Approved by NGWA Board of Directors: 1/13/2009

NGWA Best Suggested Practice

Reducing Problematic Concentrations of Nitrates in Residential Well Systems

Introduction

As a benefit to members of the National Ground Water Association, best suggested practices are developed to offer suggestions as to how best to deal with a circumstance related to water well systems and other groundwater-related practices, and to develop solutions that are expected to be of high dependability. Because of varying geologic conditions and other factors, it is not practical to develop a totally prescriptive guideline.

This document provides the water well systems professional (WWSP) the basic knowledge and suggested practices needed to serve the needs of the residential well owner related to the occurrence of nitrates in groundwater and their implications for the construction of a residential water well system, including the selection of treatment equipment as required.

There are references throughout this document to public health standards in the United States; other nations may have different standards.

By knowing the potential sources of, and reasons for, the presence of nitrates in groundwater used by a residential well system, the WWSP can take proactive steps to locate and construct a new well to minimize the concentration of such constituents. Likewise, the WWSP has the basic knowledge, experience, and equipment to help the homeowner ensure good-quality groundwater from an existing well. If physical inspection of an existing water well system shows no obvious defects and the water well is constructed in an appropriate aquifer, water quality testing becomes the first step. To obtain a valid water quality sample requires the well be clean (see NGWA's Best Suggested Practice, *Residential Well Cleaning*, August 2008).

Sometimes the concentrations of select constituents will prove to be unacceptably high even after careful site selection and well construction, or after cleaning an existing well. The WWSP can recommend cost-effective water treatment options to mitigate such problems. For instance, it may be less expensive for the consumer to install an appropriate water treatment technology to remove or lower concentrations of a contaminant than to replace or deepen an existing well or to use a more expensive drilling technology to emplace a new well. On the other hand, if a water intake area in an existing well has to be replaced or an aquifer lined off, economics will probably

national ground water association®

Phone/ Toll-free 800 551.7379/ 614 898.7791 **Fax/** 614 898.7786
Web/ www.ngwa.org and www.wellowner.org
Address/ 601 Dempsey Road/ Westerville, Ohio 43081-8978 U.S.A

dictate that a new water well be constructed. Such decisions are site-specific and, thus, based on careful analysis by the WWSP.

- Section 1 offers background on the health effects from excessive levels of nitrates and the related regulatory responses.
- Section 2 is guidance about how geologic conditions and land-use settings may affect the concentrations of nitrates in groundwater.
- Section 3 provides a description of well location and construction methodologies related to minimizing the presence of nitrates. Generally, all construction and maintenance practices must comply with local and state requirements.
- Section 4 deals with well operations.
- Section 5 deals with water sampling methods and water treatment options.

Definitions

Contaminant:

Any physical, chemical, biological, or radiological substance or matter in water that has an adverse impact.

Maximum Contaminant Level:

Under the U.S. Safe Drinking Water Act, the maximum allowable concentration of some contaminants in surface or groundwater to be used in the drinking water supply.

Microgram:

A unit of mass equal to 1/1,000,000 of a gram (1×10^{-6}), or 1/1000 of a milligram. Expressed as µg.

Milligram:

A unit of mass equal to one thousandth (1×10^{-3}) of a gram. Expressed as mg.

Nitrate:

An oxidized ion of nitrogen. Nitrifying bacteria can convert nitrites to nitrates in the nitrogen cycle. Sodium nitrates and potassium nitrates are used as fertilizer. The nitrate ion is regulated by the U.S. Environmental Protection Agency.

Nitrite:

A salt or ester of nitrous acid.

Point-of-Entry (POE) Treatment Device:

A treatment device applied to the drinking water entering a house or building to reduce the contaminants in the water distributed throughout the house or building.

Point-of-Use (POU) Treatment Device:

An approach to the management of the quality of drinking water that locates a water treatment device at the distribution points in an individual household.

Residential Water Well System:

The well system used by a private household, including the well, pumping equipment, and treatment equipment, if needed.

Well:

Any test hole or other excavation that is drilled, cored, bored, washed, fractured, driven, dug, jetted, or otherwise constructed when intended use of such excavation is for the loca-

“Nitrates are nitrogen-oxygen chemical units that combine with various organic and inorganic compounds. They are essential nutrients for plants, which absorb them from soil. The excess nitrates not used by the plants are carried through the soil to groundwater in a process called leaching.

tion, monitoring, dewatering, observation, diversion, artificial recharge, or acquisition of groundwater, or for conducting pumping equipment tests or aquifer tests.

1. About Nitrates

Nitrates are nitrogen-oxygen chemical units that combine with various organic and inorganic compounds. They are essential nutrients for plants, which absorb them from soil. The excess nitrates not used by the plants are carried through the soil to groundwater in a process called leaching. Once in water, they remain there until used by plants or organisms.

Because nitrates do not bind to soils and are highly water soluble, they easily travel through the soil into groundwater supplies from sources such as fertilizers, animal manure, sewage, septic systems, industrial effluent, landfills, and decaying plants and animals. Certain plants (legumes) harbor bacteria which are capable of creating nitrates from nitrogen gas in the air, and most plants utilize nitrates as nutrients from the soil. Many food crops require fertilization to provide the necessary quantities of nitrates.

The greatest source of nitrates in groundwater is thought to be fertilizers used to provide nitrates to crops. Animal and human waste also contains nitrogen in the form of ammonia. Decomposing plants and animal materials also generate nitrates.

Nitrates are very soluble and do not bind with soil, so the potential is high for them to migrate to groundwater. This is particularly true if the well system is near agricultural land or animal feedlots. Incidents such as heavy rains, flooding, chemical spills, or failed sewage systems can cause nitrates to enter soil near a residential water well system, also.

The U.S. EPA's maximum contaminant level (MCL) for nitrates in drinking water is 45 mg/L (as nitrates) or 10 mg/L, expressed as nitrogen. The MCL for nitrite is 1 mg/L.

Residential wells are not covered by the U.S. EPA Safe Drinking Water Act; however, some states and municipalities require that new residential water wells be tested for nitrates. Additionally, requirements for testing of residential wells for nitrates may be included in property transfer laws or as a stipulation of the lender.

“. . . some states and municipalities require that new residential water wells be tested for nitrates. Additionally, requirements for testing of residential wells for nitrates may be included in property transfer laws or as a stipulation of the lender.

The U.S. EPA's health effect from nitrates of most concern is the “blue baby syndrome” (methemoglobinemia), seen most often in infants exposed to nitrates from drinking water used to make baby formula. Infants ages 0 to 3 months are at the highest risk for blue baby syndrome because their normal intestinal flora contributes to the generation of methemoglobin.

Exposure to higher levels of nitrates has been associated with increased incidence of cancer in adults, and possible increased incidence of brain tumors, leukemia, and nasopharyngeal (nose and throat) tumors in children in some studies.

Health effects associated with nitrates or nitrite exposure during pregnancy include increased incidence of intrauterine growth retardation, cardiac defects, central nervous system defects, sudden infant death syndrome (SIDS), and miscarriage.

2. Geologic Settings and Land Uses

Some local and state government agencies have access to records that may identify areas likely to have water quality challenges. The WWSP should check for these data and, if available, consider the information when preparing to construct and/or service a residential water well system.

Nitrate concentrations in samples from background sites sampled by the U.S. Geological Survey for a 1996 report generally were less than 2 mg/L for groundwater.

Because nitrate contamination above the MCL typically is a result of human activities on the surface of the Earth, many of the instances of groundwater contamination by nitrates are associated with shallow, unconfined aquifers. Nitrates can come from very local sources such as septic systems, fertilizers, or animal feeding sites.

A 2009 U.S. Geological Survey study of groundwater used by residential water wells reported the following findings related to nitrate.

"Nitrate is the only contaminant derived primarily from man-made sources that was found at concentrations greater than a human-health benchmark in more than 1 percent of wells.

Concentrations of nitrate were greater than the U.S. Environmental Protection Agency Maximum Contaminant Level of 10 milligrams per liter (mg/L) as N in 4.4 percent of the wells. Elevated concentrations of nitrate occurred throughout the United States, but least commonly in the Southeast. Concentrations greater than 1 mg/L as N, which is usually indicative of human activities in many areas, were found in about 40 percent of wells located throughout the sampled areas. Concentrations were greater than the MCL most frequently in several aquifers, including the Basin and Range and Central Valley basin-fill aquifers in the Southwest and in California, the west-central glacial aquifers in the Upper Midwest, the North Atlantic coastal plain aquifers in the central Appalachian region, and the Piedmont crystalline-rock aquifers, also in the central Appalachian region. Concentrations were lowest in coastal plain aquifers in the Southeast; the low concentrations may result from aquifer and soil conditions that promote denitrification of nitrate to a harmless nitrogen gas (N2)."

3. Well Location and Construction Methodologies

Location guidelines serve to minimize exposure to local and regional sources of contamination. The construction of a new residential well is often priced by the foot, both with regard to drilling costs and for the cost of the well's water intake area. Thus, traditional construction practices often result in the emplacement of the shallowest well with the shortest water intake area interval that is needed to produce adequate water quantity. Although cost-effective at the time of drilling, this well construction practice has the unforeseen effect of potentially placing the well water intake area in a shallow aquifer most likely to be affected by nitrates contamination.

In addition:

- Wells should be emplaced in water-bearing formations that minimize the effects of local and regional known constituents that if found in high concentrations may create a health risk.
- All wells should have a sanitary seal by having a tight-fitting cover at the upper terminal of the water well casing and have no cracks in the water well casing material (e.g., steel, PVC, concrete, brick, fiberglass) above the land surface.
- There should be no cracks or gaps in the soil around the casing as these unwanted openings can lead to direct runoff of surface water into the well.
- At a minimum, the top 10 feet of casing below the land surface should be watertight in order to prevent microorganisms and other surface waterborne contaminants from entering a well along its casing; deeper well seals may be required depending on the nature of the soil/rock type, the diameter of the well, and other site-specific factors.
- Dug wells should be replaced with bored or drilled wells whenever possible.
- Wells should be sited at appropriate distances from farm fields, feedlots, barnyards, septic systems, leach fields, underground storage tanks, and any other potential contaminant sources.
- The WWSP should inform the homeowner of the importance of maintaining a clean environment near his/her well and that the well should be routinely inspected and actively maintained, including periodic cleaning.

"Identify and remove sources of nitrates near the well.

Specific Concerns Related to Nitrates

Wells should be located as appropriate to local regulation.

Identify and remove sources of nitrates near the well. Fertilizers, animal wastes, and sewage systems, which are common sources of nitrates, should be located and managed so that they do not contaminate the well.

Nitrate problems are sometimes caused by structural flaws in the well system, which allow contaminated surface water to enter the well. Repairing the well may result in a significant reduction of the levels of nitrates. The age of a well may correlate with levels of nitrates, and it is suggested this may be because of structural flaws that have developed over time.

Earth berms should be built to divert surface runoff away from the wellhead. The well casing should extend above ground to a height consistent with local regulations. If the casing was cut off below ground, an extension should be welded onto the top of the existing casing. Proper well protection also includes a surface seal, as well as grouting around the outside of the well casing.

4. After-Drilling Well Operations

Mixing groundwater of differing levels of nitrates within the same well is not recommended. Some local and state regulations prohibit interconnection of multiple aquifers within the same well.

As access to an uncontaminated source of water should be safeguarded, it is better to focus on other alternatives and uniquely deal with the problem each time it occurs. It is not possible to know at what level a contaminant will be found to be harmful in the future. Mixing within the well may have the potential to raise a contaminant concentration in an aquifer to a concentration currently below the present MCL, but it is uncertain what the consequence will be should the MCL for that contaminant be lowered at some future time.

If the groundwater exceeds the MCL for nitrates, a qualified water well contractor can determine if it is pragmatic to retrofit the well to zone off the areas producing nitrates. If this does not result in levels of nitrates consistently below the MCL, then it may be necessary to construct a new well system that isolates the likely zones producing nitrates in groundwater, or to install appropriate water treatment technology.

5. Groundwater Analyses and Water Treatment Methods

Because nitrates are tasteless and odorless, the best way to know for certain if water has nitrates in it is to have the water tested.

“Because nitrates are tasteless and odorless, the best way to know for certain if water has nitrates in it is to have the water tested.

Water testing can be done at any time of the year following appropriate residential well cleaning practices. The clean water well system should be flushed for a sufficient period of time to ensure that water that represents the aquifer is captured in the sample container. Since groundwater quality may change due to rainfall amounts, length of pumping time, seasonal change, etc., at least two samples should be collected at different times of the year in order to determine the ambient groundwater quality.

Testing water for nitrates ranges in cost from $20 to $40 per test (certified laboratory).

Nitrates Treatment Choices

The WWSP can serve a role of explaining to consumers the various treatment options available for dealing with nitrates. If repeated testing confirms that the well water exceeds the MCLs for nitrates and/or nitrites, the homeowner can consider installing a new well or installing a water treatment technology.

The following water treatment options are based upon an expectation that the water to be treated complies with the water treatment equipment manufacturer's water parameters for its specific water treatment devices. The appropriate residential technologies can be categorized as:

1) Reverse osmosis
2) Ion exchange.

The type of removal system utilized may create a concern for other constituents beyond nitrates. For example, manufacturers of reverse osmosis systems may need a general water analysis that includes assessments of alkalinity, hardness, iron, and sulfates, as well as total dissolved solids and pH.

Treatment Technologies

Boiling water will not get rid of or lower nitrates levels in water. In fact, boiling will increase the concentration of nitrates in water.

Water treatment systems require operation and maintenance exactly to the manufacturers' specifications. Failure to properly operate and maintain these systems could result in other water quality issues that could create a health risk.

With regard to removing nitrogen compounds from residential well water, the consumer has two options as to where to treat the water — POE or POU.

POE involves placing the treatment technology where the water enters the house, such as where a water softener or iron filter would be located. In this way, all of the water used within the home will be treated. POE treatment is appropriate for those consumers who are concerned about coming into contact with contaminated water in any way (bathing, showering, laundry, etc.), in addition to drinking and cooking.

POU involves placing the treatment technology on a single (or more than one) tap designated for cooking and drinking only. POU treatment units are typically smaller and less expensive than POE units, but they do not treat taps used for bathing, showering, laundry, etc. With infants, there is a danger that water from these appliances could be ingested.

1) Reverse Osmosis. Reverse osmosis (RO) is capable of removing the majority of ionic contaminants (salts) from water supplies. An advantage of this approach is that RO can improve the aesthetic quality of water by lowering the TDS (total dissolved solids), as well as remove possible health-related contaminants.

It should be noted that most RO units can be fouled by low concentrations of slightly soluble minerals such as calcium, magnesium, iron, and manganese, so some pretreatment may be required. Typically, the lowest water pressure required for POU RO performance is 30 psi. Low water temperatures will reduce the production rate of the unit.

With these units, a minimum of three gallons of waste water is discharged for every gallon of treated water produced and collected in a storage tank for drinking and culinary purposes. They are equipped with an automatic shutoff valve that stops the flow of water to the unit once the storage tank is full. For example, for a family using two gallons per day of RO water for drinking and cooking, six gallons are discharged.

Maintenance involves replacement of pre- and post-filters and the membrane. Filter replacement frequency depends on the quality of the incoming water; membrane elements typically last at least three years.

Performance monitoring can be accomplished with an inexpensive conductivity meter, either by the homeowner or a serviceperson.

As the discharged water is usually only slightly more concentrated in dissolved salts than the feed water (usually less than 33 percent), it can often be used for nonpotable applications, depending on local regulations. It is also generally acceptable for discharge to the septic system.

2) Ion Exchange. Ion exchange is a physical-chemical process in which ions are exchanged between a solution phase and a solid resin phase.

Ion exchange technology is commonly used for household POE water softening (cation exchange). For nitrates and nitrite removal, anion exchange would normally be used as POE treatment.

Anion resins are now available to selectively remove only nitrate and nitrite ions. The resin tank is regenerated with salt brine, as in household softeners. The regenerant is generally considered acceptable for discharge to the septic system.

The following table summarizes the above-named treatment technologies.

Treatment Technology	Nitrate	
	POE	POU
Reverse Osmosis	Removal performance range: 2 Capital Cost: 5 Operating Cost: 2	Removal performance range: 2 Capital Cost: 2 Operating Cost: 1
Anion Exchange	Removal performance range: 1 Capital Cost: 4 Operating Cost: 2	Removal performance range: 2 Capital Cost: 2 Operating Cost: 1
Distillation	N/A	Removal performance range: 1 Capital Cost: 3 Operating Cost: 1
Activated Carbon	N/A	N/A
Aeration	N/A	N/A
Chemical Oxidation	N/A	N/A
Chlorine Compounds	N/A	N/A
Ozone	N/A	N/A
UV Irradiation	N/A	N/A

Performance Keys: 1 = excellent; **2** = good; **3** = limited, poor; **4** = not effective/applicable
Capital Cost Keys: 1 = ≤ $100; **2** = ≤ $500; **3** = ≤ $1,000; **4** = ≤ $3,000; **5** = ≥ $3,000
Operating Cost Keys: 1 = ≤ $100/yr; **2** = ≤ $500/yr; **3** = ≤ $1,000/yr
N/A: not applicable
**Careful monitoring of nitrate reduction treated water effluent is required to prevent the possibility of nitrate dumping due to chromatographic peaking in the ion exchange column as the resin approaches exhaustion.

There are voluntary performance testing programs for POE and POU treatment systems, such as those of the Water Quality Association and NSF International, although there may not be systems listed that have been evaluated for their effectiveness in dealing with nitrates. A contractor should evaluate if the technology being provided to the customer has been voluntarily submitted for performance testing.

The contractor should recognize that each manufacturer may have unique operation and maintenance expectations to assure the long-term treatment performance of its equipment. The contractor should discuss these expectations with the treatment equipment customer and make certain it is understood who holds responsibility for adhering to the manufacturer's expectations.

Following installation of a treatment device, water quality should again be tested to verify the operation of the device. After that, water should be tested at least annually to confirm treatment effectiveness. A maintenance agreement for such devices is highly recommended.

References

General

American Water Works Association. 1998. *ANSI/AWWA C654: AWWA Standard for Disinfection of Wells*. Denver: American Water Works Association.

Borch, M.A., S.A. Smith, and L.N. Noble. 1993. *Evaluation, Maintenance, and Restoration of Water Supply Wells*. Denver: American Water Works Association Research Foundation.

Holben, R.J., and M. Gaber. 2003. *Water Well Disinfection Manual*. Lansing, Michigan: Michigan Department of Environmental Quality.

Illinois Association of Groundwater Professionals. 1996. Disinfection Program Year-end Report for Fiscal Year Ending June 30, 1996. River Forest, Illinois: Illinois Association of Groundwater Professionals.

Lehr, J.H., T.E. Gass, W.A. Pettyjohn, and J. DeMarre. 1988. *Domestic Water Treatment*. Dublin, Ohio: National Water Well Association.

National Ground Water Association. 1998. *Manual of Water Well Construction Practices*, 2nd ed. Westerville, Ohio: National Ground Water Association.

Schnieders, John. 2003. *Chemical Cleaning, Disinfection and Decontamination of Water Wells*. St. Paul, Minnesota: Johnson Screens.

Nitrates

Basin Water. 2008.
http://www.businesswire.com/portal/site/google (accessed May 13, 2008)

Bouwer, Herman. 1990. Agricultural chemicals and ground water quality – issues and challenges. *Ground Water Monitoring & Remediation* 10, no. 1, 71-79.

Chandler, Jim. 1989. Nitrates in water. *Water Well Journal* 43, no. 5, 45-47.

DeSimone, L.A., P.A. Hamilton, and R.J. Gilliom. 2009. *Circular 1332: Quality of Water from Domestic Wells in Principal Aquifers of the United States*, 1991–2004. Reston, Virginia: U.S. Geological Survey.

Illinois Department of Public Health, Environmental Health Fact Sheet, 1999.
http://www.idph.state.il.U.S>/envhealth/factsheets/NitratesFS.htm (accessed June 2008)

Mueller, D.K., and D.R. Helsel. 1996. *Nutrients in the Nation's Waters-Too Much of a Good Thing?* U.S. Geological Survey Circular 1136. Accessed from http://pubs.usgs.gov/cir/cir1136/cir1136.html. Last modified September 5, 2008.

National Ground Water Association. 2003. Nitrates: what you need to know. *Water Well Journal* 57, no. 5, 80.

Stone, Andrew. 2000. Nitrates in ground water. *The American Well Owner*, no. 1.

Stone, Andrew. 2002. Solutions to nitrates problems. *The American Well Owner,* no. 4.

U.S. Environmental Protection Agency, 2008.
http://epa.gov/OGWDW/contaminantes/dw_contamfs/nitrates.html (accessed September 3, 2008)

U.S. Environmental Protection Agency. 2007. http://epa.gov/teach (accessed June 2008)

Wisconsin Department of Natural Resources. 2003.
http://dnr.wi.gov/org/water/dwg/WELLTEST.HTM, (accessed June 2008)

This document was prepared as the result of regular meetings of a task group composed of representatives from among the NGWA membership and duly affected individuals. These included:

Peter Cartwright, PE
Joseph F. Harrison, PE, CWS-VI
Vince Kent
John Pitz, CPI
Stephen Ragone, Ph.D.
Roger Renner, MGWC
John H. Schnieders, Ph.D.
Stuart Smith, CGWP
Mike Wiedorn

NGWA also extends its thanks to the Water Quality Association for its assistance in compiling the treatment technologies table published here.

Disclaimer:
This publication is a collaborative effort to try to set forth best suggested practices on this topic but individual situations and local conditions may vary, so members and others utilizing this publication are free to adopt differing standards and approaches as they see fit. The Association assumes no liability or responsibility for the contents of the publication.

ISBN 1-56034-082-7

national ground water association
NGWA Press

Published by: NGWA Press
National Ground Water Association
601 Dempsey Rd.
Westerville, OH 43081-8978
Phone/ 614 898.7791
Fax/ 614 898.7786
Email/ customerservice@ngwa.org

Revised 11/2009