# Septic Systems and Nitrate Nitrogen as Indicators of Ground Water Quality Trends in New Jersey

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*Abstract: Controlling ground water quality is a major environmental goal for New Jersey citizens. Controlling nitrate nitrogen in ground water is particularly important because of the risk it poses to human health, and because of its ability to enter streams and lakes and to enhance the harmful process of eutrophication. In order to control nitrate levels in ground water and surface water, it is necessary to control where and how septic systems are constructed, because nitrate nitrogen is a natural component of onsite waste disposal (septic system) effluent. By reviewing United States census data, it is possible to evaluate onsite waste disposal nitrate loading trends. Between 1970 and 1990 New Jersey's population increased by more than 500,000 persons; a 7.1% increase. During this same period, the number of onsite sewage disposal systems (septic systems) in the state decreased by about 70,000; a 16% decrease. The decrease in the number of onsite disposal systems is probably the result of municipal sewer system construction projects that proliferated during those same years. When viewed on a statewide basis, there now are fewer septic systems and decreased nitrate mass loading, but this is not true for all counties or municipalities. Counties that were primarily rural in 1970 have become more developed and nitrate mass loading from the septic systems has increased since 1970. These developing counties are at risk from new nitrate loading from septic systems and from associated impacts of suburban development. Without careful planning, increased nitrate loading from septic systems is likely to create additional burdens on ground water and surface water in these rapidly developing areas of the state.*

## Introduction

Nitrate nitrogen is a naturally occurring essential plant nutrient. It is a fundamental component of amino acids which are the building blocks of proteins in plant tissue. When animals consume plants, the nitrogen in the plant proteins are assimilated into animal proteins. When the plants or animals die, the proteins are decomposed, primarily by bacteria, releasing the nitrogen back into the ground. The nitrogen, released as nitrate or ammonia is rapidly assimilated by another plant or animal, and the "Nitrogen Cycle" is complete.

In most natural ecosystems, nitrogen in the form of nitrate or ammonia are limiting nutrients, and little of either are lost to leaching or recharge into the ground water or surface water. Mankind, however, has disturbed the natural "Nitrogen Cycle" through agriculture and waste disposal practices. Thus, excess nitrogen is often produced in areas occupied by man, resulting in nitrogen compounds entering ground water or surface water, where they are often considered pollutants.

New Jersey's ground water has nitrate concentrations that tend to be far below the drinking water standards. Statewide ambient nitrate levels typically occur at less than 1 mg/L, whereas the federal drinking water standard is 10 mg/L. Any level of nitrate above the natural ambient level represents a concern that man is having a negative impact on water quality. Drinking ground water that contains elevated levels of nitrate poses a health risk for humans. The ecological health of surface water is at risk from high levels of nitrate because it enhances the harmful process of *eutrophication*, especially when phosphates are abundant. In New Jersey, the major sources of nitrate mass loading to waters of the state (measured in pounds per year) are natural sources, agriculture, fertilizer impacts from suburban development, and septic systems.

The “natural” sources of nitrate are plant and animal decay and precipitation. These natural sources are ecologically important, and they are not normally at levels likely to cause pollution problems. However, natural sources from waterfowl (Canada geese) are increasing in some areas, and effective controls are elusive. Natural loading from precipitation is typically about 1 or 2 pounds per year per acre in New Jersey, but due to air pollution, it may be increasing. Reduction of air pollution sources requires additional control of automobile emissions, which is a significant task. In general, natural sources of nitrogen may be increasing due to the impact of man, but they are still quite low and can be tolerated by the global ecosystem.

Agriculture, through overuse of fertilizers or improper management of animal wastes, can cause significant loading of nitrogen into streams and ground water. Studies conducted by the United States Geological Survey indicate that agricultural areas in the coastal plain typically have elevated ground water nitrate levels. However, United States Department of Agriculture initiatives are continuing to encourage and educate farmers to practice nitrogen management, and great progress is being made in controlling these sources.

Suburban development results in substantial use of lawn fertilizer. As suburbia grows, so too does lawn fertilizer use, but it is not clear by how much. Universities recommend using about 3 pounds of nitrogen per 1000 square feet of lawn. This amounts to about 130 pounds per acre. Not all the nitrogen is nitrate, and not all of it enters the ground water, but unless the clippings are removed, much of it does. Future studies by NJDEP will attempt to determine the actual mass loading from this source. If it is found to be excessively high, future NJDEP initiatives will provide guidance and encourage prudent use of lawn fertilizers in certain areas.

Nitrate loading from domestic septic systems is the last but not least source, and it is not currently being controlled. Loading from septic systems could be controlled, though not easily, through planning and establishment of zoning that limits where septic systems are located, how they are constructed, and the number of onsite systems that are located in a given area. Large flow onsite sewage disposal systems like strip malls, schools, and small businesses located in areas not served by public sewers also generate significant nitrate loading. These facilities are being controlled and must maintain nitrate loading at acceptable levels since they are required to comply with NJPDES permits issued by the NJDEP.

It is the nitrate loading from domestic septic systems that is emphasized in this report, because this source is not currently being controlled, and because it represents a significant mass loading contribution in some areas.

## Environmental Characteristics of the Septic System

Modern domestic septic systems, when properly constructed and operated, safely control pathogens, thereby protecting against epidemics and outbreaks of various diseases. They also convert organic nitrogen to ammonia nitrogen and they direct the wastewater to the subsurface, effectively eliminating odors and most surface water pollution. Thus, pathogens and ammonia nitrogen are only a concern when a septic system is constructed or operated improperly. But contrary to popular belief, even properly functioning septic systems generate a certain amount of pollution. When conventional septic systems operate properly, they effectively convert organic nitrogen first to ammonia nitrogen, then to the nitrate form of nitrogen. Nitrate nitrogen is soluble and generally non-degradable in ground water and it is the nutrient or pollutant most commonly identified when people talk about the pollution risk from septic systems.

Each domestic septic system in New Jersey is estimated to discharge about 32 pounds of nitrate nitrogen annually. This mass loading rate is based on the amount of total nitrogen produced by each person, and the conversion of total nitrogen to nitrate nitrogen that occurs in the soils. A simple way to calculate mass loading is to multiply three factors together; the number of people per home, the annual flow, and the concentration of nitrate. Applying these factors as in the equation below, annual nitrate loading from each home septic system equals 14.49 kg, or 32 pounds[i], since there are 2.24 pounds per kg. Another way to express this mass loading is to base it on the per capita total nutrient load, expressed in grams per day. Thus, for Total Nitrogen, 13 g/day are generated by each person as measured in the household waste stream[ii].

Nitrate nitrogen generated by septic systems is water-soluble and easily percolates through the ground and enters the ground water. This increases the nitrate concentration of ground water to some extent, but much of the nitrate entering the ground does not go deeply, and it emerges into surface water (streams, lakes) as base flow. Therefore, when ground water has elevated levels of nitrate, surface water may also become contaminated too.

Nitrate is considered to be a non-degradable or "conservative" pollutant in ground water. It degrades only slightly by the biological process of *denitrification*, but conditions conducive to *denitrification* (low oxygen content, high organic matter content) rarely occur near properly sited septic systems. Conservative pollutants can only be attenuated (minimized) by dilution or advanced treatment. Thus, to reduce the nitrate risk it is necessary to provide adequate lot sizes for dilution, or to institutionalize advanced treatment type onsite sewage disposal systems. At this time, neither strategy is being actively implemented in New Jersey for domestic onsite sewage disposal systems, except when "50 or More Realty Improvement" certifications are issued by the Department of Environmental Protection (NJDEP), because these limit the number of lots that can be built on a subdivision. The NJDEP is aware that strategies to control the risk from septic systems are important if we are to protect our water supplies, and they will likely become more widely implemented in the future.

## Data Characteristics

Official United States census data [iii]were reviewed for all New Jersey counties. The census reports provided the number of septic systems per county. Data obtained from the 1970, 1980, and 1990 census reports allows one to review trends over time. At the time this report is written, there is no updated information regarding the trends after 1990. The census data is the only available data compiled to assess statewide statistics even though the local health departments maintain records of the number of septic systems they permit. In the future, better record keeping by the NJDEP and better coordination with the local health departments may enable a more precise and timely tally of trends.

In order to simplify display of the data, counties were placed into several trend classes, based on whether they had an increase or decrease in the number of septic systems. A *major increase* means that over 500 pounds per day more nitrate is being generated on a daily basis. A minor increase means that between 100 and 500 pounds per day more nitrate is being generated on a daily basis. A *major decrease* means that between more than 500 per day less nitrate is generated on a daily basis. A *minor decrease* means that between 100 and 500 pounds less nitrate is being generated on a daily basis. No *significant change* is indicated when less than 100 pounds per day increase or decrease is observed.

Nitrate loading is not a measured value but is an estimate. It is estimated based on a reasonable assumption that each home is occupied by 3.5 people, that each person generates 75 gallons per day of septic system wastewater, and that the septic effluent enters the groundwater at a concentration of 40 mg/L. Although these numbers are similar to other published data from affluent areas of the United States, there are other ways to calculate loading rate which could result in slightly higher or lower mass loading values. For example, new data suggests that there may be only 3 persons per home (or less), and that they each use about 85 gallons of water per day. The NJDEP is studying these trends and will modify the mass loading estimates if necessary in the future.

The data are available from the Bureau of Nonpoint Pollution Control by calling (609) 292-7021.

## Discussion

Between 1970 and 1990 New Jersey's population increased from 7.2 million to 7.7 million, and it is estimated as over 8 million in 1996. During this same period, the number of septic systems increased from 404,231 to 336,310. Consequently the nitrate loading to ground water from septic systems has generally decreased by over 4,100 pounds per day (Figure 1). This reduction occurred because of the increased availability of municipal sewer systems. At least from the septic system source, ground water all over the State is becoming cleaner with respect to nitrate, but this is not necessarily the case in all counties and municipalities.

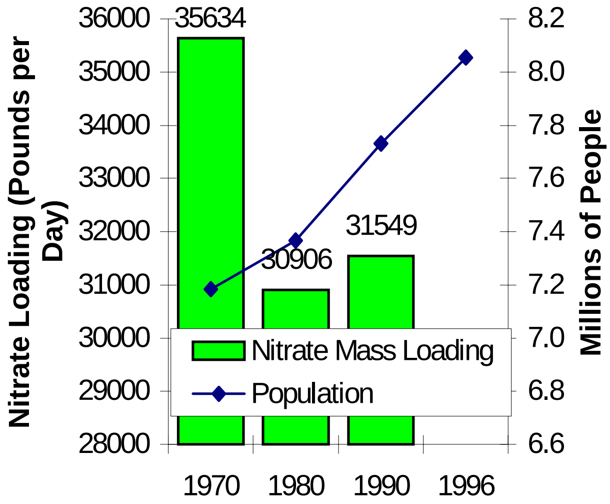


**Figure 1. Nitrate loading to ground water from septic systems in New Jersey over three decades, compared to population growth.**

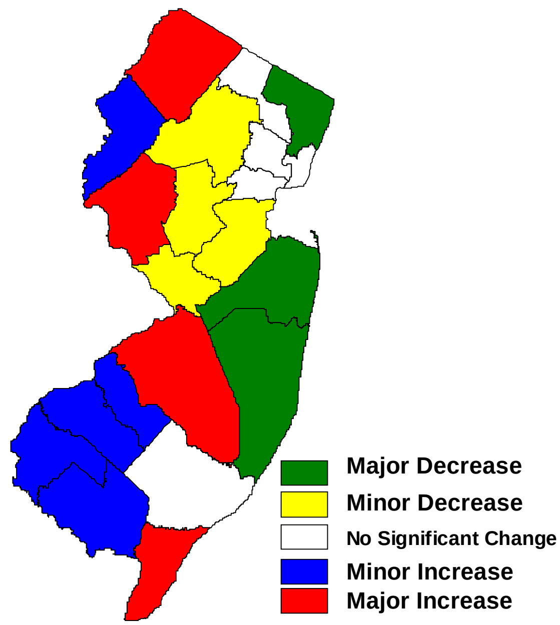


**Figure 2. Change in nitrate loading to ground water from septic systems in New Jersey counties, between 1970 and 1990.**

Further evaluation of the data (Figure 2) reveals that some counties had a net loss of nitrate loading, measured in pounds per day, while others had a net increase in loading. Counties that were mostly rural in 1970 have become more developed and have higher nitrate loading than in 1970. These once rural counties are Sussex, Hunterdon, Burlington, Cape May, Cumberland, Warren, Salem, Camden, and Gloucester. The developing counties may be at risk from the pressures of new nitrate loading, and without careful planning, the nitrate loading is likely to create additional burdens on ground water and surface water in these areas. The New Jersey Department of Environmental Protection is currently considering planning and zoning strategies in conjunction with State development plan objectives, to control rural development and to ensure that septic system density is protective of the water resources. In addition, the Department is evaluating strategies for enabling the use of advanced treatment technologies that will control or minimize the pollutant loading from septic system effluent.

Table 1. Estimated nitrogen loading in New Jersey, based on the number of homes using septic systems.

| County | Number of Homes 1990 | Homes with Septic Systems | | | Nitrate Loading (Pounds per Day) | | | Nitrate Loading Change (Pounds per Day) | Map Color |
|---|---|---|---|---|---|---|---|---|---|
| | | 1970 | 1980 | 1990 | 1970 | 1970 | 1990 | | |
| ATLANTIC | 106877 | 19774 | 19192 | 20784 | 1743 | 1692 | 1832 | 89.0 | |
| BERGEN | 324817 | 48589 | 19303 | 16871 | 4283 | 1702 | 1487 | -2796.0 | |
| BURLINGTON | 143236 | 17614 | 21589 | 23973 | 1553 | 1903 | 2113 | 560.6 | |
| CAMDEN | 190145 | 10820 | 12194 | 12176 | 954 | 1075 | 1073 | 119.5 | |
| CAPE MAY | 85537 | 10820 | 10134 | 16601 | 954 | 893 | 1463 | 509.6 | |
| CUMBERLAND | 50297 | 15853 | 18381 | 20682 | 1397 | 1620 | 1823 | 425.7 | |
| ESSEX | 298710 | 2717 | 1244 | 1657 | 240 | 110 | 146 | -93.4 | |
| GLOUCESTER | 82459 | 17865 | 16867 | 19796 | 1575 | 1487 | 1745 | 170.2 | |
| HUDSON | 229682 | 676 | 591 | 834 | 60 | 52 | 74 | 13.9 | |
| HUNTERDON | 39987 | 16653 | 20626 | 24408 | 1468 | 1818 | 2152 | 683.6 | |
| MERCER | 123666 | 9861 | 10438 | 7714 | 869 | 920 | 680 | -189.3 | |
| MIDDLESEX | 250174 | 10956 | 6881 | 5659 | 966 | 607 | 499 | -466.9 | |
| MONMOUTH | 218408 | 52686 | 23312 | 21446 | 4644 | 2055 | 1891 | -2753.9 | |
| MORRIS | 155745 | 48605 | 47690 | 46170 | 4285 | 4204 | 4070 | -214.7 | |
| OCEAN | 219863 | 46973 | 34169 | 25405 | 4141 | 3012 | 2240 | -1901.3 | |
| PASSAIC | 162512 | 15515 | 16980 | 15761 | 1368 | 1497 | 1389 | 21.7 | |
| SALEM | 25349 | 8110 | 9598 | 10409 | 715 | 846 | 918 | 202.7 | |
| SOMERSET | 92653 | 17618 | 14856 | 12371 | 1553 | 1310 | 1091 | -462.5 | |
| SUSSEX | 51574 | 19739 | 32794 | 39724 | 1740 | 2891 | 3502 | 1761.7 | |
| UNION | 187033 | 958 | 548 | 862 | 84 | 48 | 76 | -8.5 | |
| WARREN | 36589 | 11829 | 13211 | 14587 | 1043 | 1165 | 1286 | 243.1 | |
| Entire State | 3075313 | 404231 | 350598 | 357890 | 35634 | 30906 | 31549 | -4085.1 | |

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[i] $\text{Nitrate Loading} = 3.5\frac{\text{persons}}{\text{Home}} * 75\frac{gallons}{day * person} * 365\frac{day}{year} * 3.78\frac{L}{gallon} * 40\frac{mg}{L} * 1\frac{kg}{1*10^6 mg} = 14.49\frac{kg}{year * Home}$

[ii] Laak, Rein. 1980). Wastewater Engineering Design for Unsewered Areas. Ann Arbor Science Publishers, Inc. Ann Arbor, Michigan. 179 p..

[iii] United States Census Data. Report 1999, CH-2-32, Table 66.