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NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

WATER QUALITY AND SEPTIC SYSTEMS

OCEAN ACRES SUBDIVISION

STAFFORD AND BARNEGAT TOWNSHIPS

OCEAN COUNTY, NEW JERSEY

Prepared by: Wayne R. Saunders, Principal Geologist
John J. Trela, Senior Geologist
Joseph A. Benintente, Senior Environmental Engineer

Bureau of Water Quality Planning and Management
Division of Water Resources
New Jersey Department of Environmental Protection

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Background

In September 1973 the Department of Environmental Protection received information pertaining to the Ocean Acres Subdivision located in Stafford and Union (Barnegat) Townships. At that time approximately 2,000 lots were pending final approval before the Barnegat Township Planning Board and approximately 3,000 lots were pending final approval before the Stafford Township Planning Board. The Division of Water Resources sent telegram orders to both townships on October 5, 1973 apprising them of the fact that they were in violation of the "Realty Improvements Sewerage and Facilities Act (1954)" N.J.S.A. 58:11-23 et seq. as amended on January 7, 1972 which requires state certification for all subdivisions of 50 or more realty improvements, and ordering them to submit these subdivisions to the Division for review under the aforementioned statute. A separate letter was sent to each township indicating the data which must be submitted for review under the Act and gave the planning boards thirty days to indicate their willingness to comply with the law. Thirty days passed without response from either township and on December 18, 1973 all of the facts surrounding this situation were compiled and a decision was made to refer the case to the Attorney General's Office for action.

The Ocean Acres Subdivision, under Delstar Corp., became the subject of bankruptcy proceedings before the United States District Court for the District of New Jersey. On October 29, 1973 the Court ordered Stafford and Union Townships to approve the final plot plan of the subdivision. The court ruled that such approval was in the public interest and not contrary to the requirements of the Realty Improvement Act of 1954, Chapter 199. The case was referred to the Attorney General on January 14, 1974. The Attorney General's Office issued an opinion on May 5, 1975 summarizing previous advice to the Department on the matter. Their interpretation of the ruling was that the court took the position that the Realty Improvement Sewerage and Facilities Act did not apply because the owners of the subdivision were not proposing to construct realty improvements on the lots but were simply subdividing the tract for the purpose of selling lots to individual buyers. Apparently, the court ruled in this manner to protect the innocent third parties to whom the owner had sold lots, prior to subdivision approval.

Although the Attorney General had doubts concerning the courts' interpretation of Chapter 199, his position was that the issue was moot in this case, since subdivision approval had already been granted, and therefore, the 50 unit or more provision of Chapter 199 could not be applied. Further, he noted that under Chapter 199 standards then in effect, it appeared the subdivision would have complied with Chapter 199 and would have been approved by the Department. The Attorney General suggested as alternatives that the Department supervise reviews by the local boards of health of applications for individual systems under Chapter 199, and, if and when necessary to order the townships to install sanitary sewers

There are approximately 8,000 building lots in Ocean Acres and at the time of this writing there were 1625 approved subsurface sewage disposal systems, 1080 of which had received final inspection by the Ocean County Health Department and 545 had been approved for construction. The 545 approvals are for homes which are presently in various stages of construction. Building permits for these homes were issued prior to January 23, 1978. (Information obtained from Ocean County Health Department).

Introduction

Historically mankind has generally taken the position that disposal of his wastes was one of "out of sight-out of mind". Man, because of limited knowledge, had little or no concern over the fate or consequences of his wastes upon the environment. As long as population densities remained low, damage was relatively minor. This report discusses the potential degradation of an important ground-water aquifer due to applying more waste than can be assimilated by the environment.

The advent of the septic system came into use as man wanted greater convenience for the disposal of his personal and household wastes. As knowledge was gained, local authorities began recognizing potential pathological hazards associated with the improper disposal of wastes. Most of the disposal problems were in rural areas where conventional sewer systems were not present and the overriding factor was one of disposal into the subsurface with no concern of the impact on ground water. There was some justification in this thinking because the sparse density of the disposal systems allowed the soil to treat some of the wastewater products with the remainder mitigated by dilution. As more and more of our population moved from the highly urbanized areas served by sewerage systems and public water supplies to rural areas dependent on individual septic systems and potable wells, the impact of septic disposal systems upon the surface and ground water has become critical in some areas, both to the environment and the public health. Therefore, it is incumbent upon the Department of Environmental Protection to review subsurface disposal systems in areas declared "critical" for sewage purposes in order to protect the quality of ground and surface water. To understand the effects of septic effluent upon the ground and surface waters one must take a closer look at the quality of the effluent being discharged to the system and the treatment limitations within the system itself (Table 1).

TABLE I

RAW WASTEWATER CHARACTERISTICS

	Average (mg/l)	Range (mg/l)
Total Solids	700	300-1500
Suspended Solids	200	100-350
Fixed	50	30-75
Volatile	150	70-275
Dissolved Solids	500	200-1150
Fixed	300	150-500
Volatile	200	100-300
Settleable Solids	10	5-20
BOD (Biochemical Oxygen Demand)	200	100-300
COD (Chemical Oxygen Demand)	500	250-1000
TOC (Total Organic Carbon)	200	100-300
Total Nitrogen - N	40	20-85
Organic - N	15	8-35
Ammonia - N	25	12-50
Nitrate - N	0.5	0-1
Total Phosphorus - P	10	6-20
Organic - P	3	2-5
Inorganic - P	7	4-15
Chloride	50	30-100
Fats, Oils, Grease	20	1-40
pH		6-8.5
Total Coliforms (per 100 ml)	20	1-40
Virus (PFU/liter)		200-7000+

The standard septic system is made up of three main components;

1) Septic Tank
2) Distribution Box
3) Disposal Area (either trench, field, or seepage pit)

Each unit has a distinct purpose in the treatment and disposal of the effluent.

Septic Tank

The functions of the septic tank are to:

1) Separate solids from wastewater by sedimentation and flotation.
2) Stabilize and neutralize pollutants through the biological actions of anaerobic microorganisms.

Distribution Box

The function of the distribution box is:

1) To direct wastewater to disposal area.

Disposal Area (Beds, Trenches, Seepage Pits)

1) Disposal by Soil Infiltration and Evapotranspiration.
2) Continuation of biological action by aerobic microogranisms.

The standard septic system functions in a hydraulic-soil environment and usually is capable of reducing bacteria and viruses to within acceptable limits after effluent has passed through approximately 4 feet of soil.

The transformation of ammonia-nitrogen and organic nitrogen to nitrates in the disposal area is the problem that is of utmost concern. In human wastes, nitrogen compounds are released from both urine and feces. Urine contains nitrogen principally in the form of urea resulting from the metabolic breakdown of protein. The urea hydrolyzes rapidly to ammonium carbonate. Feces contain appreciable amounts of nitrogen as protein. This protein converts to ammonia by bacterial action under either aerobic or anaerobic conditions. Therefore nitrogen in septic tank effluent appears in the greatest quantities as ammonium.

The primary processes which govern the transformation of nitrogen in the soil are nitrification and denitrification, which are described below (19):

Nitrification

Under aerobic conditions ammonium is transformed to nitrite by the Nitrosomones group of bacteria, as given by the equation:

$$NH_4^+ + 1.5\ O_2 \xrightarrow{\text{bacteria}} NO_2^- + 2\ H^+ + H_2O \quad (I)$$

Under continued aerobic conditions nitrite is rapidly transformed to nitrate by the Nitrobacter group of bacteria, as given by the equation:

$$NO_2^- + 0.5\ O_2 \xrightarrow{\text{bacteria}} NO_3^- \qquad \text{(II)}$$

The overall process by which ammonium is transformed to nitrate is termed "nitrification", and can be represented by combining equations (I) and (II) above:

$$NH_4^+ + 2_2 0 \xrightarrow{\text{bacteria}} NO_3^- + 2\ H^+ + H_2O \qquad \text{(III)}$$

The hydrogen ion further reacts to destroy bicarbonate alkalinity, which is naturally present in sewage, according to equation:

$$H^+ + HCO_3^- \longleftrightarrow H_2CO_3 \qquad \text{(IV)}$$

$$H_2CO_3 \longleftrightarrow CO_2 + H_2O \qquad \text{(V)}$$

Denitrification

Denitrification, takes place if the sewage is given ample detention time and subjected to low dissolved oxygen conditions, which will allow Nitrate - Nitrogen and residual Nitrite - Nitrogen to be reduced to nitrous oxide (N_2O) or free nitrogen (N_2). These reductions are brought about mainly by facultative bacteria, and take place only if there is an adequate supply of biologically oxidizable carbon. If a carbon source, is present, reduction of nitrate to nitrogen gas occurs in two steps. In the first step (using methanol as a carbon source) nitrate is transformed to nitrite as follows:

$$NO_3^- + 0.33\ CH_3OH \xrightarrow{\text{bacteria}} NO_2^- + 0.33\ CO_2 + 0.67\ H_2O \qquad \text{(VI)}$$

In the second step nitrite is transformed to nitrogen gas as follows:

$$NO_2^- + 0.5\ CH_3OH \xrightarrow{\text{bacteria}} 0.5\ N_2\uparrow + 0.5\ H_2O = OH^- + 0.5\ CO_2\uparrow \qquad \text{(VII)}$$

The overall process by which nitrate-nitrogen is transformed to nitrogen gas is termed "denitrification," and can be represented by combining equation (VI) and (VII) above:

$$NO_3^- + 0.83\ CH_3OH \xrightarrow{\text{bacteria}} 0.5\ N_2\uparrow + 0.83\ CO_2\uparrow + 1.17\ H_2O + OH^- \qquad \text{(VIII)}$$

After the septic system has been in operation for a period of ± 6 months an organic mat develops in the disposal area. This mat consists of different organic and inorganic solids contained within the effluent. The mat also contains bacteria which convert the organic nitrogen present in the effluent to ammonium. The ammonium is only weakly adsorbed in most sandy soils and is rapidly converted, under aerobic conditions, to nitrate which is highly mobile.

Effects of Nitrogen on Humans

Nitrates which exceeded United States Public Health Standards, of 10 ppm as Nitrate-Nitrogen in the potable supply can cause serious illness or death to those infants who are less than 6 months of age. The long term effect of nitrate or nitrite ingestion by adults is not known. The disease caused by nitrate ingestion is called methemoglobinemia. (21)

"Methemoglobinemia, is caused by bacterial conversion of nitrate to nitrite which chemically combines with the hemoglobin of the blood to form methemoglobin. The bacteria necessary for the conversion of nitrate to nitrite are more likely to exist in infants because of pH of an infant's stomach is alkaline and therefore more suitable for the growth of nitrate reducing bacteria. Once the nitrite has combined with the hemoglobin to form methemoglobin, asphyxia and possible death may result. Approximately 2,000 cases have been reported in North American and Europe with a fatality rate of 7-8%. Nitrogen in a septic tank is 80% ammonium-nitrogen and 20% organic nitrogen; both may be converted to nitrate. Ammonium is readily absorbed by fine soil particles (clay). It is postulated that many more cases of methemoglobinemia have occurred but the United States Public Health Service does not keep records of such, since it does not require health agencies to report this disease.

The attached appendix discusses the variety of health hazards associated with the ingestion of nitrate, nitrite and nitrosamines.

Documented Cases of Pollution from Septic System Wastes

There have been many cases of reported nitrate pollution of the ground water by individual septic systems. Miller (20 studied two (2) areas within Delaware, one with a high water table and low permeability soils, and another with a low water table and very permeable soils. Both had homes with individual septic systems on 1/4 to 1/2 acre lots. The latter study area showed nitrate pollution in the ground water exceeding potable limits. The soils in the study area were similar to those at Ocean Acres. The nitrate pollution in this case was directly attributable to septic systems. Studies also have been undertaken on Long Island (7) and the University of Wisconsin (25) with similar results on sandy soils.

Documented cases of ground and surface water pollution from subsurface disposal systems in New Jersey coastal plain sediments are contained within the files of the Bureau of Water Quality Planning and Management and the Burlington County Health Department.

Increasing residental development of rural areas within the coastal plain have caused the degradation of both ground and surface waters. This degradation has been caused by individual subsurface disposal systems on inadequate lot sizes in conjunction with sandy soils (clean) and/or high water tables.

Surface water bodies such as Deal Lake, Lebanon Lake, Medford Lakes and others (29) have shown increased levels of bacteria, phosphates, ammonia-nitrogen and nitrate-nitrogen. Surface water samples have indicated that degradation has increased with the increased density of septic systems.

In Burlington County near the towns of Masonville - Rancocas Woods (30) a subdivision with septic systems and individual potable wells located on approximately 1/4 acre lots have shown that the ground water has become contaminated with NO_3-N levels exceeding the 10 ppm maximum by the Environmental Protection Agency. In Bass River Township (30) NO_3-N levels have also exceeded the maximum levels. Again lots were not of sufficient areal extent to allow proper dilution of the septic effluent.

Since NO_3-N is not routinely sampled in private home wells, it is entirely feasible that other developments on coastal plain sediments may be causing ground-water contamination by NO_3-N. Testing programs by various health departments have been instituted to ascertain NO_3-N contamination by individual septic systems in the subdivision. To date, only Burlington County has submitted results to the Department. However, at this time there is adequate scientific information to clearly justify the NJDEP's concern relative to the maintenance of public health and safety.

Phosphorus

The bulk of phosphorus found in typical household wastewater emanates from household cleaning agents and human excretment. The effect of phosphorus emitted from a subsurface disposal system on the ground-water system is subject to widely differing opinions. Douglas (3) feels that the typical solids found in the Pine Barrens have little effect on phosphorus fixation. Other writers (1,9,21) state that phosphorus is readily fixed and presents little or no problem. Most researchers do agree that in areas where a high water table persists and very coarse materials are present that phosphorus may be flushed from a system with little or no attenuation by the in situ soil. It is expected that the Rutgers University study presently being funded by the Department will provide a better understanding of this problem. Phosphorus is not a health hazard at the levels found in septic system effluent.

Effect of Nitrate and Phosphorus on the Environment

The discharge of ground water containing nitrates and phosphates provides nutrients to the surface water environment. Nitrates in low quantities, with low amounts of phosphate can cause stream or lake eutrophication, and a complete change of the environment. The Central Pine Barrens Critical Area ground-water standards set phosphate limits of 0.7 mg/l and a nitrate-nitrogen limit of 2 mg/l. These standards were imposed to prevent degradation of the present aquatic environment. Vegetative uptake of these nutrients is limited in sandy soils due to the rapid infiltration of these nutrients into the ground water past the shallow root zones of the plants which could use these nutrients. It is unknown what effect large amounts of nutrients would have on these plants which have evolved over the centuries with low nutrient waters.

OCEAN ACRES

Surface & Subsurface Characteristics

The Ocean Acres subdivision is located in Ocean County, New Jersey and straddles Stafford and Barnegat (Union) Townships. The subdivision is bordered on the East by the Garden State Parkway and on the South by Route 72 and Route 534. Surface elevations vary from ±40 m.s.l. to ± 169 m.s.l, as shown on U.S.G.S. Brookville and West Creek (photo revised, 1972) quadrangles. Surface drainage (and most likely ground-water movement) flows toward two (2) streams; the Four Mile Branch and Eight Mile Branch of Mill Creek.

The site is underlain by the following soil series as defined in the Interim Soil Survey Report, Ocean County, New Jersey (15):

1) Downer
2) Woodmansie
3) Evesboro
4) Atsion

Downer Series - Downer Soils are well drained with a sandy loam subsoil overlying stratified sand and loamy sand strata, which normally contains small amounts of gravel. Permeability is moderate or moderately rapid.

Woodmansie - Woodmansie soils are deep, well-drained sandy soils of the Coastal Plain uplands. The soil normally has a bleached sand surface soil and a loamy subsoil. Permeability is moderate or moderately rapid.

Evesboro - Evesboro soils are excessively drained, deep sandy soils. Most soils are underlain below 40 inches by sand, loamy sand, sandy laom, or sandy clay loam. Permeability is rapid or moderately rapid.

Atsion - Atsion soils are very sandy throughout the profile and have a very high seasonal water table.

As can be seen, the soils underlying the Ocean Acres Development are well drained, composed mainly of clean sands with little or no fines (clay-silts). The permeabilities are moderate to moderately rapid. These characteristics are substantiated by percolation tests and soil logs on file at the Division of Water Resources.

The geologic formation underlying the site is known as the Cohansey Sand. The Cohansey Sand is defined in Special Report 29, 1969 (12), as a "...yellowish-brown, unfossiliferous, cross-stratified, pebbly, ilmenitic, fine to very coarse-grained quartz sand that is locally cemented with iron oxide. White, dark gray, and red kaolinitic clays are interbedded with the sands. Individual beds are difficult to trace as the clays and sands are lenticular and discontinuous." Nearly all the individual potable wells in this area (Ocean Acres) draw from this water-table aquifer.

Surface Disposal Systems at Ocean Acres

As the effluent moves downward into the surrounding well-drained aerobic soils at Ocean Acres, the effluent is subjected to unsaturated flow due to two (2) factors:

1) The effluent is not applied to the disposal area under a constant flow.

2) The underlying soils are made up of different particle sizes, therefore, different pore spaces. The larger pore spaces will drain first and the smaller pore spaces will drain at a slower rate.

These conditions promote an aerobic environment in the subsoils above the water table. As discussed earlier, the aerobic conditions in the underlying soils will promote the nitrification of the ammonium. It has been found that the nitrification of the effluent usually takes place within 3 feet of vertical travel under aerobic conditions in sandy soils.

Denitrification will only occur if the particular denitrifying bacteria and carbon source are present with the effluent or the soil itself. This process must be done in an anaerobic environment. Neither of these factors exist in the underlying soils of Ocean Acres. Therefore, mostly all of the nitrate will reach the ground water in that form since nitrate is an anion and the underlying soils have extremely low anion exchange capacities. The only natural way the nitrates in the ground water may be reduced is by dilution.

Calculations

The following calculations are presented for a single lot for the expected concentration of nitrates in the ground water for average and drought precipitation conditions. These calculations are given as an example. To calculate for a specific lot size, the total square footage of the lot should be entered in the infiltration equation. Then substitute the value calculated from the infiltration equation into the dilution equation to calculate nitrate-nitrogen level at the property line. According to Rhodehamel (13, average precipitation is 45 in/yr. Approximately 20 inches/year infiltrates and the reamining 25 inches/year is lost through runoff, evapotranspiration, interception, and precipitation falling on surface waters. Under drought conditions infiltration may drop to 12.3 in/year (28). Average lot size in Ocean Acres is ± 10,000 square/feet. We are assuming an average wastewater discharge per person of approximately 60-100 gallons and an average of 3.5 person/home (28).

Average Conditions:

Infiltration - 20 in/year = .0046 ft/day x 10,000 ft^2 = 46 ft^3/day

60 gallons/person/day x 3.5 person/home = 210 gallons/day/home (28.07 ft^3/home)

80 gallons/person/day x 3.5 person/home = 280 gallongs/day/home (37.43 ft^3/home)

100 gallons/person/day x 3.5 persons/home = 350 gallons/day/home (46.79 ft^3/home)

The dilution factor (DF) is the quantity of ground water needed to reduce the nitrate-nitrogen level from an average of 40 ppm to 10 ppm at the property line or 2 ppm at a surface water body (10 ppm NO_3-N=potable water standard; 2 ppm NO_3-N= Central Pine Barrens Critical Area Standards) assuming an equidimensional lot size with the disposal system in the center and nearly complete nitrification of ammonia nitrogen.

Dilution Factor = Total Infiltration/day + Effluent Discharge/day / Effluent Discharge/day

To get the anticipated nitrate level at the property boundary, the Nitrate-Nitrogen concentration is divided by the dilution factor.

If drought conditions are used (one standard deviation from the mean/avg.), the amount of infiltration is 12.3 in/yr (0.0028 ft^2/day). Therefore the dilution factor for 60 gallons/per day and other flow and infiltration rates may be found in Table II.

TABLE II

Constants: 40 ppm NO_3-N
3.5 people/home
Lot size: 10,000 $ft.^2$

Flows (ED)	Rainwater Infiltration in/yr.	Dilution Factor	Anticipated NO_3-N Level (ppm) at property line
60 gpd/person	20.0 average	2.63	15.23
60 gpd/person	12.3 drought	2.00	20.00
80 gpd/person	20.0	2.22	18.02
80 gpd/person	12.3	1.75	22.85
100 gpd/person	20.0	1.98	20.24
100 gpd/person	12.3	1.60	25.00

The anticipated nitrate-nitrogen levels per lot, even, in average rainfall years, are in excess of public health standards, and far in excess of the non-degradation standards in effect. The installation of 8000± standard subsurface disposal systems in this area would in all probability create a serious threat to the region's potable water supply aquifer.

CONCULUSIONS

In general, the use of the standard septic system on the typical 10,000 sq. ft. lot in the Ocean Acres Development will present a potential public health problem. These septic systems at the density now proposed will also have a severe impact on local surface water bodies and downstream primary contact recreation lakes and the shellfishery of the bay. (31)

DEVELOPMENT

OPTIONS

The following options are presented to find a solution to this problem:

1) Sewers

Sewer the entire project immediately. Federal and State monies are not currently available for sewer projects that would be used primarily to promote development. Approximately 80% of Ocean Acres is not developed at the present time. Lots which have been built (previous to 1/23/78) are scattered throughout the tract. Information is not available to predict where new development will occur. Sewers could be installed if both Stafford and Barnegat Townships assessed each individual lot owner (including unimproved lots) the cost of sewers. Presumably, the township could float bond issues to cover the costs of the sewers. This would be a viable solution because of the potential high density of the project. Also, there would be little engineering difficulty due to the geology of the area and the fact that the rights of way for the lines have been cleared. The cost to the home owner would be somewhat off-set by construction and maintenance costs of standard septic systems.

2) Waterless Toilet

Each individual lot owner may be able to split the septic effluent into its gray and black water components. Since the black water component (toilet Waste) contains most of the total nitrogren ±85%, the nitrate problem would be reduced to a manageable level if it were treated separately. To accomplish this treatment separation, the black water component would have to be treated in what is commonly called a "waterless toilet". This device uses no water and urine and fecal matter are collected in a compartment and biodegraded. This system is temperature dependent and must be used with caution (No foreign materials may be introduced into the toilet). The cost of such a system is $2,000-3,000. Gray water would be disposed in a standard subsurface disposal system. Since the volume of effluent is reduced 22%-31% (1) with the use of the waterless toilet, the concentration of phosphorus in the effluent leaving the home will be increased. It appears that in soils which contain appreciable amounts of fines (silts and clays) and/or where the ground-water table is fairly deep from the land surface, phosphate pollution from the gray water is greatly reduced. At the present time the Department is continuing its investigation in this area, with a literature search, and possible installation of a test facility in the Ocean Acres Development. Another problem is one of "culture shock" for individuals to use such a toilet without water. If for any reason the individual(s) do not like the system or it fails, the occupants of the home would have to vacate the property since a standard septic system would not be permitted on the small lots.

3) Holding Tank

The gray and black water would be split with the black water going to a holding tank. The holding tank would have to be pumped periodically and the wastes taken to an approved disposal site. The gray water would be disposed with a standard subsurface system. The individual would have to obtain a service contract for black water removal and disposal. The initial expense of the tank would be high since the tank would have to be constructed with fail-safe systems to operate properly and there is a paucity of sewerage plants or landfills which will accept the black water. The problem of phosphorus attentuation in the soil is the same as previously mentioned in waterless toilets. Historically, operational costs have been a financial burden to homeowners.

4) Increase lot size

Individuals would have to purchase additional acreage to allow for sufficient dilution to comply with the standards. This would decrease the number of home sites at least one-third. The additonal expense to purchase these lots could pose a potential economic hardship on many individuals, however, several individuals have already combined lots to allow the construction of conventional septic systems.

5) Spray Irrigation

The use of Spray Irrigation to treat the effluent is another possibility. The effluent would have to be treated to a secondary level, and approximately 61 acres of open space would have to be found to spray the effluent. However, this process would be discontinued once the Ocean County Sewerage Authority has the capacity to accept the wastes.

RECOMMENDATIONS

Option one (1) is considered the preferred method of resolving the disposal wastewaters within Ocean Acres for the following reasons:

1) The development has already been subdivided, with most of the lots owned by individuals. Because of the high density, the cost to each lot owner would be relatively small.

2) The Ocean County Sewerage Authority has the capacity to accept wastewaters from this proposed development.

3) A main sewer line already exists on Route 72 adjacent to the Ocean Acres Development. Roads throughout the site have already been constructed and the subsurface environment is conducive to sewer line construction with minimal effort.

4) Construction of a sanitary sewer system would be somewhat offset by the lack of need for the installation and operation of septic systems.

To implement the above plan, it is incumbent that the two (2) townships involved initiate a program to finanace these systems. The assessment of the cost to cover the sewers would be charged to each individual lot owner(s), even if such lots are unimproved.

A plan may be devised utilizing options 2 or 3 until sufficient density warranted installation of sewers. Implementation of a plan requires approval by the Pinelands Planning Commission and the Department of Environmental Protection, Division of Water Resources.

REFERENCES

1) Alternatives for Small Wastewater Treatment Systems. Part 1. On-Site Disposal/Septage Treatment and Disposal. EPA 625/4-77-011, October 1977.

2) Alternatives for Small Wastewater Treatment Systems. Part 3, Cost/Effectiveness Analysis. EPA 625/4-77-011, October 1977.

3) Bass River Township Project by L. Douglas. Center for Coastal and Environmental Studies, Rutgers, Unitersity, 1977.

4) "Bass River Methodology" Presentation to DEP, Rutgers University, 1977

5) Climatological Data, Pine Barrens, 1977, for Chatsworth, Hammonton, Indian Mills and Pemberton Stations.

6) "Denitrification in Subsoils of North Carolina Coastal Plain as Affected by Soil Drainage." Journal Environmental Quality, Volume 4, Nov. 3, 1975.

7) "Development of Criteria for Wastewater Management Policy Related to Population Density." (Long Island 208 Study) by Geraghty & Miller, Inc. 1978.

8) "Disposal of Septic Tank Effluent in Soils", by John M. Cain and M. T. Beatty appearing in Focus on Environmental Geology, 2nd. end. Ronald W. Tank, ed, New York, Oxford University Press, 1976.

9) On Site Disposal of Small Wastewater Flows University of Wisconsin, 1977

10) Effects of Septic Tank Effluent on Groundwater Quality in New Jersey Pine Barrens, by Thomas J. Harlukowicz and R. C. Ahlert, Rutgers College of Engineering, Nov. 1978 (Final Report to the Rockefeller Foundation).

11) Environmental Effects of Septic Tank Systems, by Marion R. Sealf and William Dunlap EPA-600/3-77-096, Aug. 1977.

12) Geology and Ground-Water Resources of Ocean County, N.J. by H. R. Anderson and C. A. Appel, U.S. Geological Survey. Report No. 29

13) A Hydraulic Analysis of the N.J. Pine Barrens Region, by E. C. Rhodehamel, U.S. Geological Survey, Water Resources Circular No. 22, 1970.

14) Influence of Domestic Waste Water Pretreatment on Soil Clogging, by R. Leek.

15) Interim Soil Survey Report, Ocean County, N.J., prepared by U.S. Department of Agriculture, Soil Conservation Service, July, 1976.

16) Land Treatment of Municipal Wastewater Effluents, Design Factors - I. EPA 625/4-76-010, January, 1976.

17) Land Treatment of Municipal Wastewater Effluents, Design Factors II. EPA 625/4-76-010, January, 1976.

18) Manual of Grey Water Treatment Practice. Ann Arbor Science 1974.

19) Nitrogen Removal in a Modified Residential Subsurface Sewage Disposal System Pilot Plant Study by Aldo Andreoli, et al, Suffolk County Department of Health Services, Oct. 1977.

20) Nitrate Contamination of the Water Table Aquifer in Delaware, Report on Investigation No. 20, Delaware, May 1972 (Miller).

21) Nutrient, Bacterial, and Virus Control as Related to Groundwater Contamination by James F. McNabb et al. EPA 600/8-77-010, July 1977.

22) On Site Wastewater Disposal for Homes in Unsewered Areas, University of Wisconsin.

23) "Research Project on Septic Tank Systems," Virginia Polytechnic Inst., March, 1973.

24) "Septic Tank Effluent Percolation through sands under Laboratory Conditions", Soil Science, 1975

25) "Soil Absorption of Septic Tank Effluent," Information Circular #20, University of Wisconsin, 1972.

26) "Survival and Movement of Fecal Bacteria in Soil under Conditions at Saturated Flow" Journal of Environmental Quality, Volume 7, No., 1, 1978.

27) "Waste Characteristics", William C. Boyle, Dept. of Civil & Environmental Engineering, University of Wisconsin. (Land Treatment of Waste Wastewater System Design, Nov. 1978, Short Course).

28) "Soils, Septic Systems and Carrying Capacity in the Pine Barrens", John J. Trela and Lowell A. Douglas, in, Natural and Cultural Resources of the New Jersey Pine Barrens Stockton State College, Pomona, N.J. pp 37-58

29) Files of the NJDEP-Div. of Water Resources, Bureau of Water Quality Planning and Management, Lake Management Section.

30) Files of the Burington County Health Dept.

31) Files of the NJDEP-Atlantic Basin Shellfish Control Unit.

Nitrogen: Nitrates, Nitrites and N-nitroso Compounds and Water Quality

Prepared by: John J. Trela, Bureau of Water Quality Planning and Management, Ground-Water Management Section

Introduction: Some basic principles

Nitrogen occurs in a variety of forms. As a gas it may occur as molecular nitrogen (N_2), nitrous oxide (N_2O) or as ammonia (NH_3). It also occurs in combined forms such as amine (nitrogen with variable amounts of hydrogen and univalent hydrocarbon radicals) and amide (nitrogen with variable amounts of hydrogen and univalent acid radicals) groups, ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-).

The various chemical forms of nitrogen interact with the organic (animals and plants) and the inorganic (soil, water, and atmosphere) components of the environment. In its various forms, nitrogen is cycled or transferred from plant and animal tissues to soils or waters and then to the atmosphere as a gas. Nitrogen gas may be absorbed by some organisms and incorporated into protein. The nitrogen may be passed from one organism to another through the food chain or it may be transferred to the environment by the decomposition of tissues or through excrement. This cycling of nitrogen from living organisms through soils and waters to the atmosphere and back to living organisms is known as the nitrogen cycle. The nitrogen cycle is composed of a variety of processes. A process whereby organisms absorb atmospheric nitrogen and incorporates it into their tissues is known as nitrogen fixation. The conversion of ammonia or ammonium (through an intermediate stage of nitrite) to nitrate is known as nitrification. The process of denitrification occurs under anerobic conditions (environments without oxygen) when nitrate may be converted to nitrite, molecular nitrogen, nitrous oxide or, in some circumstances to ammonium or ammonia.

The occurrence and interrelationships of the various forms of nitrogen in the nitrogen cycle are complex but may be generalized as follows. The amide and amine groups occur in soil organic matter and as components of plant and animal protein. The decomposition of protein, soil organic matter and urea often produces ammonia or ammonium. The complete oxidation of ammonium or ammonia by microorganisms produces nitrate. Incomplete oxidation of ammonia or ammonium by microorganisms produces nitrite. Nitrite may be produced from nitrate (or ammonium) by certain microorganisms found in soil, water, sewage, and the digestive tract. Under oxygenated conditions in soils and waters most of the nitrogen occurs in the form of nitrate. Under conditions of poor oxygenation, nitrate often occurs as ammonium or nitrite.

Sources of Nitrogen

For the purpose of discussion, the sources of nitrogen may be subdivided into two major categories; point sources and non-point or diffuse sources. Some of the major point sources of nitrogen include, municipal and industrial wastewater, septic tanks, feedlot discharges, and leachate from waste disposal dumps and sanitary landfills. Diffuse sources of nitrogen include atmospheric fallout, mineralization of soil organic matter, animal wastes, lawn and farm fertilizers, and nitric oxide and nitrite discharges from combustion processes such as auto exhaust. By definition, diffuse sources of nitrogen are "spread-out" over the landscape and often add nitrogen in lower concentrations per unit area of land than point sources. Conversely, point sources often add less total nitrogen than diffuse sources, however the concentrations immediately adjacent to the source may be high. (It should be noted that these are generalities which may not be valid in all cases.) We are concerned, however, with those sources of nitrogen that may produce high concentrations of nitrogen in surface or ground water. Hence, in most cases, concern is focused on point sources.

Hazards of Nitrate and Nitrite to Human Health

Man is exposed daily to nitrate and nitrite in drugs, water and food. When the concentrations of nitrate and nitrite are low no harm results. If however, the concentration of nitrate and nitrite are high the potential exists for illness and even death to both livestock *and humans. Nitrates are generally toxic when there is the potential for their chemical conversion to nitrites.

Acute Toxicity

The symptons associated with acute nitrite toxicity have been summarized by Luhrs (1973) as follows:

> "The major clinical manifestation of acute nitrite toxicity is cyanosis (a bluish-purple discoloration of the skin and lips, which generally occurs within 1 to 2 hours after exposure if unrelieved by oxygen therapy). There may be nausea, vomiting, and profuse sweating--in severe cases, lethargy--

*(Although we are not directly concerned with the adverse effects of high nitrate on livestock we should note that a variety of hazardous effects on livestock have been associated with high nitrate or nitrite concentrations (see for example, Keller and Smith, 1967 and Maynard et al. 1976). These include; oxygen deficiency (methemoglobinemia), decrease in milk production, reduced rate of gain (unthriftiness), reproductive difficulties and abortions, vitamin A deficiency, thyroid disturbances (iodine deficiency), rapid heartbeat peripheral vasodilation, vomiting, diarrhea, and death. Nitrosamines have been associated with cancer, mutations and birth defects (see Maynard et al. 1976 and Luhrs, 1973) Nitrosamines are produced by the reaction of nitrite with certain organic amines.)

progressing to unconsciousness. Blood drawn from a patient with nitrite-induced cyanosis is a chocolate-brown color. These manifestations are explained by the oxidation of hemoglobin, the oxygen-carrying red pigment of blood, into methemoglobin, which is a brown pigment incapable of carrying oxygen. Death from asphyxia (suffocation) may result when large amounts of methemoglobin are formed and oxygen transport is severely impeded."

Methemoglobin is normally present in blood, constituting about 1 percent of the total hemoglobin of a healthy adult, 4 percent in healthy newborn infants and 6% or greater in infants with respiratory illness or diarrhea (Luhrs, 1973; Maynard, 1976). Cyanosis results when about 15% of the hemoglobin is converted to methemoglobin. When methemoglobin constitutes 70 percent or more of the total hemoglobin death may occur. Nitrates are toxic to man because of the potential for their conversion to nitrite. The conversion may occur outside the body (in food or water) or inside the body (by the action of intestinal bacteria on ingested nitrates).

Infants are more susceptible to nitrite toxicity than adults for the following reasons;

1) hemoglobin of a very young infant (fetal hemoglobin) is converted to methemoglobin twice as rapidly as the hemoglobin of children or adults.

2) the red blood cells of infants are not able to convert methemoglobin back into hemoglobin as well as adults.

3) infants with gastrointestinal infections and gastric pH insufficiently acid to kill nitrate/nitrite converting bacteria have very special conditions in the upper gastrointestinal tract which make them more susceptible to nitrite production and absorption (Luhrs, 1973).

Although it is most often infants who are most susceptible to nitrite poisoning, other segments of the population must be cautious against ingestion of nitrate or nitrite. These include individuals born with congenital defects such as high methemoglobin levels or unstable hemoglobin, adults who are exposed to conditions which increase methemoglobin accumulation (e.g., medications for heart disease), or those who are anemic.

Chronic Toxicity

In comparison to the relative wealth of information available on acute toxicity in humans, reliable data are lacking on the physiological effects, if any, of chronic nitrate/nitrite toxicity or mild, non-cyanotic methemoglobinemia (Luhrs, 1973). Many chronic adverse effects in animals, as previously cited, have been linked to ingestion of nitrates/nitrites however, data demonstrating a "cause and effect" relationship of these ailments in humans is lacking. Nitrate/nitrite toxicity must be classified as a "suspected or possible" cause in some cases. It should be emphasized that one of the more important aspects of chronic nitrate/nitrite toxicity are the potential carcinogenic effects.

Health Hazards Associated with N-nitroso Compounds

Nitrosamines are formed by the reaction of nitrites and organic compounds known as amines. Nitrites (and their precursor, nitrate) are present in food, water, drugs and human saliva. Amines are found in food, tobacco smoke, beer, wine, tea, toothpaste and hundreds of drugs. Certain nitrosamines have been found to be carcinogenic in animals. The concern about the potential hazards to human health arise from;

1) contact with preformed carcinogenic nitrosamines and,

2) the formation of carcinogenic nitrosamines within the human body after exposure to precursor nitrites and amines (Tuhrs, 1973).

The Toxicity of nitrosamines has been summarized by Luhrs (1973) as follows;

"Nitrosamines have potent biological effects, including acute cellular injury (primarily involving the liver), carcinogenesis, mutagenesis, and teratogenesis. Approximately a hundred nitrosamines have been tested so far in animals. The vast majority are carcinogenic. Many species of animals and many different organs (the liver, esophagus, and kidneys) are susceptible to the cancer-producing effects of these compounds. These effects can be elicited experimentally by various routes of nitrosamine adminstration (oral, intravenous, inhalation) by extremely low doses (ppm) of nitrosamines and, in some instances, after only one exposure.

Studies showing certain nitrosamines to be potent carcinogens in a wide range of animal species, including the monkey, suggest that the same compounds would also be carcinogenic for man. However, at present, there is no definitive data confirming this hypothesis".

Recent studies (Tannenbaum, 1978) of the nitrate balance in humans indicate that nitrate and nitrite are formed in the human intestine, possibly by heterotrophic nitrification. "The findings significantly alter our previous conceptions of human exposure to nitrite and suggest an even wider role for nitrite in the etiology of human cancer." The combined effects of nitrite and nitrate produced in the human intestine and nitrites and nitrate ingested in food or drinking water on cancer awaits investigation. Earlier studies (Tannenbaum, 1976) had established that high nitrate intake can lead to large increases in the concentration of salivary nitrite. This implicitly raises the potential for the formation of nitrosoamines.

Nitrates in Potable Waters

Comly (1945) first correlated the large amounts of nitrates in well-water with infant cyanosis. Walton (1951) surveyed the literature (90 articles) and reported 278 cases of methemoglobinemia and 39 deaths in 18 states from this disease. This survey showed that there were no cases of methemoglobinemia where the nitrate nitrogen content of the water was less than 10 ppm. Sattelmacher (1962, cited by Nichols 1965) considered 249 references and concluded that the limiting value of nitrate nitrogen in drinking water to prevent methemoglobinemia was 6.8 ppm. Luhrs (1973) reports that consumption of water containing high levels of nitrates has accounted for more cases of methemoglobinemia than all other causes combined (nearly 2,000 reported in the U.S. and Europe). Almost all cases have been reported in infants; approximately 7 or 8 percent of affected infants died. The United States Environmental Protection Agency (1976) reports, "high nitrate concentrations frequently are found in shallow farm and rural community wells, often as the result of inadequate protection from barnyard drainage or from septic tanks."

Conclusions

Two health hazards are associated with the consumption of water containing large concentrations of nitrate (or nitrite);

1) induction of methemoglobinemia, particularly in infants

2) possible formation of carcinogenic nitrosamines.

It is the position of the N.J.D.E.P. that the concern over the hazardous effects of nitrates, nitrites and nitrosoamines is justified. Furthermore, it is the Department's opinion that the present potable water criteria for nitrate-nitrogen (10 mg/l) are scientifically justifiable and that the maintenance of potable water at or below this level is in the best interest of public health, well-being, and safety.

References

1) Comly, H.H. 1945. "Cyanosis in Infants Caused by Nitrates in Well Water" Journal American Medical Assocation 129:112-116.

2) Keller, W.D. and Smith, G.E. 1967. "Ground Water Comtamination by Dissolved Nitrate" Geological Society of America, Special Paper 90.

3) Tuhrs, C.E. 1973. "Environmental and Health Effects of Nitrogenous Compounds"; In, Nitrogenous Compounds in the Environment Hazardous Materials Advisory Committee, U.S. Environmental Protection Agency, EPA-SAB-73-001.

4) Maynard, D.N. et al. 1976. "Nitrate Accumulations in Vegetables" Advances in Agronomy, Vol. 28:71-118.

5) Nichols, M.S. 1965. "Nitrates in the Environment" Journal of the American Water Works Association. Vol. 57:1319-1327.

6) Tannenbaum, S.R. et al., 1976. "The effect of nitrate intake on nitrite formation in human saliva" Food and Cosmetic Toxicology Vol. 14:549-552.

7) Tannenbaum, S.R. et al. 1978. "Nitrite and Nitrate are formed by Endogenous Synthesis in the Human Intestine" Science, Vol. 200:1487-1489.

8) Walton, G. 1951. "Survey of Literature Relating to Infant Methemoglobinemia Due to Nitrate-Contaminated Water" American Journal of Public Health. Vol. 41:986-996.

9) U.S. Environmental Protection Agency, 1976. "Nitrates, Nitrites" pages 104-110, In Quality Criteria for Water USEPA Washington, D.C.