Importance of Regular Testing of Private Drinking Water Systems in North Carolina

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North Carolina state laws require that water from newly constructed private wells be tested for chemical and microbiologic contamination, but existing wells are not routinely tested. This commentary highlights the importance of regular testing of all private sources of drinking water.

Drinking water can be obtained from public water systems or drawn from a nonpublic source such as a well, spring, or cistern [1]. The Safe Drinking Water Act, which was passed in 1974 and amended in 1984 and 1996, authorizes the US Environmental Protection Agency (EPA) to protect the public against naturally occurring and manmade contamination by setting standards for what is allowable in public water systems [2]. Public drinking water systems are defined as those providing water to at least 15 service connections—which could be residences, businesses, schools, or other buildings—or to an average of at least 25 persons for at least 60 days per year [3]. These systems provide drinking water for approximately 90% of the US population [4]. The remaining 10% of the population obtain their drinking water from private water sources, which are outside the scope of the Safe Drinking Water Act. Unlike public drinking water systems, there is no requirement for private drinking water sources to be routinely monitored, reported, or treated for contamination.

Well water is not typically tested as often as water from public drinking water systems. To ensure the safety of private drinking water sources, well owners need to regularly test their well water to detect any potentially contaminating sources around the well that could affect water quality. Testing for certain contaminants should be performed annually. Regular testing of private drinking water is also advised; for many types of contaminants (microorganisms, metals, nitrates, radon, and many chemicals), changes in water quality can sometimes be detected only by laboratory testing [1].

Approximately 3.2 million people in North Carolina obtain their drinking water from private wells; this is the third-largest population of well-water consumers in the United States [5]. Private well owners are responsible for the safety of their well water. If testing indicates that a water source is contaminated, the owner of the water supply is usually responsible for treating the water and taking any additional steps needed to ensure its safety. However, owners of private drinking water sources may be hindered from monitoring water quality because of the cost and inconvenience of such monitoring.

Types of Contaminants Found in Drinking Water Sources

Contamination of drinking water can result from natural or manmade activity. Sources of drinking water contamination can be classified as *point sources* or *nonpoint sources*. Point source contamination refers to pollution discharged from a discernible, confined, discrete conveyance—such as a pipe, container, or vessel [6]. Nonpoint source contamination is pollution that comes from several origins or diffuse sources, such as storm water runoff (which may contain pesticides applied to crops or livestock waste), precipitation (eg, snowmelt or rainfall), drainage from abandoned mines, erosion, or atmospheric deposition [6]. As pollutants move through the ground, they come in contact with precipitation, rock formations, and soil, and ultimately they are deposited in water basins [6].

One criterion for determining whether a contaminant needs to be regulated under the Safe Drinking Water Act is the occurrence and frequency of that contaminant in public drinking water systems [7]. The EPA has established drinking water standards for more than 90 contaminants, which include disinfectants (additives to control microbes), disinfection byproducts (byproducts of drinking water disinfection), inorganic chemicals, microorganisms (bacteria found naturally in the environment and in human and animal wastes), organic chemicals, and radionuclides (radioactive decay from natural deposits) [8].

Health Effects of Exposure to Contaminants in Drinking Water

The risk of adverse human health outcomes from exposure to contaminants in drinking water depends on several factors. These include the characteristics of the particular

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contaminant(s); the level of the individual's exposure, taking into account both the concentration of the contaminant(s) in the water and the duration of exposure; the exposure pathway (eg, ingestion); and the immune status of the exposed person. The potential health effects from exposure to drinking water contaminants range from short-term effects such as gastrointestinal distress to long-term effects such as an increased risk of cancer or complications affecting multiple organ systems [8].

The maximum contaminant level (MCL) is the highest level of a contaminant that is permitted in public drinking water; this is an enforceable standard. The MCL is set as close to the maximum contaminant level goal (MCLG) as is feasible, after considering health, cost, and available treatment technology [9]. The MCLG is the level of the contaminant below which there is no known or expected risk to human health; the MCLG is a public health goal that is not enforceable [9].

The removal of a contaminant from well water can prevent further exposure. There are various methods for removing contaminants from well water. Some common types of household systems for treating water include filtration systems, water softeners, distillation systems, and disinfection [10].

Required Testing of Newly Constructed Wells

In 2008, to ensure the safety and quality of drinking water from newly constructed private wells in the state, the

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North Carolina General Assembly enacted a statute requiring all newly constructed wells to be tested for the presence of microorganisms and inorganic chemical contaminants [11]. Before this rule was adopted, private domestic well water was tested only when there was evidence of improper well construction, when there were signs of contamination (eg, changes in the appearance, taste, or odor of the water), or at the owner's request.

Section 3800 of the North Carolina Administrative Code [12] provides instructions for collecting samples of private well water, analyzing the samples in the laboratory, reporting the results of the analyses, and reviewing data for contaminants detected at levels exceeding the MCL for public drinking water. Local health departments are responsible for collecting well-water samples within 30 days after the certification of a newly constructed well, submitting these samples to a certified laboratory (eg, the North Carolina State Laboratory of Public Health) for analysis, and provid-

ing information to the well owner regarding any chemical or biological contaminants exceeding the MCL for public drinking water.

Once a well-water sample is received, a laboratory determines the pH of the sample and analyzes it for the presence of microorganisms (it is first tested for total coliform bacteria and then, if present, further analyzed for fecal coliform bacteria or *Escherichia coli*), metals (arsenic, barium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, selenium, silver, sodium, and zinc), and inorganic chemicals (fluoride, nitrates, and nitrites). Table 1 lists the MCLGs and MCLs for these contaminants [9]. The laboratory then reports the results of the analyses to the North Carolina Division of Public Health.

The Division of Public Health evaluates all well-water test analyses using federal drinking water standards, provides the local health department with information about any contaminants that exceed the MCL, makes recommendations for water usage limitations and treatment options, and advises about the need for and the frequency of repeat sampling of the well water. The local health department then conveys these recommendations to the well owner. Currently, local health departments do not perform any follow-up to determine whether well owners carry out testing recommendations. Without the statute requiring testing of newly constructed wells and the safe well-water recommendations that accompany every well-water laboratory analysis report, many private well owners would not know whether their drinking water was safe.

TABLE 1.
Health Goals and Legal Limits for Contaminants That Must Be Tested For in Water From Newly Constructed Wells in North Carolina

Contaminant	MCLG[a] (health goal) (mg/L)	MCL[b] (legal limit) (mg/L)
Metals		
Arsenic	0	0.010
Barium	2	2
Cadmium	0.005	0.005
Chromium	0.1	0.1
Copper	1.3	TT, action level=1.3
Iron	—	—
Lead	0	TT, action level=0.015
Magnesium	—	—
Manganese	—	—
Mercury (inorganic)	0.002	0.002
Selenium	0.05	0.05
Silver	—	—
Sodium	—	—
Zinc	—	—
Inorganic chemicals		
Fluoride	4.0	4.0
Nitrate	10	10
Nitrite	1	1
Microorganisms[c]	See note[c]	See note[c]

Note. MCL, maximum contaminant level; MCLG, maximum contaminant level goal; TT, treatment technique.
Source: US Environmental Protection Agency Web site [9].
[a]The MCLG is the level considered to be desirable for health.
[b]The MCL is the maximum level that is legally permitted in drinking water.
[c]Well-water samples to be tested for total coliform bacteria are collected after the disinfectant agent has been flushed from the well and water supply system. The MCLG for total coliform bacteria is zero, and the MCL requires that no more than 5% of samples from the well contain any coliform bacteria. If total coliform bacteria are found in a sample, the sample is further analyzed for the presence of fecal coliform bacteria or *Escherichia coli*.

Quality of Water Obtained From Private Wells in North Carolina

A review of well-water safety was conducted by the Environmental Public Health Tracking Program of the North Carolina Division of Public Health; assistance with data management and analyses was provided by the Superfund Research Program of the University of North Carolina. This review covered well-water analyses performed by the North Carolina State Laboratory of Public Health on samples submitted by county health departments statewide from 1998 through 2011. Based on this review, an advisory group for the North Carolina Private Well Water Initiative deemed it a public health priority for certain contaminants in private well water to be tracked as part of the North Carolina Environmental Public Health Tracking Program. Two of the contaminants for which tracking was prioritized were arsenic [13] and nitrate, which are the top well-water contaminants of concern for North Carolina. Arsenic and nitrate were prioritized as a result of the high frequency with which they were detected at levels above their respective MCLs.

Arsenic is an element that is found widely in the environment; it can be released into ground water from rock formations and into surface water as runoff from fertilizers and animal feeding operations [14]. Possible health effects from exposure to arsenic include cancer, reproductive complications, and respiratory difficulties [14]. The EPA has set the MCL for arsenic in drinking water at 0.010 mg/L. From 1998 to 2011, the counties in North Carolina with the greatest percentage of well-water tests in which arsenic exceeded the MCL were the southern central counties of Union and Stanly, which had arsenic levels above the MCL in 19.7% and 19.6% of well-water tests, respectively (Table 2). The median arsenic concentration for both of these counties combined was 0.022 mg/L (range, 0.010–0.806 mg/L), which was approximately twice the MCL.

Another contaminant of concern in North Carolina is nitrates/nitrites. Nitrates are used mainly in fertilizer; once in the body, they are converted to nitrites. Exposure to nitrate is a health concern primarily for infants, in whom possible health effects include weakness and a rapid heart rate, both of which are symptoms of methemoglobinemia. In severe cases, exposure can result in difficulty breathing, dizziness, loss of consciousness, and convulsions. The MCL for nitrate in drinking water is 10 mg/L [15]. In North Carolina,

TABLE 2.
Top 10 North Carolina Counties[a] With Well-Water Tests Exceeding the Maximum Contaminant Level (MCL) for Arsenic (0.010 mg/L), 1998–2011

Ranking	County	No. of well-water tests performed[b]	Tests on which arsenic level exceeded MCL No. (%)	Median concentration of arsenic (range) (mg/L)
1	Union	3,559	701 (19.7)	0.024 (0.010–0.303)
2	Stanly	986	193 (19.6)	0.021 (0.010–0.806)
3	Anson	108	11 (10.2)	0.020 (0.010–0.070)
4	Montgomery	413	34 (8.23)	0.018 (0.010–0.088)
5	Dare	630	37 (5.87)	0.015 (0.010–0.040)
6	Alexander	166	9 (5.42)	0.015 (0.010–0.175)
7	Randolph	1,901	92 (4.84)	0.019 (0.010–0.106)
8	Cleveland	294	13 (4.42)	0.016 (0.011–0.036)
9	Davidson	577	24 (4.16)	0.016 (0.010–0.100)
10	Currituck	341	13 (3.81)	0.013 (0.010–0.038)

Source: North Carolina State Laboratory of Public Health, September 1998–April 2011.
[a]Counties were ranked by the percentage of well-water tests exceeding the MCL.
[b]There were 4,132 well-water tests performed by the North Carolina State Laboratory of Public Health from 1998 through 2011 for which the county name is missing, so these figures may be underestimates of the total number of tests by county.

TABLE 3.
Top 10 North Carolina Counties[a] With Well-Water Tests Exceeding the Maximum Contaminant Level (MCL) for Nitrate (10 mg/L), 1998–2009

Ranking	County	No. of tests of well water performed[b]	Tests on which nitrate level exceeded MCL No. (%)	Median concentration of nitrate (range) (mg/L)
1	Hoke	54	40 (74.1)	2.00 (1.15–8.24)
2	Northampton	66	41 (62.1)	3.74 (1.20–36.5)
3	Cumberland	539	315 (58.4)	3.60 (0.23–37.3)
4	Scotland	64	37 (57.8)	3.49 (1.21–13.9)
5	Franklin	511	283 (55.4)	2.72 (1.01–31.4)
6	Warren	63	34 (54.0)	2.48 (1.05–8.21)
7	Richmond	1,358	719 (52.9)	4.59 (1.00–58.0)
8	Halifax	176	93 (52.8)	4.21 (1.00–42.8)
9	Edgecombe	1,238	646 (52.2)	3.30 (1.00–45.5)
10	Wilson	167	86 (51.5)	3.50 (1.01–12.6)

Source: North Carolina State Laboratory of Public Health, September 1998–December 2009.
[a]Counties were ranked by the percentage of well-water tests exceeding the MCL.
[b]There were 722 well-water tests performed by the North Carolina State Laboratory of Public Health from 1998 through 2009 for which the county name is missing, so these figures may be underestimates of the total number of tests by county.

Hoke County had the highest percentage of well-water tests that exceeded the MCL for nitrate (74.1%), followed by Northampton (62.1%) and Cumberland (58.4%) counties. The 2 counties with the highest median concentrations of nitrate in well-water samples from 1998 through 2009 were Richmond and Halifax, which had median nitrate concentrations of 4.59 mg/L (range, 1.00–58.0 mg/L) and 4.21 mg/L (range, 1.00–42.8 mg/L), respectively (Table 3); although a few of the measured nitrate concentrations were high, potentially due to contamination from nearby source(s), the median concentrations for each of the counties were less than the MCLG.

Vulnerabilities of Unregulated Drinking Water Systems

Only a small percentage of wells each year are tested to determine whether their water contains certain microorganisms, metals, or inorganic chemicals. Most of these are newly constructed wells. North Carolina state regulations for well-water testing do not include any requirements for routine testing of existing private wells. Thus many wells receive only initial testing and are not retested. Because many contaminants cannot be identified by taste, sight, or odor, it is difficult for private well owners to discern whether

the quality of their well water has changed. It is therefore very important for well owners to test well water regularly (as often as once a year for certain contaminants) to detect any contamination that may have occurred since initial testing took place.

Recommendations

In an effort to help provide local health departments, communities, and the public with accessible information about well-water testing and private well safety, the Division of Public Health partnered with the Superfund Research Program of the University of North Carolina at Chapel Hill and with North Carolina State University to develop maps of contaminants, educational materials, and a well-water and health Web site (http://testyourwell.nc.gov/). The Division of Public Health advises well owners to test their well water annually for microbial indicators of contamination (ie, total coliform bacteria and *Escherichia coli*); to test for heavy metals, nitrates, nitrites, lead, copper, and organic chemicals every 2 years; and to test for pesticides every 5 years. Also, well-water testing is recommended after repairs to or replacement of a well, after flooding events, and if there is known contamination in an area. For consumers of nonpublic drinking water, the only way to determine whether the water is safe to drink is to test it on a regular basis, regardless of whether changes in taste, smell, or color of the water have been noted. NCMJ

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