intake are important in connection with development of the disease."

4. Parsons, M. L., 1977, Current Research Suggests the Nitrate Standard in Drinking Water is Too Low. *Journal of Environmental Health*, (November-December, 1977), Volume 40, No. 3, page 140. Parsons proposed raising the 10 ppm limit on nitrate nitrogen to 100 ppm based on evidence that both high nitrate nitrogen levels and bacterial contamination of water supply are needed to cause methemoglobinemia. In addition, he points out the lack of recent documentation of public health problems resulting from nitrates in spite of the high concentrations begin injected in water and food.

5. Craun, Gunther F., 1981, An Alternative for Meeting the Nitrate Standard for Public Water Supplies. *Journal of Environmental Health*, (July-August, 1981), Volume 44, No. 1, pages 20-24. Craun supports directing enforcement activities to the specific population that is susceptible to methemoglobinemia (infants less than 3 months of age). He proposes requiring alternative water supplies for this population along with an education program. Support for this proposal follows that provided in reference 4 above, and a review of capabilities States and Health Agencies to carry out such an approach. This proposal is intended to be a substitute for EPA's requirements to treat for nitrates in public water supplies.

   No cases were found in two studies where concentrations were as much as 20 mg/l nitrate nitrogen.

6. EPA letter of March 19, 1979, from Bernie Sarnoski, Chief, State Program Section, Water Supply Branch to J. Stephen Schmidt, Pennsylvania DEP. Mr. Sarnoski discussed the nitrate nitrogen problem stating that "the U.S. Environmental Protection Agency's draft of the amendments to the National Interim Primary Drinking Water Regulations relating to non-municipal water systems under the Safe Drinking Water Act has expanded Section 141.11 to give discretionary authority to the States with respect to the maximum contaminant level (MCLs) for nitrates. This amendment provides that the nitrate levels up to 20 mg/L (as N) may be allowed in a non-community water system only if it has been demonstrated to the State that whenever the nitrate level exceeds 10 mg/L (as N) a number of control measures, such as informing local physicians and providing continuous public notification to parents not to feed such water to infants under six months of age, will be implemented."

7. Winton E. F.; Tardiff, R. G.; and McCabe, L. J., 1971, Nitrate in Drinking Water, *Journal of American Waterworks Association*, (February 1971), Volume 63, pages 95-98. This paper studies the validity of the 10 ppm nitrate nitrogen limit placed on public water supplies. A review of the causative factors of a study of 111 infants exposed to nitrates in formulas under controlled conditions lead the authors to conclude in the 10 ppm nitrate nitrogen (45 mg/L nitrate) limit on water supplies is valid.

8. Environmental Protection Agency, 1985, *Occurrence of Nitrate in Drinking Water, Food, and Air*. Supports 10 mg/L standard.

9. Bouchard, Dermont C;. Williams, Mark K.; Surampalli Rao Y., 1992. Nitrate Contamination of Groundwater: Sources and Potential Health Effects. *Journal of the American Water Works Association*, (September 1992), Volume 84, Number 9, page 85-90. This is an overview of health concerns of nitrate-nitrite exposure. Concludes that information to date supports the current drinking water standard.

10. Jenkins, P. F. and Paluzzo, A. J., 1991. Wastewater Treatment by a Prototype Slow Rate Land Treatment System, *CRREL Report 81-14*. A six year study was conducted of six disposal systems in sandy loam and silt loam receiving either primary or secondary effluents sprayed under controlled conditions. The study revealed that denitrification and other nitrate nitrogen removal mechanisms other than plant uptake and leaching account for only about 9% removal of the total nitrogen applied.

11. Kristinsen, Roly, 1981. Sand-Filter Trenches for Purification of Septic Tank Effluent: II. The Fate of Nitrogen, *Journal of Environmental Quality*, (July-September, 1981), Volume 10, Number 3, Page 358. A study of sand filters was conducted to determine what occurred in such systems with regard to nitrate nitrogen. The study determined that insignificant amounts of nitrogen were removed during renovation in the sand filter due to the aerobic conditions in the sand and subsequent nitrification. Uptake of nitrogen by microbial biomass, cation exchange complexes and dead organic matter accounted for only three months of nitrogen loading from households. The report recommended intermittent loading as a possible means of increasing denitrification in subsurface systems.

12. Aulenbach, D. B. 1974. Recharge of Treated Sewage into Sand -- Nutrient Transport Through the Sand. *Ground Water*, (September-October 1974), Volume 12, Number 5, page 301. An extensive study of the disposal of secondary sewage onto sandbeds revealed that nitrate nitrogen levels in excess of 10 ppm generated in the beds traveled downgradient in the groundwater system. The study also indicated that nitrification occurs under aerobic conditions in such filters and that dilution and dispersion is responsible for natural attenuation of nitrate nitrogen in the groundwater system.

13. Bouma, J., Keney, D. R., Magdoff, F. R., and Walker, W. B., 1973. Nitrogen Transformations During Subsurface Disposal of Septic Tank Effluent in Sands: Soil Transformation. *Journal of Environmental Quality*, (October-December 1973), Volume 2, Number 4, page 475. This article studies several subsurface sewage disposal systems to determine the changes taking place in relation to nitrogen as sewage passes through the soil under the drain field. Nitrogen in the form of NH_4-N and organic nitrogen in the septic tank was nitrified to nitrate nitrogen under aerobic conditions in most of the systems. Nitrification did not occur in one drain field that was completely saturated and had anaerobic conditions present. No significant denitrification occurred in these systems and concentrations of nitrate nitrification in the water below the system averaged between 43 and 110 mg/L. A second study, II. Ground Water Quality, showed concentrations of as much as 40 mg/L nitrate nitrogen under drain fields. Dilution and dispersion of these concentrations to an acceptable 10 ppm nitrate nitrogen level did not occur until a distance of 231 feet from the disposal system.

14. United States Environmental Protection Agency, 1980. *Design Manual, On Site Wastewater Treatment and Disposal Systems*. Provides data on nitrate nitrogen in relation to onlot disposal and provides a discussion of denitrification treatment methods.

15. United States Environmental Protection Agency, 1975. *Process Design Manual for Nitrogen Control*. Provides information as to nitrification/denitrification and treatment systems available for denitrification.

16. Robertson, W. D. and Chorry, J. A., 1995. In situ Denitrification of Septic-System Nitrate Using Reactive Porous Media Barriers: Field Trails. *Ground Water*, (January-February 1995) Vol. 33, No. 1, page 99. A study of saturated silt/sawdust/sand layered porous media barriers.