TROUBLED WATERS
FARM POLLUTION THREATENS DRINKING WATER

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America's pure drinking water is at risk from poor farming practices that contaminate streams, lakes and groundwater with fertilizer and manure.

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Table of Contents

Acknowledgments 3

Troubled Waters

Farm Pollution Threatens Drinking Water

Executive Summary 4

Careless Farming Takes a Toll on Drinking Water 7

In Most Agricultural Watersheds, Farm Runoff Causes the Bulk of Water Quality Problems 7

Source Water Overloaded with Nutrients Threatens Tap Water 7

Nitrate 10

Disinfection Byproducts 10

Cyanobacteria and Cyanotoxins 10

The Health Risks – Why It Matters 11

Nitrate – Deadly for Infants, Dangerous for Adults 11

Disinfection Byproducts – Cancer, Asthma and More 12

Cyanobacteria and Cyanotoxins – No Legal Limits 13

Nutrient Overload is Common 14

Nutrient Pollution in Streams 14

Nutrient Pollution in Lakes 15

Nitrogen Pollution in Groundwater 17

Agricultural Contaminants in Source Water and Tap Water 21

Nitrate in Tap Water 21

Domestic Wells are Especially Vulnerable 22

Disinfection Byproducts – Making a Bad Situation Worse 25

Disinfection Byproducts are Too Often Found in Tap Water 25

Cyanobacterial Blooms are a Worsening Problem 26

Cyanobacteria in Iowa Lakes 30

National Lake Survey Findings of Cyanobacteria in Illinois, Minnesota and Wisconsin lakes 33

Cyanobacteria in Illinois Lakes 34
Cyanobacteria in Minnesota Lakes 36
Cyanobacteria in Wisconsin Lakes 36
The High Cost of Cleaning Up Source Water 36
Iowa Water Utility Survey: Treating Source Water Contaminated with Agricultural Chemicals 36
Case Studies 38
Nitrate Removal 38
The Cost of Cyanotoxins 41
Conclusion 43
Source Water and the Farm Bill 43
References 46

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EXECUTIVE SUMMARY

Water that runs off fields treated with chemical fertilizers and manure is loaded with nitrogen and phosphorus, two potent pollutants that inevitably end up in rivers and lakes and set off a cascade of harmful consequences, contaminating the drinking water used by millions of Americans. Treating this water after the fact to clean up the contamination is increasingly expensive, difficult and, if current trends continue, ultimately unsustainable. The only solution that will preserve the clean, healthy and tasty drinking water that people expect is to tackle the problem at the source. This paper explains why.

Nitrate, the most common form of nitrogen in surface and groundwater, is directly toxic to human health. Infants who drink water with high nitrate levels can develop an acute, life-threatening blood disorder called blue baby syndrome. High nitrate levels in water can also affect thyroid function in adults and increase the risk of thyroid cancer.

Phosphorus stimulates explosive blooms of aquatic algae, including the especially dangerous cyanobacteria (blue-green algae) that produce toxins that can be deadly to pets, livestock, wildlife – and people. Toxins produced by cyanobacteria can harm the nervous system, cause stomach and intestinal illness and kidney disease, trigger allergic responses and damage the liver. Even after a brief exposure, cyanobacterial toxins can cause skin rashes, eye irritation and breathing problems.

The cascade continues when utilities try to combat these and other threats by treating drinking water with chemical disinfectants such as chlorine. Treating algal contamination this way gives rise to carcinogenic disinfection byproducts, whose levels typically spike during the summer months – when algae blooms peak. Commonly used measures to reduce algal contamination add hundreds of thousands of dollars annually to water utilities' treatment costs. Algae can also give tap water an unpleasant taste and smell, a recurrent annoyance for agricultural areas and the water utilities that serve them.

This report focused on four states in the core of the Midwestern corn belt – Illinois, Iowa, Minnesota and Wisconsin. Nutrient overload in surface and groundwater is a significant water quality problem for these states, making nitrate and phosphorus levels higher and algal blooms more frequent compared to national averages.

To tackle polluted source water, water utilities in the region are often forced to install expensive treatment plants that can cost millions to install and operate. USDA economists estimate that removing nitrate alone from drinking water costs more than $4.8 billion a year. The cost of dealing with algal blooms is particularly daunting. The total capital cost of water treatment that would address cyanobacterial blooms and cyanotoxins, can range between $12 million and $56 million for a town of 100,000 people.

The only true solution is to confront the issue upstream, at the point where pollution – much of it from farms – first flows into America's precious surface water and groundwater. This year's debate over renewing the federal farm bill is a referendum on America's commitment to protecting our drinking water supplies at the source.

With the exception of large animal feeding operations, farm businesses are exempt from the pollution control requirements of the federal Clean Water Act, and few states have authority to compel farm businesses to adopt practices that reduce the amount of farm pollution reaching our rivers, lakes and bays. As a result, the farm bill, which is renewed every five years, serves as the primary tool for addressing the environmental damage caused by polluted runoff from agricultural operations.

Congress should take three steps to ensure the new farm bill protects drinking water:

- Reform Farm Subsidies – Congress should end direct payments, reduce subsidies for farm insurance programs and refuse to create new farm entitlement programs that encourage all-out production to the detriment of the environment. Instead, lawmakers should help farmers when they suffer deep losses in yields and provide options for them to purchase additional crop and revenue insurance at their own expense.

- Renew the Conservation Compact -- Congress should renew the "conservation compliance" provisions of the 1985 farm bill by relinking wetland and soil protection requirements to crop insurance programs. In addition, legislators should require farm businesses that receive subsidies to update their conservation plans and should strengthen the government's enforcement tools.

- Strengthen Conservation Incentive Programs – Congress should strengthen programs that reward farmers who take steps to protect sources of drinking water. In addition to providing adequate funding, Congress should expand "collaborative conservation" tools that award funds to groups of farmers working together to protect drinking water sources. Greater focus should be placed on restoring buffers and wetlands that filter runoff of farm pollutants.

CARELESS FARMING TAKES A TOLL ON DRINKING WATER

In Most Agricultural Watersheds, Farm Runoff Causes the Bulk of Water Quality Problems

Every year, farm operators apply more than 12 million tons of nitrogen fertilizer and 8 million tons of phosphorus fertilizer to agricultural land in the U.S.[1] Unless carefully managed, much of it is carried off the fields by runoff or percolates into drainage systems, eventually ending up in streams, rivers, lakes and underground aquifers. Animal manure from livestock is also an important contributor to nutrient pollution, particularly phosphorus. Two recent reports have estimated that nationally, livestock production generates between 350 million and 1 billion tons of manure each year.[2] According to the U.S. Geological Survey, manure contributes 7-to-48 percent of the total phosphorus entering U.S. waters, depending on the number of livestock farms in a watershed.[3]

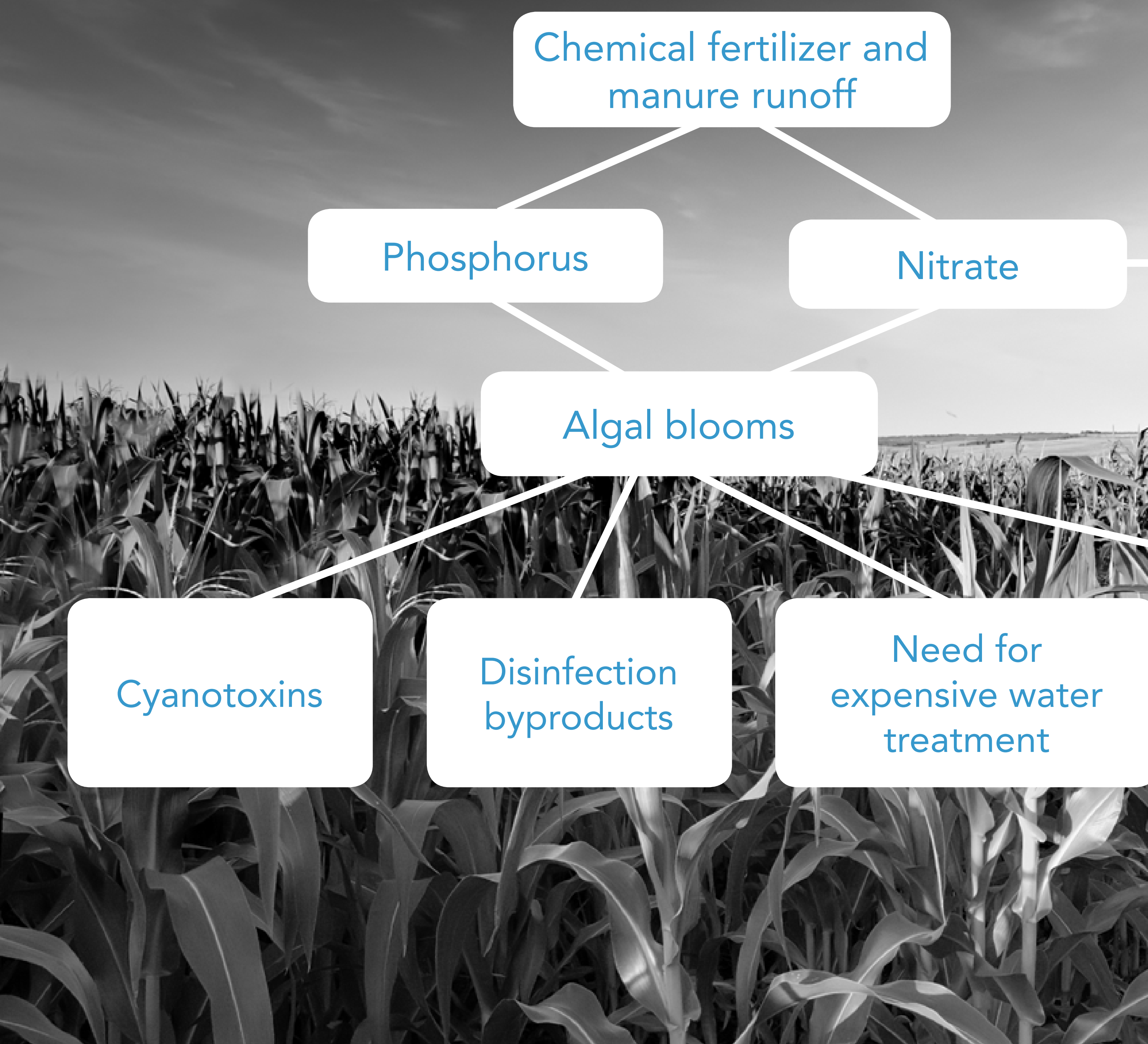
The consequences of this nutrient overload include nitrate buildup in groundwater, eutrophication of lakes and ponds, algal blooms and oxygen depletion.[4] As a group of leading U.S. researchers from 14 research universities and government agencies concluded in a 2008 paper, "Degraded water quality from increased nutrient pollution promotes the development and persistence of many harmful algal blooms, and is one of the reasons for their expansion in the U.S. and other nations."[5]

National studies and regional assessments of waterways in the Mississippi River Basin consistently point to chemical fertilizers and manure spread on fields as the main sources of nutrient pollution.[6] U.S. Department of Agriculture researchers estimate that on two-thirds of the nation's agricultural land, fertilizer use does not conform to science-based best management practices. Growers spread too much, spread it at the wrong times and use methods that are prone to losing nutrients into runoff.[7] Additionally, tile drainage, which is common across the Midwest, particularly in Iowa and Illinois, promotes the movement of nutrients into streams.

Source Water Overloaded with Nutrients Threatens Tap Water

Nutrient overload in source water increases the challenges that public water utilities face in producing safe and healthy drinking water.

Water Pollution Cascade from Agricultural Runoff




Direct health effects
Unpleasant taste and smell of tap water

Nitrate

Nitrogen, found in commercial fertilizers and manure, is applied in many different chemical forms. Bacteria can convert all of them to nitrate, a form of nitrogen that can be taken up by plant roots. Nitrate is very soluble in water and is easily carried from farm fields into streams and rivers. Perforated pipes called tiles, which farmers bury under their fields to manage water drainage in an effort to maximize crop production, make the situation worse. Nitrate quickly moves through the soil and enters the tiles, which then rapidly pour drainage water and nitrate to streams and rivers. Nitrate-laden runoff can also percolate through the soil and pollute groundwater, a major source of drinking water.

Disinfection byproducts

Chlorine and other chemicals used to disinfect source water can form carcinogenic compounds when they react with organic matter. These compounds become a serious problem when nutrient overloads trigger recurrent and persistent blooms of algae that contaminate source water. The reaction between chlorine and algal organic matter generates trihalomethanes and haloacetic acids, two types of disinfection byproducts that are federally regulated, as well as many other types of toxic byproducts.[8] A study sponsored by the U.S. EPA and the Water Research Foundation found that algal blooms also lead to formation of highly carcinogenic nitrogenous disinfection byproducts, which are not currently regulated.[9]

A 2010 U.S. Geological Survey (USGS) report estimated that in the intensively cultivated Mississippi River basin, up to 54 percent of total organic carbon in rivers and streams can be due to photosynthesis by algae.[10] Algal growth contributes far more carbon than runoff from agricultural, forest, urban and wetlands sources. Further, direct runoff from agricultural sources produces 20 percent of the total organic carbon in rivers and streams, more than four times as much as urban sources. In sum, agriculture's contribution to organic carbon levels in source water and the formation of disinfection byproducts is highly significant.

Cyanobacteria and cyanotoxins

Phosphorus plays a major role in triggering the growth of a type of algae known as cyanobacteria, which pose a direct threat to health. Unlike other freshwater algae, cyanobacteria synthesize poisonous chemicals, known as cyanotoxins, that are lethal to pets, wildlife, domestic livestock and humans. When water is overloaded with phosphorus, cyanobacteria's ability to pull and use (or fix) nitrogen from the atmosphere allows it to outcompete other types of algae and aquatic vegetation.[11]

Applying much more phosphorus fertilizer and manure than crops can use builds up phosphorus in soil.[12] After continuous over-fertilization, agricultural fields become a persistent reservoir for phosphorus that ends up polluting water bodies. Recent USGS study found that in the agricultural Midwest, many streams have their highest nitrogen concentrations in the spring, peaking in April-May.[13] Nitrogen concentrations in many of these streams drop after crops emerge and begin taking up nitrogen, but phosphorus levels are often higher in the summer, creating ideal conditions for cyanobacteria blooms. In the Mississippi River basin, agricultural sources are the primary contributor of phosphorus, according to the USGS.[14] Nationwide, a third of all streams have high concentrations of phosphorus that allow cyanobacteria to thrive, making phosphorus overload a persistent problem for public water supplies.[15]

THE HEALTH RISKS – WHY IT MATTERS

Source water overloaded with nutrients poses serious health risks – and major problems – for drinking water utilities and communities they serve.

Nitrate – Deadly for Infants, Dangerous for Adults

Nitrate, an essential nutrient for plant growth, becomes very dangerous to human health when ingested at high levels. In the body, nitrate is converted into a related chemical, nitrite, which interferes with the ability of hemoglobin in blood to deliver oxygen to tissues. Infants younger than six months who drink nitrate-contaminated water by itself or mixed in formula at levels above the current legal limit of 10 milligrams per liter can develop an acute, life threatening blood disorder called blue baby syndrome (methemoglobinemia).[16] Many private wells and small community water systems in agricultural regions exceed that limit.[17]

Even below the legal limit, nitrate in drinking water may be a risk to the fetus.[18] Nitrate competes with iodine uptake into the thyroid, disrupting thyroid function.[19] In February 2012, National Cancer Institute researchers published a study that found a significant association of nitrate exposure from drinking water with subclinical hypothyroidism in women.[20] Thyroid dysfunction during pregnancy has been linked to developmental problems such as premature birth and low birth weight. A study by scientists at the California Department of Health Services and the California Birth Defects Monitoring Program reported an association between a mother's exposure to nitrate in drinking water and abnormalities in brain and head development of the fetus.[21]

Nitrate also poses a long-term health risk to adults. Two large epidemiological studies by the National Cancer Institute found an association between nitrate intake and thyroid cancer. The National Institutes of Health-American Association of Retired Persons Diet and Health study, which included more than 490,000 people 50-71 years old, found that in men, increasing nitrate intake was associated with a more than doubled risk of developing thyroid cancer.[22] In a second study of a cohort of more than 21,000 Iowa women 55-69 years old who had used the same water supply for more than 10 years, those who drank water with more than 2.5 mg/L of nitrate (a quarter of the EPA's legal limit) were more than twice as likely to have thyroid cancer as women whose tap water contained less than 0.36 mg/L nitrate.[23]

Thyroid cancer incidence in the United States and worldwide has been on the rise since the 1970s, particularly among women.[24] Since nitrate contamination of drinking water supplies is widespread, the possible link between nitrate and thyroid-related health problems is a significant concern.

Human epidemiological studies also point to a link between long-term nitrate ingestion and higher risk of colon and stomach cancer.[25] Tap water is just one source of nitrate, since people are also exposed to nitrate and nitrite from dietary sources, especially preserved meats. Nevertheless, a case-control study in Iowa from 1986 to 1989 pinpointed nitrate exposure from drinking water as a risk factor for colon cancer, particularly among subgroups with low vitamin C intake and high meat consumption. The highest risk was found in people who ingested water with average nitrate levels above 5 mg/L, half of the legal limit, for longer than 10 years.[26]

Disinfection Byproducts – Cancer, Asthma and More

Disinfecting drinking water is essential to kill harmful pathogens, but it results in forming toxic byproducts. Every disinfectant in use today – chlorine, ozone, chlorine dioxide and chloramines – produces a variety of chemical byproducts. Legal limits have been set for two families of these – trihalomethanes and haloacetic acids. For the four regulated trihalomethanes (chloroform, bromoform, bromodichloromethane and dibromochloromethane), the legal limit is 0.08 mg/L (80 parts per billion or ppb); for the five regulated haloacetic acids (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, bromoacetic acid and dibromoacetic acid), the legal limit is 0.06 mg/L (60 ppb).

In studies of laboratory animals, trihalomethanes, haloacetic acids and other classes of disinfection byproducts have been associated with elevated risk of cancer and damage to DNA.[27] Epidemiological studies in humans have consistently found a link between exposure to disinfection byproducts in drinking water and the risk of bladder cancer.[28] A 2010 study reported that approximately 25 percent of the population has a genetic susceptibility that places them at a greater risk of bladder cancer from disinfection byproducts.[29] Another study reported an association between disinfection byproducts and an elevated risk of two common forms of skin cancer – basal cell carcinoma and squamous cell carcinoma.[30]

Inhalation and skin exposure to disinfection byproducts in water while showering and bathing may also contribute to health problems. Heavy inhalation exposure, as in swimming pools with chlorinated water, has been associated with increased risk of asthma.[31] Some epidemiological studies also suggest that there may be a link between high levels of disinfection byproducts and problems in fetal development such as birth defects, growth retardation, pre-term delivery and miscarriage.[32] Not all studies agree, but the association appears to be stronger for trihalomethanes at concentrations above the current regulatory limits.[33]

Overall, the evidence indicates that minimizing disinfection byproducts in tap water by promoting cleaner source water would likely result in multiple health benefits.

Cyanobacteria and Cyanotoxins – No Legal Limits

Cyanobacteria, also called blue-green algae, can cause severe water quality problems when waterways are overloaded with phosphorus. Cyanobacteria pose a particular threat because they synthesize a variety of highly toxic chemicals known as cyanotoxins. In aquatic environments, cyanotoxins usually remain contained within the cells of cyanobacteria and are only released in substantial amounts when the cells die. This occurs when algal blooms die off naturally, and, paradoxically, when chemicals such as copper sulfate are applied to reservoirs to kill algae. Chlorination and other water treatment processes also break open cyanobacteria cells and release cyanotoxins.[34]

These toxins can affect the nervous system, produce stomach and intestinal illness and kidney disease, trigger allergic responses and damage the liver.[35] They may also lead to liver cancer and promote tumor growth.[36] Even at low levels or following an occasional exposure, cyanobacterial toxins can cause skin rashes, eye irritation and respiratory symptoms. Cyanotoxins that become airborne and are inhaled can cause trouble breathing.[37] Harmful algal blooms and cyanotoxin poisonings, primarily from recreational exposure, have been reported in at least 36 states.[38]

There are currently no legal limits on the amount of cyanotoxins in drinking water, although the U.S. EPA has listed three common forms (anatoxin-a, microcystin-LR, and cylindrospermopsin) on its Contaminant Candidate List as substances that occur in public water systems and may require regulation.[39] In the absence of federal leadership in tackling the algal bloom problem, the limited data currently available come mostly from state water programs.

Nutrient Overload is Common

Nutrient overload, mostly from farm runoff, is extensive and problematic in U.S. waterways.[40] Agricultural regions, where concentrations of nitrogen and phosphorus compounds are substantially higher than naturally occurring levels, are the most polluted.

Nutrient Pollution in Streams

In 2010, the U.S. Geological Survey published a comprehensive assessment of nitrogen and phosphorus in streams and groundwater based on data collected between 1992 and 2004. In agricultural areas, runoff of chemical fertilizer and manure is the primary source of nutrient pollution. USGS found that in those areas, median concentrations of total phosphorus and total nitrogen in streams were about six times greater than background levels.[41]

Nitrogen in water comes in several forms. Typically, nitrate is the most prevalent, constituting up to 90 percent of the total, with much smaller amounts of nitrite, ammonia and organic nitrogen. Nitrite is unstable in surface water and contributes little to the total, although it has significant effects on groundwater. The concentrations of ammonia in water vary depending on the timing of ammonia releases from fertilizer, manure or wastewater sources, but they are generally much lower than nitrate levels.

This paper's state-level analysis of nitrogen contamination in Midwest streams focuses on nitrate as the primary, most stable form commonly measured in water quality tests. For phosphorus, the most relevant parameter is "total phosphorus," which includes both soluble and insoluble forms. All forms of phosphorus contribute to algal blooms.

Table 1: Nutrient concentrations in Midwest streams far exceed background levels.

State[1]	Average nitrate (as N)[2] compared to background levels	Average total phosphorus[3] compared to background levels
Illinois	13 times greater (3.1 mg/L, 143 sites)	9 times greater (0.31 mg/L, 291 sites)
Iowa	24 times greater (5.8 mg/L, 221 sites)	6 times greater (0.21, 173 sites)
Minnesota	8 times greater (2.0 mg/L, 350 sites)	5 times greater (0.17 mg/L, 346 sites)
Wisconsin	7.5 times greater (1.8 mg/L, 286 sites)	9 times greater (0.32 mg/L, 998 sites)
USGS estimate of background concentrations in streams[4]	0.24 mg/L	0.034 mg/L

Source: USGS National Water Information System (available: http://waterdata.usgs.gov/nwis) for 1992-2001; downloaded on 10/05/2011.

1. Of note, while the USGS National Water Information System dataset used for this analysis has a broad coverage across all four states, these data were not specifically collected for the purposes of state-by-state comparison.
2. Nitrate data correspond to nitrate in filtered samples (USGS parameter code P00618) averaged over all sites and observations, expressed as N in mg/L.
3. Phosphorus data correspond to total phosphorus in unfiltered samples (USGS parameter code P00655), averaged over all sites and all observations.
4. Dubrovsky NM, Burow KR, Clark GM, Gronberg JM, Hamilton PA, et al. 2010. The Quality of our Nation's waters – Nutrients in the Nation's Streams and Groundwater, 1992–2004: U.S. Geological Survey Circular 1350. For comparison, USGS estimate for background total nitrogen (nitate+nitrite+ammonia+organic nitrogen) in undisturbed streams is 0.58 mg/L; median total nitrogen in agricultural streams is around 4 mg/L; median total phosphorus in agricultural streams is around 0.25 mg/L.

Nutrient Pollution in Lakes

The 2010 National Lake Assessment, based on sampling more than a thousand lakes, found that 40 percent were polluted with nitrogen and 46 percent with phosphorus at levels considered eutrophic or hypereutrophic. These levels put them at risk of algal blooms that would affect recreation and drinking water quality.[42] Across

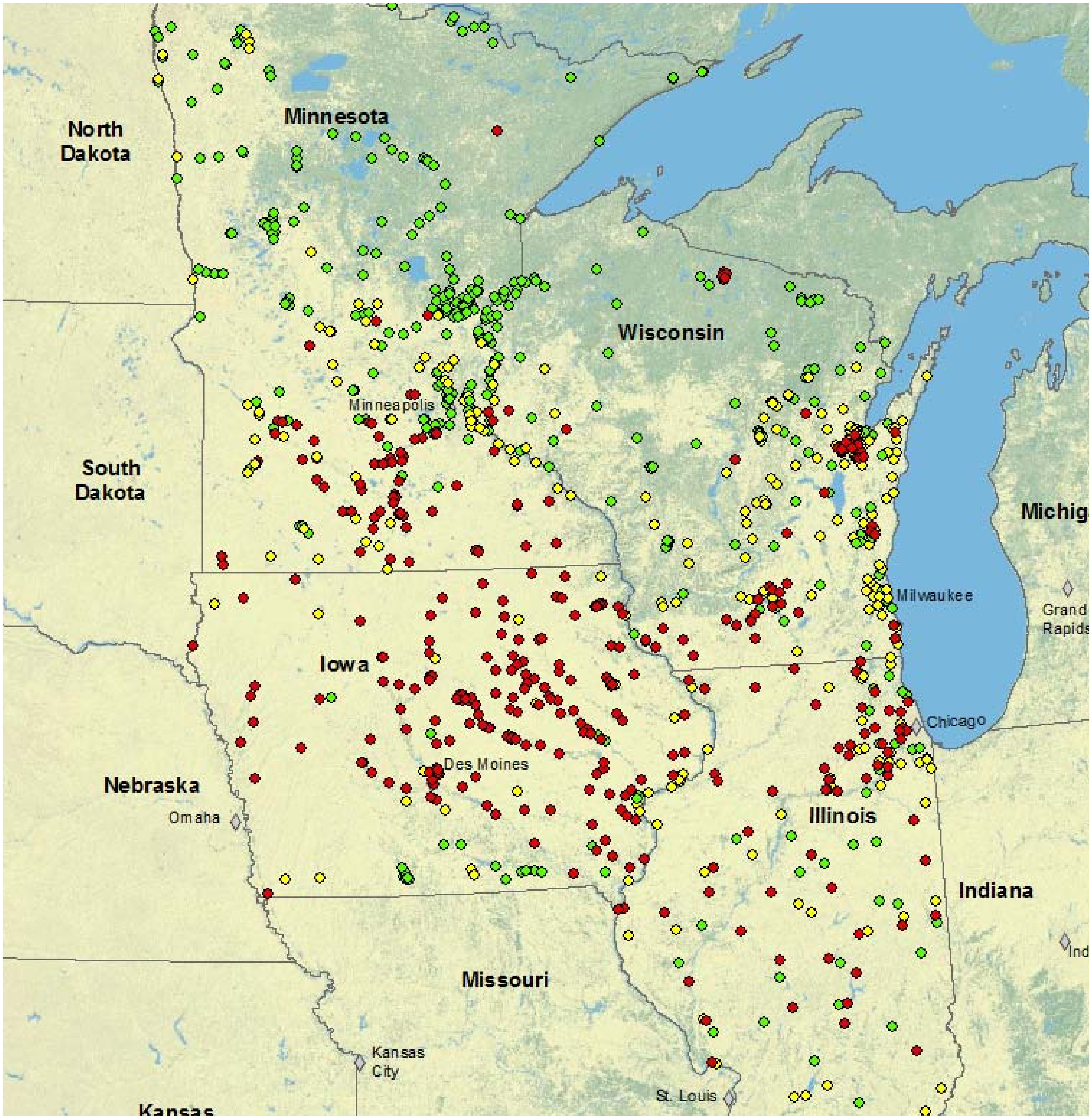


Figure 1-A: Nitrate concentrations in streams

Nitrate as N, mg/L. Data color-coded according to USGS definitions for total nitrogen concentration in streams: Low (<0.66 mg/L, green); Medium (0.66 - 3.17 mg/L, yellow); High (>3.17 mg/L, red).
Data processed as described in Table 1.

the Midwest Corn Belt (defined as the Temperate Plains ecoregion in the EPA lake survey), lake pollution was significantly worse than the national average. EPA rated only 38 percent as having good phosphorus levels and only 26 percent as having good nitrogen levels. All the others suffered from various degrees of nutrient pollution. State-by-state analysis shows that nutrient pollution was worst in Iowa and Illinois lakes.

Table 2: Nitrogen and phosphorus in Midwest lakes

State	Number monitored	Number (percent) with elevated N and/or P (either eutrophic or hypereutrophic)	Number (percent) classified as eutrophic		Number (percent) classified as hypereutrophic	
			P = 0.025-0.05 mg/L	N = 0.075-1.4 mg/L	P greater than 0.05 mg/L	N greater than 1.4 mg/L
Iowa	22	19 (86%)	8 (36%)	4 (18%)	10 (45%)	15 (68%)
Illinois	21	18 (86%)	8 (38%)	10 (48%)	9 (43%)	6 (27%)
Minnesota	66	37 (56%)	14 (21%)	22 (33%)	14 (21%)	15 (23%)
Wisconsin	35	15 (43%)	10 (29%)	12 (34%)	1 (3%)	3 (9%)
National findings	1252	667 (53%)	331 (26%)	244 (19%)	289 (23%)	254 (20%)

Source: U.S. EPA. 2010 National Lakes Assessment. http://water.epa.gov/type/lakes/lakessurvey_index.cfm. Classifications of lake nutrient pollution status as eutrophic or hypereutrophic and N/P concentration ranges defined by the U.S. EPA.

Nitrogen Pollution in Groundwater

Nitrate, unlike phosphorus, is highly soluble and mobile, which allows it to seep deep into underground aquifers. As a result, nitrate pollution of groundwater is widespread. The 2010 USGS assessment found that concentrations of nitrate were highest in shallow groundwater beneath agricultural lands, with a median concentration three times greater than the national background level of 1.0 mg/L.[43] The USGS study found that from 1993 to 2003, the proportion of shallow wells in agricultural areas with nitrate exceeding the drinking water standard of 10 mg/L rose from 16 percent to 21 percent, in parallel with increasing fertilizer use.[44]

This state-level analysis of nitrogen contamination in Midwest groundwater focuses on the combination of nitrate plus nitrite, the most commonly measured parameter in groundwater tests. Compared to nitrate, nitrite is found at significantly lower levels, but it is a more potent toxicant.

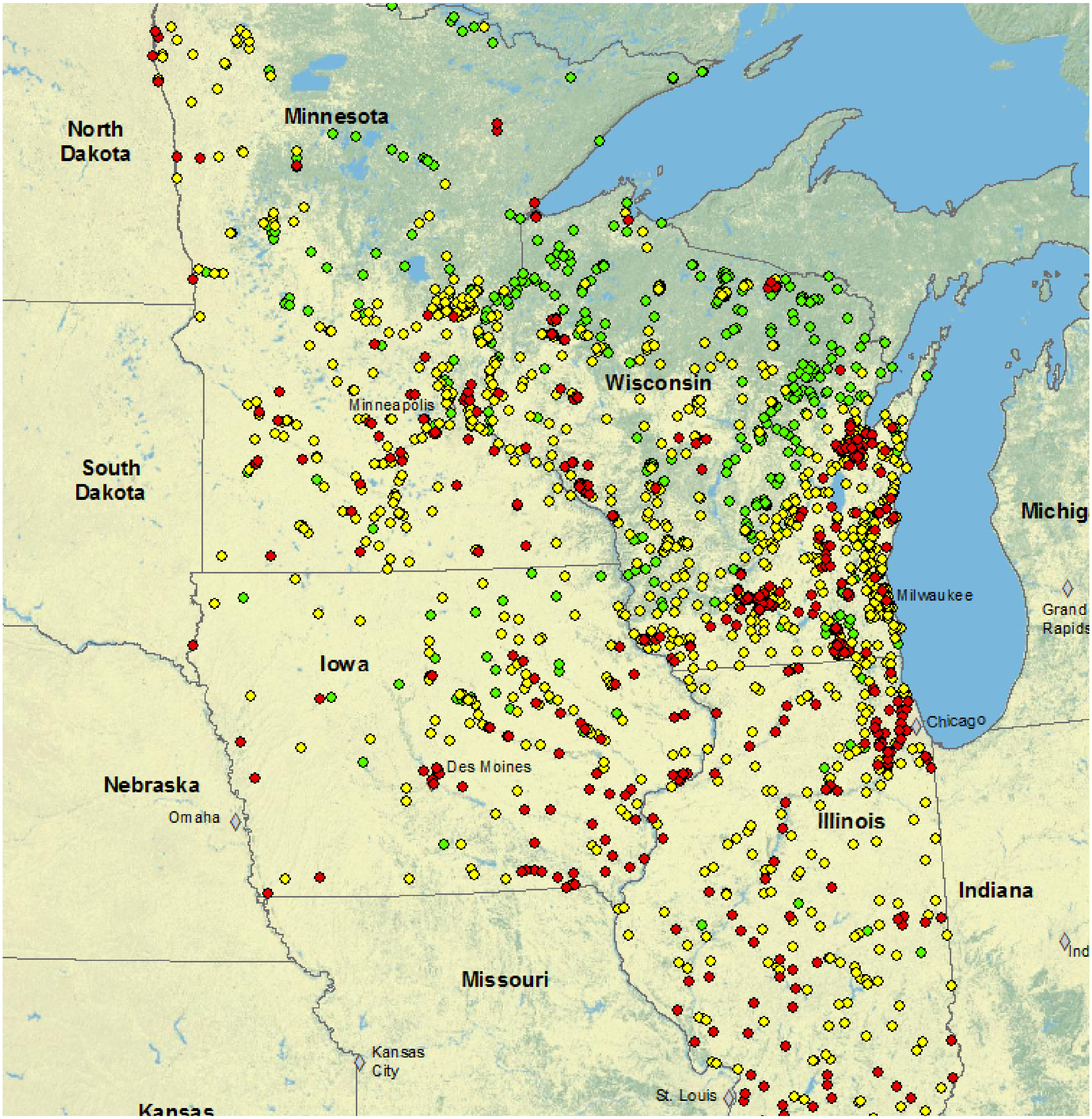


Figure 1-B: Total phosphorus concentrations in streams

Total P concentrations, mg/L. Data coded according to USGS definitions for total phosphorus in streams: Low (<0.05 mg/L, green); Medium (0.05 - 0.28 mg/L, yellow); High (>0.28 mg/L, red).

Data processed as described in Table 1.

Table 3: Average nitrate + nitrite (as nitrogen) in groundwater compared to background nitrate levels

State[1]	Well depth[2]			Range of concentrations detected, well depth 33-152 feet
	33-50 feet	51-100 feet	101-152 feet	
Illinois	2 times greater (2.2 mg/L, 53 sites)	2 times greater (1.7 mg/L, 60 sites)	0.5 mg/L (26 sites)	0-18 mg/L
Iowa	3 times greater (3.2 mg/L, 140 sites)	3 times greater (2.8 mg/L, 145 sites)	1.8 mg/L (64 sites)	0-18 mg/L
Minnesota	4 times greater (4.4 mg/L, 88 sites)	2 times greater (2.2 mg/L, 81 sites)	0.6 mg/L (44 sites)	0-28.5 mg/L
Wisconsin	4 times greater (3.9 mg/L (43 sites)	3 times greater (2.9 mg/L, 56 sites)	1.0 mg/L (23 sites)	0-21 mg/L
USGS estimate for background nitrate concentration in groundwater	1 mg/L (well depth 100 feet or less)[3]		N/A	N/A

Source: Data for 1992-2011 downloaded on Oct. 5, 2011 from USGS National Water Information System http://waterdata.usgs.gov/nwis/, for USGS parameter code P00631 (nitrate + nitrite in filtered samples, expressed as N in mg/L).

1. Of note, while the USGS National Water Information System dataset used for this analysis has a broad geographic and well depth coverage, these data were not specifically collected for the purposed of state-by-state comparison or for comparison of nitrate pollution at different depths.

2. Analysis included wells 33-152 feet deep. This range was chosen based on 2010 USGS report, "Nutrients in the Nation's Streams and Groundwater, 1992–2004," which defined a median depth of 33 feet as shallow, representing recently recharged groundwater. Wells tested in major aquifers had a median depth of 152 feet, representing older groundwater. It takes time for nitrate to travel deeper in the ground, so concentrations are higher in shallow groundwater.

3. Burow KR, Nolan BT, Rupert MG, Dubrovsky NM. 2010. Nitrate in Groundwater of the United States, 1991−2003. Environ Sci Technol 44(13): 4988-97; Nolan, BT & Hitt, KJ. 2003. Nutrients in shallow ground waters beneath relatively undeveloped areas in the conterminous United States. U.S. Geological Survey Water-Resources Investigations Report 02–4289. Available: http://pubs.usgs.gov/wri/wri024289/

The USGS study highlighted the long-term threat posed by nitrate in shallow groundwater. According to the USGS, "even if nitrate inputs are decreased, concentrations in deep groundwater are expected to increase as the contaminated young shallow water moves downward." In light of the harmful effects of nitrate on human health, this makes it essential to minimize nitrate runoff from farmland.

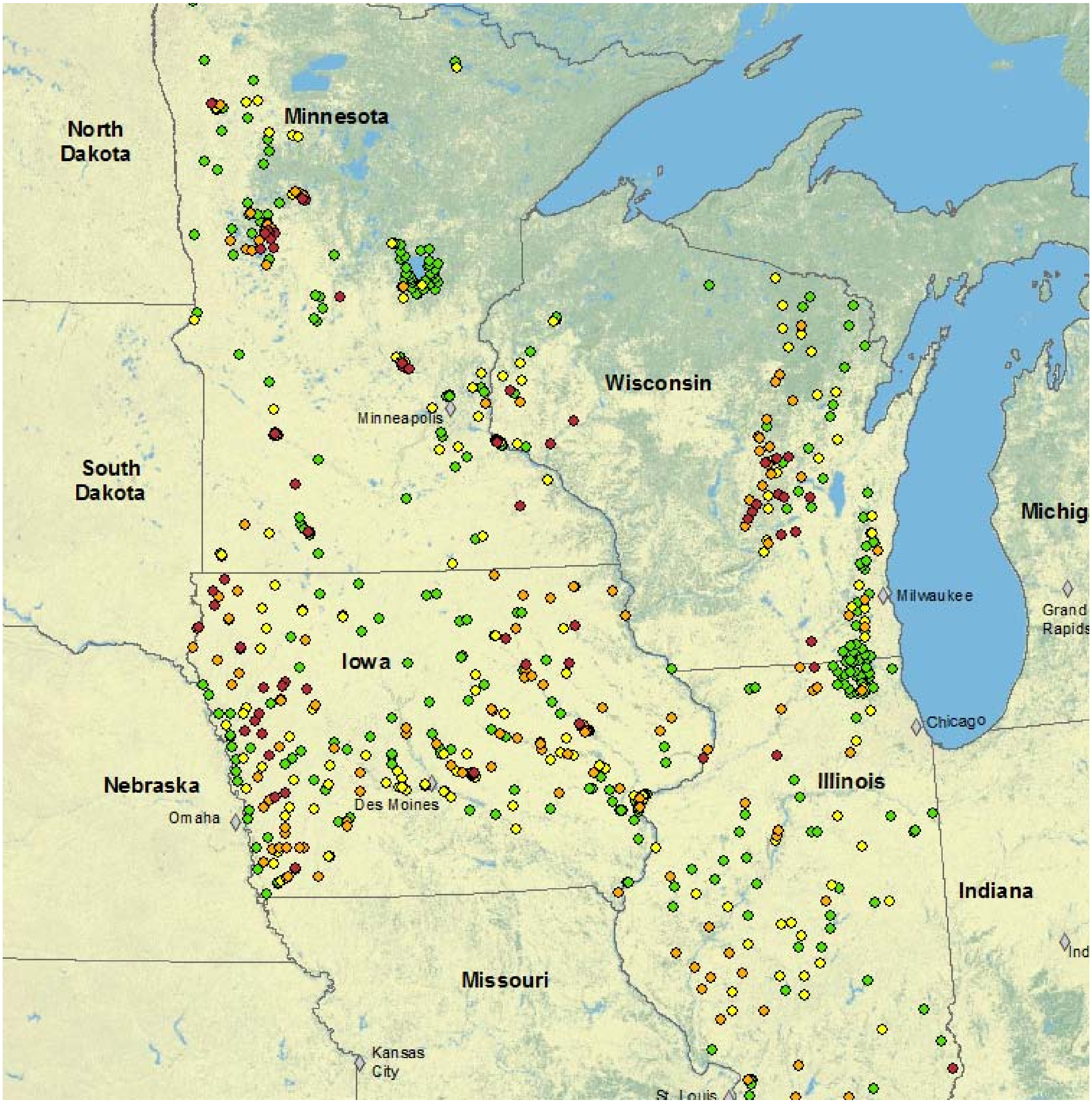


Figure 2: USGS data for combined nitrate and nitrite levels in groundwater

Samples for well depth 33-152 feet. Sample concentrations color-coded according to USGS definitions for nitrate in groundwater: Low (<0.08 mg/L, green); Medium (0.08–2.6 mg/L, yellow); High (>2.6 mg/L, orange). Samples exceeding the health standard of 10 mg/L indicated in red. Every point represents an average of all observations for that site for a well of defined depth. Source: Data for 1992-2011 downloaded on Oct. 5, 2011 from USGS National Water Information System (NWIS).

In 2009, a State-EPA Nutrient Innovations Task Group emphasized that nutrient pollution is a health risk in and of itself, as well as an indicator of a range of water quality problems, including formation of disinfection byproducts; the presence of co-occurring contaminants such as pathogens and pesticides; harmful algal blooms; and increased treatment costs. The Nutrient Task Force concluded that "the problem of nutrient pollution is nationally significant, expanding, and likely to substantially accelerate" and that "existing efforts are not succeeding at improving water quality."

AGRICULTURAL CONTAMINANTS IN SOURCE WATER AND TAP WATER

Nitrate in Tap Water

U.S. EPA assessment found that between 1998 and 2005, tests detected nitrate exceeding the legal limit at least once in each of 2,973 community and non-community water systems serving 16.7 million people.[45] Despite these nitrate spikes, many of these systems remained in compliance with federal drinking water regulations because compliance is determined by averaging two samples collected during the monitoring period.

The consequences of nitrate levels spiking above the legal limit 10 mg/L can include:

- health risks, even if the water does not violate legal drinking water standards;
- ongoing contamination that could affect other water sources, especially domestic wells;
- growing nitrate pollution in surface and groundwater, particularly in areas where agricultural activity is expanding and more acres are being planted;
- need to install expensive nitrate removal systems.

Nitrate contamination is a particularly severe problem in the Midwest. In Iowa, for example, 17 percent of residents – about 500,000 people – were exposed to high nitrate levels in drinking water between 1998 and 2005, the second highest rate in the nation. (California tops the list with 32 percent of residents exposed.) During that same period, tests found nitrate above the legal limit of 10 mg/L at least once in 114 Iowa public water systems. A more recent assessment by the Iowa Department of Natural Resources, moreover, found that more than 250 water systems were at risk of nitrate pollution.[46] Wisconsin reported 309 systems with at least one detection of nitrate levels above the legal limit, and Minnesota had 235 systems at risk. Many are in communities of fewer than 1,000 residents that don't have ready financial means to address nitrate contamination.

Table 4: Occurrence of high nitrate in drinking water in the Midwest

State	Number of public water systems affected; population served[1]
Iowa	114 (41 community water systems); 458,000 people
Illinois	74 (5 community water systems); 18,000 people
Minnesota	235 (15 community water systems); 68,000 people
Wisconsin	309 (16 community water systems); 120,000 people

1. A public water system, in U.S. EPA's definition, serves at least 25 people or 15 service connections for at least 60 days per year. A community water system supplies water to the same population year-round, while a non-community water system supplies water for shorter periods or only transiently. Examples of non-community water systems are schools, factories, office buildings, campgrounds or gas stations that have their own water systems. Non-community water systems are typically groundwater systems. Elevated levels of nitrate in a non-community water supply are an indicator of increasing groundwater pollution.

Source: 1998-2005 data from the U.S. EPA Six-Year Review national contaminant occurrence dataset for public water systems across the country with at least one nitrate detection over 10 mg/L. Downloaded from http://water.epa.gov/lawsregs/rulesregs/regulatingcontaminants/sixyearreview/second_review/index.cfm

Domestic Wells are Especially Vulnerable

Nitrate contamination is a health threat to users of private domestic wells in agricultural areas. About 45 million Americans, 15 percent of the population, get their water from private wells.[47] Since they are not covered by EPA's drinking water regulations, it falls to individual homeowners to test their water quality, decide how to respond when they find contamination, and then pay for often costly corrective measures. In a nationwide study, USGS found nitrate in 72 percent of 2,100 private wells tested between 1991 and 2004. It was the most common contaminant derived from human activities, and, not surprisingly, concentrations were higher in agricultural areas than elsewhere. As a 1998 survey by the Centers for Disease Control and Prevention demonstrated, nitrate contamination is very common in domestic water wells in the Midwest Corn Belt.[48] To draw a more detailed state-by-state picture of nitrate contamination, this analysis drew on studies conducted by state agencies and academic institutions over the past two decades.

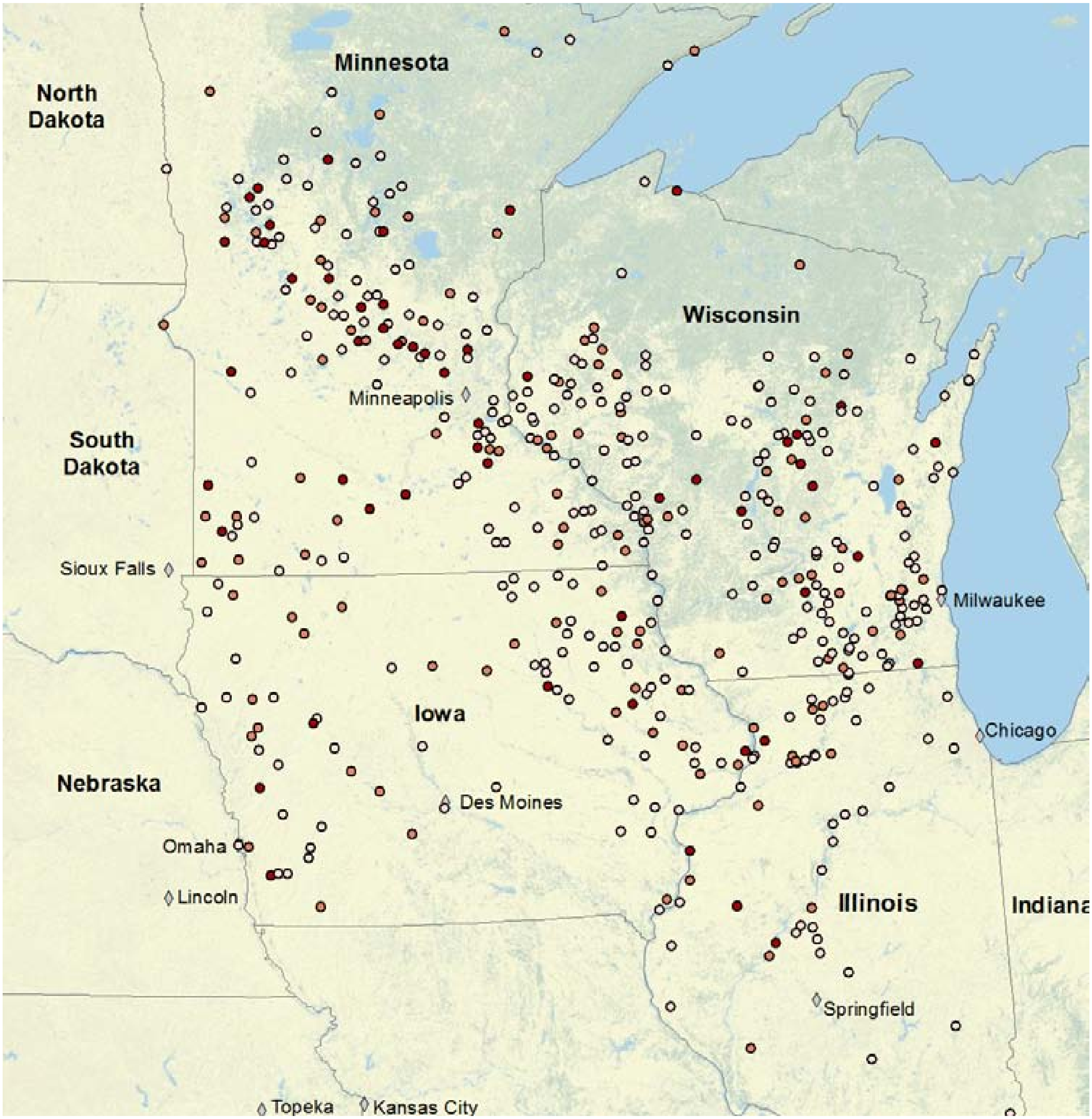


Figure 3: Water utilities with high nitrate levels in finished water.

Analysis based on 1998-2005 data from the U.S. EPA Six-Year Review national contaminant occurrence dataset. Concentration ranges color-coded: Pink: 10-14.9 mg/L nitrate; Light red: 15-19.9 mg/L nitrate; Deep red: 20 mg/L and higher concentration of nitrate.

Table 5: Summary of state-level nitrate assessments in domestic wells

State[1]	Time Period	Number tested	Percent over 10 mg/L legal limit
Iowa[2]	2006-2008	473	12%
Illinois[3]	1990-1991	240	18%[4]
Minnesota[5]	1995-1998	9,700	11.7%
Wisconsin[6]	2007	398	11.8%

1. Of note, since these datasets were collected by different sate agencies in different time periods, the data presented here cannot be directly used for state-by-state or time trend comparison.
2. University of Iowa Center for Health Effects of Environmental Contamination. 2009. Iowa Statewide Rural Well Water Survey Phase 2 (SWRL2). Available: http://www.cheec.uiowa.edu/research/SWRL2.html
3. Schock SC, Mehnert E, Caughey ME, Dreher GB, Dey WS, Wilson S, et al. 1992. Pilot Study: Agricultural Chemicals In Rural, Private Wells In Illinois. Illinois State Geological Survey, Illinois State Water Survey and Illinois Department of Agriculture Cooperative Groundwater Report 14. Available: http://www.isws.illinois.edu/pubdoc/COOP/ISWSCOOP-14.pdf
4. Pilot study in five rural Illinois counties; sample size too limited to estimate nitrate pollution of domestic wells in the entire state.
5. Minnesota Department of Agriculture. 2011. Water Testing for Nitrate. Available: http://www.mda.state.mn.us/protecting/waterprotection/nitrate.aspx
6. Wisconsin Department of Agriculture Trade and Consumer Protection. 2008. Agricultural Chemicals in Wisconsin Groundwater. Available: http://datcp.wi.gov/Environment/Water_Quality/Sampling_Reports/index.aspx

These statewide assessments highlight how serious nitrate contamination is for families and communities that depend on private wells. Contamination is most severe in areas that primarily grow row crops or have many livestock farms.[49] A recent USGS study found that in intensively cultivated areas, nearly a quarter of all wells exceed the drinking water standard for nitrate.[50]

Homeowners have three options for treating elevated nitrate in well water: distillation, ion exchange and reverse osmosis systems. In 2008, a study by University of Minnesota researchers found that the average purchase and installation cost for nitrate removal systems was around $800; maintenance can cost around $100 a year.[51] An even more expensive alternative is to drill a new, much deeper well, which averages $7,000 and can cost up to $15,000. However, even a new well might not offer a long-term solution as nitrate contamination migrates deeper into the aquifer. A deeper well might also tap into groundwater layers that are higher in minerals such as iron that spoil the taste and color of water.

Disinfection Byproducts – Making a Bad Situation Worse

Rivers and streams naturally contain decaying terrestrial and aquatic plants, but algal blooms greatly increase the quantity of organic matter that can form toxic disinfection byproducts in tap water. Summer is a particularly sensitive season, because warmer temperatures frequently result in large blooms, more intense disinfection and higher levels of byproducts.

To minimize disinfection byproducts, water utilities are required to lower the total organic carbon content of water prior to adding a disinfectant.[52] Under the federal water quality standards, utilities must remove organic matter whenever the total organic carbon in source water exceeds 2 mg/L. Technologies to do this are expensive to build and maintain. According to the U.S. EPA database, average organic carbon concentrations in surface water systems in Minnesota, Iowa and Illinois exceed this threshold level.[53]

Table 6: Total Organic Carbon (TOC) in source water in Midwestern states

State	TOC average, mg/L	TOC range, mg/L
Iowa	3.9	1.6-10
Illinois	3.5	1.5-8.3
Wisconsin	1.9	1.6-3
Minnesota	8.6	6.4-13.2

Source: U.S. EPA. 2000. Information Collection Rule. Available: http://www.epa.gov/enviro/html/icr

Disinfection byproducts are too often found in tap water

High levels of disinfection byproducts in tap water are a problem for many communities. In 2010, according to the U.S. EPA Safe Drinking Water Information System (SDWIS), 829 water systems serving 2.6 million people violated the legal limits for trihalomethanes and haloacetic acids. Authorities determine whether a water system is complying with the standard for these byproducts by calculating a "running annual average" of all quarterly samples taken over the previous 12 months. Even when one or more samples are above the legal limit, the water utility may still be in compliance if its running annual average is below the limits.

In order to more accurately calculate how many people are exposed to elevated levels of disinfection byproducts and to identify water utilities that are at risk of exceeding the legal limit at least some of the time, EWG examined systems whose average disinfection byproduct concentration was either above three-quarters of the trihalomethane standard or above three-quarters of the haloacetic acid standard. These systems are more likely to experience spikes in disinfection byproducts during times of higher organic matter content or algal blooms, especially during summer months.[54]

This analysis of tap water contaminant information in EWG's National Drinking Water Database showed that in 2004-2008, 2,888 water utilities across the country were in this higher risk category. These systems serve 11.8 million people whose health may be at risk from elevated disinfection byproducts.

Disinfection byproducts are a recurrent problem in Iowa and Illinois, which have many surface water systems. The analysis showed that from 2004 to 2008, 90 Illinois water systems serving 145,000 people and 50 Iowa water systems serving 62,000 people were above three-quarters of the trihalomethanes or haloacetic acid standard. Although utilities in Minnesota and Wisconsin primarily rely on groundwater, five systems in Wisconsin and eight in Minnesota exceeded the three-quarters level during the same period.

Research by government agencies, academia and the water industry has shown that the regulated disinfection byproducts, trihalomethanes and haloacetic acids, constitute only a portion of up to 600 different toxic chemicals that form during water disinfection.[55] This diverse group includes nitrogen-containing compounds, brominated compounds and iodinated compounds. Using alternative primary or secondary disinfectants instead of chlorine (e.g. chloramines, chlorine dioxide, ozone, ultraviolet) may minimize formation of some regulated byproducts but increase formation of other, unregulated, compounds.[56] Formation of some unregulated byproducts, such as highly carcinogenic nitrosamines, occurs when levels of nitrogen-containing compounds are higher, conditions that are linked to algal blooms and the presence of wastewater in source water.

Cyanobacteria Blooms are a Worsening Problem

Cyanobacteria blooms are a serious problem for water utilities that depend on surface water, particularly reservoirs and lakes. EPA's 2010 National Lake Assessment, the first nationwide study of cyanotoxin occurrence

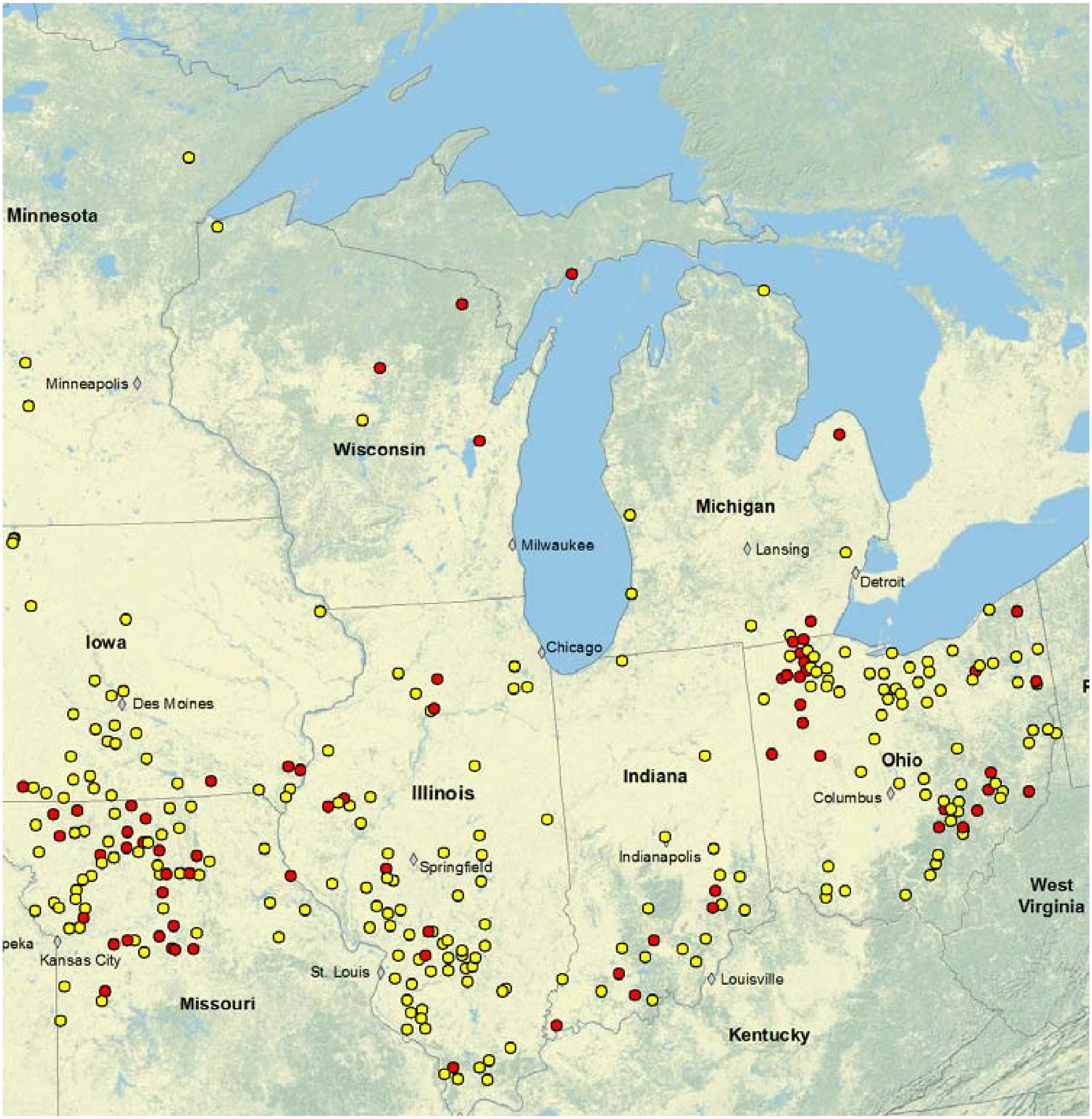


Figure 4: Water systems with average disinfection byproduct levels above three-quarters of the legal limit, 2004-2008

Source: EWG's National Tap Water Database (www.ewg.org/tap-water). Color-coding: Yellow: systems with trihalmoethane levels above ¾ of federal standard (above 60 ppb) or with haloacetic acid levels above ¾ of the federal standard (above 45 ppb); Red: systems with trihalomethane or haloacetic acid levels exceeding the federal standard.

in lakes, found that a third of the tested lakes contained microcystin, toxin produced by the Microcystis group of cyanobacteria.[57]

Table 7: Many Midwest lakes test positive for cyanobacterial toxin microcystin.

State	Number monitored	Number with microcystin	Percent with microcystin
Illinois	21	12	57%
Iowa	22	13	59%
Minnesota	66	35	53%
Wisconsin	35	14	40%
National	1,252 samples tested	391	31%

Source: U.S. EPA. 2010. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. Available: http://water.epa.gov/type/lakes/lakessurvey_index.cfm

In the Midwest, the proportion of lakes with detectable microcystin is above the national average, reflecting the severity of the nutrient overload problem there. Although local physical, hydrological and weather conditions determine whether an algal bloom will erupt in water with a particular nutrient concentration, high nutrient levels drive the occurrence of these blooms.[58]

Frequently, water system customers and operators become aware of algal blooms only when tap water develops a musty, unpleasant smell and taste.[59] This is usually linked to two chemical compounds released by cyanobacteria, geosmin and 2-methylisoborneol. They are not toxic themselves but are important indicators of worsening source water quality.[60]

In a study of 23 lakes in agricultural areas of Iowa, Kansas, Minnesota and Missouri, USGS scientists found that 91 percent of algal blooms produced both cyanotoxins and foul taste-and-odor compounds, indicating that odor may provide a useful warning that cyanotoxins are present. The study also found that multiple cyanotoxins can occur together. However, the researchers detected toxins more frequently than the taste-and-odor compounds, indicating that drinking water sources may contain potentially harmful levels of cyanotoxins even when tap water tastes and smells fine. The conclusion of the USGS report is striking:

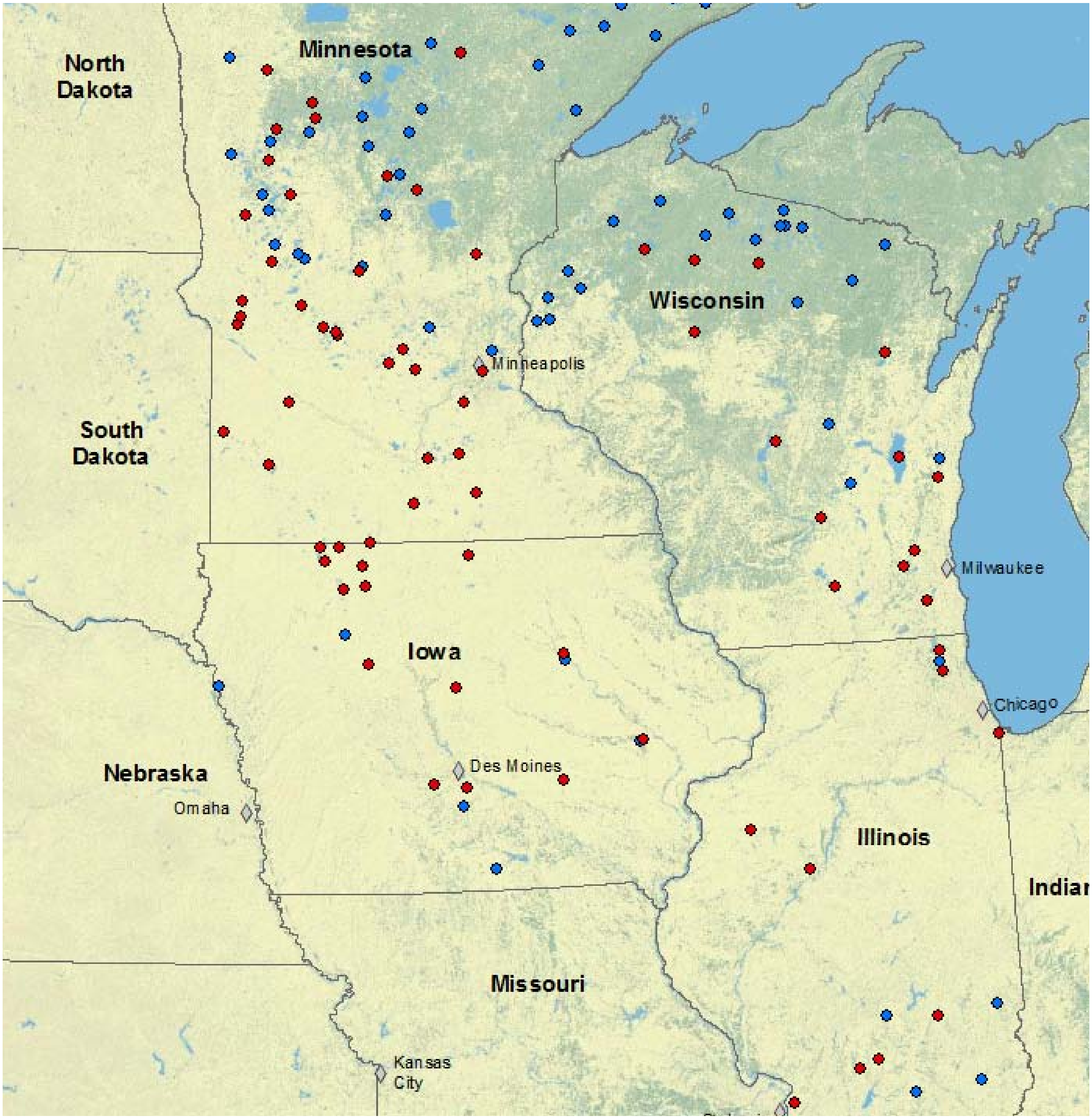


Figure 5: Location of lakes with detectable levels of microcystin in the National Lake Assessment

Source: U.S. EPA. 2010. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. Available: http://water.epa.gov/type/lakes/lakessurvey_index.cfm. Samples were collected in the summer 2007. Color coding: Red: microcystin detected; Blue: microcystin not detected.

"Drinking-water purveyors frequently tell customers during taste-and-odor outbreaks that there are no health risks. In our study, however, taste-and-odor causing compounds were always accompanied by cyanotoxins, highlighting the need for water purveyors to increase cyanotoxin surveillance during taste-and-odor outbreaks so that treatment can be modified accordingly, and to verify that cyanotoxins are not present at or above thresholds of potential health risk." [61]

Cyanobacteria in Iowa lakes

EPA's National Lake Survey tested 22 Iowa lakes in 2007 and found that 59 percent had detectable levels of the cyanotoxin microcystin. In addition, 82 percent had chlorophyll levels (a measure of algal growth) above the threshold of 10 micrograms per liter, a level that the World Health Organization considers a potential human health risk.[62] These data agree with the Iowa Lake Survey conducted by the Iowa State University scientists, which found that algal blooms are a persistent problem in many of the state's lakes.[63]

World Health Organization thresholds of risk associated with recreational exposure to cyanotoxins:

Low risk of exposure: cyanobacteria cell counts less than 20,000 cells/ml.

Moderate risk of exposure: 20,000 - 100,000 cells/ml.

High Risk of Exposure: over 100,000 cells/ml.

To examine the effect of these algal blooms, EWG focused on the Iowa Lake Survey data for 32 lakes that supply drinking water.[64] Together, they cover more than 30,000 acres. In samples collected in 2006, 2009 and 2010, 94 percent of summer averages for those lakes exceeded the WHO guidance level for cyanobacteria of 20,000 cells/ml.[65] The median cyanobacteria summer average was 84,000, four times the WHO guidance level; the highest level detected was above 45 million cells/ml, more than 2,000 times the WHO guidance level.

For this study, current use of many lakes for drinking water supply was verified with Iowa Department of Natural Resources Water Quality Bureau (electronic communication, 11/30/11). Some lakes currently used for drinking water supply were not tested for cyanobacteria in the Iowa Lake Survey, including Lake Fisher (used by

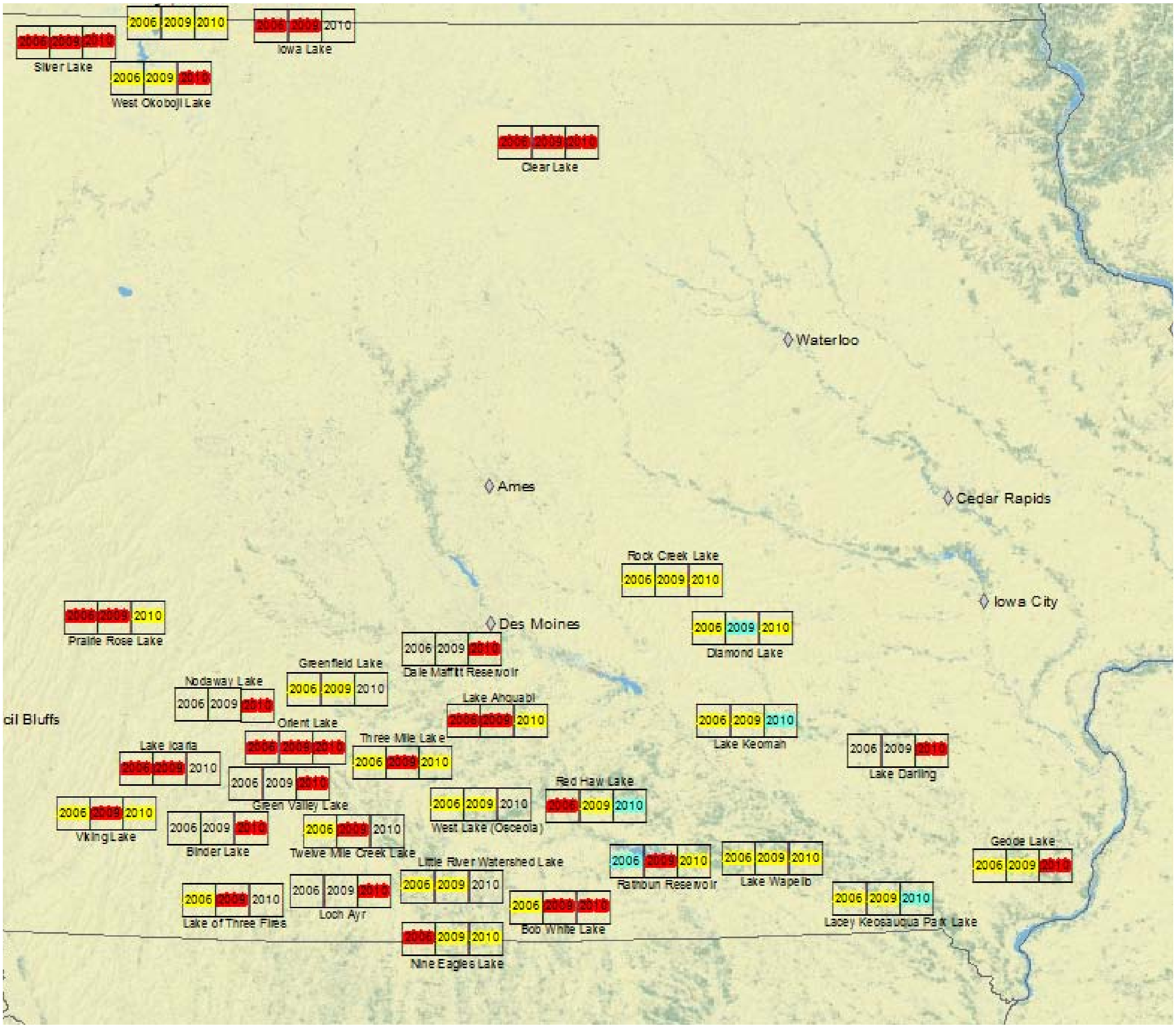


Figure 6: Cyanobacteria occurrence in Iowa lakes supplying drinking water

Source: Cyanobacteria data obtained from the Iowa Lake Survey (online at http://limnology.eeob.iastate.edu/lakereport/). List of Iowa water bodies designated for Drinking Water Use obtained from Iowa Department of Natural Resources. Lake names listed on the map. Numbers indicate the year data were collected (2006, 2009, or 2010). Color-coded according to the WHO risk levels for cyanotoxin exposure: Green: low risk; Yellow: moderate risk; Red: high risk; No color: no cyanobacteria data for the year available.

Table 8: Cyanobacteria in Iowa lakes supplying drinking water exceed health limits

Lake (currently in use or not in use for drinking water supply)	Size in acres	County	2010 summer average (cells/ml)	2009 summer average (cells/ml)	2006 summer average (cell/ml)	Highest count in a single test (cells/ml)	Date of the highest test
Greenfield Lake (in use)	50	Adair	33,117	36,942	N/A	49,177	8/6/09
Lake Orient (not in use)	15	Adair	112,875	157,461	193,454	383,496	8/1/06
Nodaway (not in use)	25	Adair	N/A	N/A	283,510	623,044	5/30/06
Binder (in use)	60	Adams	N/A	N/A	172,404	365,070	6/27/06
Lake Icaria (in use)	669	Adams	149,895	141,273	N/A	244,395	8/2/10
Rathbun Reservoir (in use)	11,000	Appanoose	17,321	249,286	44,516	462,887	8/17/09
Clear Lake (status not available)	3,684	Cerro Gordo	161,746	121,854	2,245,583	6,339,661	6/12/06
West Lake (Osceola) (in use)	337	Clarke	37,411	59,491	N/A	134,296	7/22/09
Lake Wapello (status not available)	289	Davis	23,646	20,118	41,591	65,371	7/12/06
Little River Watershed Lake (in use)	799	Decatur	77,262	48,999	N/A	124,988	8/23/10
Nine Eagles Lake (status not available)	63	Decatur	239,378	39,316	35,773	468,969	8/23/10
Big Spirit Lake (in use)	4,169	Dickinson	60,600	48,158	59,687	119,141	6/1/10
Silver Lake (not in use)	1,041	Dickinson	188,903	160,662	138,047	414,411	7/20/10
West Okoboji Lake (in use)	3,847	Dickinson	22,020	84,249	147,781	187,799	8/4/09
Lake Iowa (status not available)	308	Emmet	141,221	15,260,466	N/A	45,280,918	7/21/09
Lake Geode (status not available)	189	Henry	94,847	50,305	110,819	162,773	6/6/06
Rock Creek Lake (status not available)	602	Jasper	40,019	82,025	85,145	117,907	6/5/06
Red Haw Lake (not in use)	64	Lucas	133,870	73,908	9,352	190,154	5/24/10
Lake Keomah (status not available)	84	Mahaska	32,911	53,780	12,404	79,176	8/13/09
Viking Lake (status not available)	137	Montgomery	99,574	136,540	72,539	230,913	8/11/09
Dale Maffitt Reservoir (in use)	200	Polk	N/A	N/A	124,002	357,018	6/26/06
Diamond Lake (in use)	98	Poweshiek	75,266	15,016	31,172	132,044	9/20/10
Loch Ayr (not in use)	95	Ringgold	N/A	N/A	121,225	183,594	8/1/06
Prairie Rose Lake (status not available)	219	Shelby	247,794	133,141	31,775	339,795	8/3/10
Lake of Three Fires (not in use)	97	Taylor	56,667	177,238	N/A	454,392	7/14/09
Green Valley Lake (not in use)	393	Union	N/A	N/A	139,981	213,278	6/27/06
Three Mile Lake (in use)	880	Union	49,147	158,389	92,128	200,913	7/13/09
Twelve Mile Creek Lake (in use)	660	Union	56,433	1,075,968	N/A	2,410,950	8/6/09
Lacey Keosauqua Lake (status not available)	22	Van Buren	55,632	69,477	19,850	117,273	8/18/09
Lake Ahquabi (status not available)	108	Warren	148,340	168,434	55,438	265,165	8/17/09
Lake Darling (status not available)	299	Washington	N/A	N/A	180,825	346,123	8/8/06
Bob White Lake (status not available)	89	Wayne	80,261	161,937	135,553	395,583	7/22/09

Source: Cyanobacteria data obtained from the Iowa Lake Survey (online at http://limnology.eeob.iastate.edu/lakereport/). List of Iowa water bodies designated for Drinking Water Use obtained from Iowa Department of Natural Resources report (http://www.iowadnr.gov/portals/idnr/uploads/water/npdes/PGP_Class_C_06252010.pdf). Current use status for a number of lakes verified in email communication with the Iowa DNR Water Quality Bureau, which provided "Updated List of Active Surface Water and IGW Systems in Iowa" on Nov. 30, 2011. For some Class C lakes, Iowa DNR did not provide information on current use status, as indicated in the table. Cyanobacteria levels color-coded by WHO risk category: Green – low risk; Yellow – moderate risk; Red – high risk.

Bloomfield); Lake Ellis and Lake Morris (Chariton); Corning City Reservoir (Corning); Home Pond, Northwood Lake and Lake LaShane (Lamoni); Cedar Lake (Winterset). For purposes of comparison, it is useful to focus on available cyanobacteria data for all designated drinking water use lakes, since currently used but untested lakes would likely be similar to tested lakes.

Poor water quality is the main reason that utilities stop using lakes as a source. Some communities in Iowa that used to draw on lake water have switched to centrally treated drinking water from rural water providers, often because of poor local source water quality. In 2011 data from the Iowa Department of Natural Resources, EWG identified several communities that had ceased using lakes for source water: Bedford (Lake of Three Fires), Lake Park (Silver Lake) and Mt. Ayr (Loch Ayr). Other Iowa systems have switched from surface water to groundwater, including the communities of Fairfield, Fort Madison and Mt. Pleasant. These developments underscore that cyanobacteria in surface water bodies has been a significant problem for Iowa water suppliers, ultimately prompting some water systems to seek alternative sources, often at great cost.[66]

National Lake Survey findings of cyanobacteria in Illinois, Minnesota and Wisconsin lakes

Table 9: Cyanobacteria levels in Illinois, Minnesota and Wisconsin lakes compared to WHO's cyanotoxin risk guidance

State and number of lakes tested	Percent at "low risk" (less than 20,000 cells/ml)	Percent at "moderate risk" (20,000-100,000 cells/ml)	Percent at "high risk" (above 100,000 cells/ml)
Illinois (21)	38%	48%	14%
Minnesota (66)	62%	29%	9%
Wisconsin (35)	74%	23%	3%

Source: U.S. EPA. 2010. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. Available: http://water.epa.gov/type/lakes/lakessurvey_index.cfm

Cyanobacteria blooms have been a problem for surface water systems in other states as well. Even in states that rely mostly on groundwater, such as Minnesota and Wisconsin, surface water systems are affected by algae. The National Lakes Assessment offered a snapshot of cyanobacteria occurrence in Illinois, Minnesota and Wisconsin during the summer of 2007. The data come from a one-time sampling that could have easily missed peak cyanobacteria blooms, so they constitute a highly conservative estimate of the extent of problem.

Cyanobacteria in Illinois lakes

A 2005 survey by Illinois EPA scientists found cyanotoxin-producing algae in 13 of 15 lakes and reservoirs sampled. Their report concluded that the "harmful algal bloom issue is one that IL EPA cannot afford to overlook. While documented cases of harmful human health effects due to algal toxins are few in the U.S., it is likely that at least some cases go unreported due to general inability to recognize adverse health effects and make a correlation between those effects and recreational exposure to algal toxins."[67]

The Illinois EPA study agreed with the finding of the U.S. EPA's National Lake Survey that 57 percent of monitored lakes in Illinois had detectable microcystin, indicating that cyanobacterial blooms represent a health risk for Illinois' surface water systems and the communities that depend on them. Some of the examples of large public water supply lakes that have had algal bloom problems are Lake Bloomington (serving 72,000 people); Lake Vermillion (serving 55,000); and Otter Lake (serving 17,000).[68] Algal blooms sometimes prompt water utilities to seek alternative water supplies, but switching water sources is not an option for most.[69]

Overall, 61 public water systems in Illinois depend on inland lakes and reservoirs for their water supply. Most are in southern and central Illinois, where the groundwater has high levels of minerals that are expensive to remove.[70] Despite the significant amount of treatment that surface water requires and water quality problems caused by agricultural runoff, these communities often do not have an economically viable alternative.

EWG examined data for 59 public water supply lakes monitored in the 2010 Illinois Integrated Water Quality Report. This assessment is conducted biannually by the Illinois EPA under the requirements of the federal Clean Water Act.[71] EWG restricted its analysis to lakes of 25 acres or more, which jointly represent 99.5 percent of lakes designated for public water supplies in the state.

EWG's analysis showed that aquatic algae had harmed water quality in 45 lakes (76 percent). EWG's review of detailed algal surveys for 36 of these lakes assessed between 2005 and 2010 (data provided by the Illinois EPA on Feb. 28, 2012) found that cyanobacteria were the dominant algal group in all but one of the lakes. It is also noteworthy that more than three quarters of the assessed lakes had elevated phosphorus, which creates ideal conditions for cyanobacteria to thrive. These algae-impaired lakes are the source of water for 38 treatment plants that serve nearly a million residents in more than 100 communities.[72]

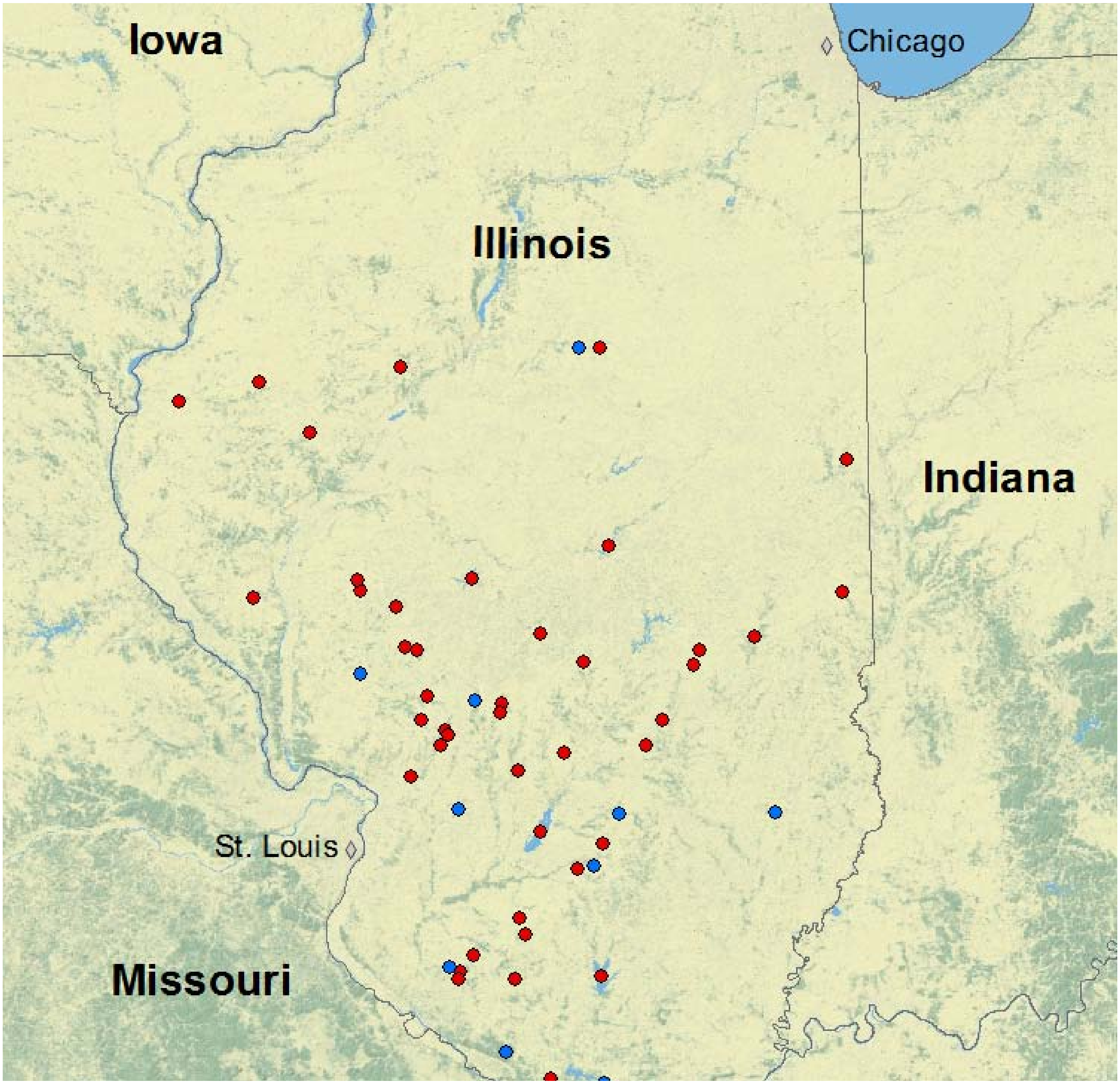


Figure 7: Aquatic algae affect water quality in Illinois public water supply lakes.

Source: Illinois EPA. 2010. Illinois Integrated Water Quality Report and Section 303(d) list. Available: http://www.epa.state.il.us/water/tmdl/303d-list.html. Color coding: Red – lakes with recorded water quality impairment caused by aquatic algae; Blue – lakes without recorded water quality impairment caused by aquatic algae. Of note, Illinois EPA uses the aquatic algae criteria for assessing aesthetic quality impairment, not for determining the lake's usability as drinking water source.

Cyanobacteria in Minnesota lakes

Taste and odor problems linked to cyanobacteria blooms have been a historical problem for water utilities serving 415,000 people in St. Paul and 11,000 in Fairmont.[73] Monitoring by state officials found that lakes in the state's southern "corn belt" are particularly susceptible to algal blooms.[74] A 2005 report by the Minnesota Pollution Control Agency warned that using water sources affected by algal blooms for drinking water "requires substantial increased dosages of chlorine during treatments including: (1) raw water transportation; (2) during water treatments to control breakdown of ammonia and other substances; (3) during final disinfection; and (4) increased usage to maintain residual chlorine in the water distribution system (due to increased consumption by the organic compounds)."[75]

Cyanobacteria in Wisconsin lakes

The frequent appearance of cyanobacteria blooms and cyanotoxins in surface waters in Wisconsin has resulted in numerous poisoning reports in people and animals. Hot, humid summer weather in 2011 led to a particularly large number of cyanobacteria-related reports.[76] Surface water systems that draw from Lake Winnebago (serving Appleton, Neenah, Menasha and Oshkosh, with a total population of 170,000) have historically experienced significant algal blooms associated with bad taste and odor in tap water and high levels of disinfection byproducts.[77]

THE HIGH COST OF CLEANING UP SOURCE WATER

For many utilities, removing agricultural pollutants from source water is a costly – sometimes prohibitively expensive – task, and the cost of water treatment is likely to rise as expanding agricultural activity and population growth further degrade source water quality. EWG's analysis documented some of the costs based on case studies and estimates from state and federal drinking water agencies and the water industry. EWG also conducted a pilot survey of Iowa utilities to collect more information about their experience with removing agricultural runoff contaminants from tap water.

Iowa Water Utility Survey: Treating Source Water Contaminated with Agricultural Chemicals

In an anonymous survey of 11 medium and large Iowa water utilities jointly conducted by EWG and the Des Moines Water Works, six utilities called agricultural contamination a significant concern and five considered it a moderate concern. The survey included six that rely on groundwater and five that either use surface water or groundwater directly influenced by surface water. Among the 11 utilities:

- Algal blooms were a concern for five that depend on or are affected by surface water.
- Pesticides were a concern for nine. Four listed specific pesticides, citing atrazine in two cases and both atrazine and alachlor in the other two.
- Nitrate was a concern for eight.

The EWG survey identified several specific steps utilities had taken to treat agricultural contaminants, including:

- shutting down some wells during high nitrate periods and mixing water from other wells;
- building a nitrate removal facility (construction cost $4 million, operating cost $500,000/year);
- using holding ponds for natural removal of nitrates (construction cost $450,000, operating/maintenance costs $50,000/year);
- building a new reverse osmosis water treatment plant using only groundwater;

Table 10: Nutrient overload increases the cost of water treatment

Contaminant	Treatment approach	Cost (range, if available)	Construction cost per resident
Nitrate	Ion exchange	$300,000-$600,000 for 500-1,000 residents[1]	$500-to-$1,000
Nitrate	Reverse Osmosis	$1.7 million for 4,000 residents[2]	$400+
Nitrate	Reconstructing or drilling new wells	$35,000-$650,000[3]	up to $300-$400
Algal blooms, disinfection byproducts	Algae removal, turbidity control, organic carbon removal	$9 million-$32 million (see case studies below)	$400-$2,900
Cyanotoxins	Treatment by ozone; granular activated carbon; reverse osmosis; advanced oxidation with UV light and peroxide	$12 million-$56 million for 100,000 people[4]	$120-$560

1. Minnesota Department of Health, Minnesota Department of Agriculture. 2004. Nitrate Contamination – What is the Cost? Available: http://www.mda.state.mn.us/protecting/waterprotection/drinkingwater.aspx
2. Minnesota Department of Health, Minnesota Department of Agriculture. 2004. Nitrate Contamination – What is the Cost? Available: http://www.mda.state.mn.us/protecting/waterprotection/drinkingwater.aspx
3. Survey conducted by the Wisconsin Department of Natural Resources in 2005.
4. Alvarez M, Rose J, Bellamy B. 2010. Treating Algal Toxins Using Oxidation, Adsorption, and Membrane Technologies. Water Research Foundation Project # 2839. Available: http://www.waterrf.org

- installing ultraviolent treatment (cost $750,000);
- installing a new treatment plant, adding new water sources and distribution system improvements (overall cost $50 million).

EWG's analysis indicates that installing and operating treatment technologies to remove agricultural contaminants is very costly for water utilities and their communities. The most extensive data are available for nitrate removal and surface water treatment to address algal blooms and disinfection byproducts. In the absence of specific information on the costs of treating disinfection byproducts alone, the analysis primarily focuses on treatments for nitrate and algal blooms.

CASE STUDIES

Nitrate removal

National estimates of the cost of nitrate removal vary, but all studies consider the economic impact very significant. A conservative estimate by the American Water Works Association put the annual cost of nitrate removal at $131 million-to-$159 million just to comply with the EPA drinking water standard. In contrast, a study by USDA economists estimated the cost of removing nitrate from drinking water supplies so as to meet water quality standards to be more than $4.8 billion a year.[78] And a study by researchers at the University of Texas at Austin concluded that with the expansion of agriculture in the United States, water utilities might require up to a 2,100 percent increase in energy use for water treatment for nitrate pollution in agricultural areas, which would become a significant financial burden for many communities.[79]

To fill in the picture, EWG collected several case studies. Documented project costs ranged between $400,000 and $7.5 million and included construction of deeper wells and installation of ion exchange or reverse osmosis treatment.

Small groundwater systems faced with nitrate contamination frequently seek to reconstruct an existing well or drill a new, deeper well that avoids groundwater layers that have been polluted by agricultural chemicals. A 2005 survey by the Wisconsin Department of Natural Resources found that the cost of reconstruction or drilling a new well ranged from $35,000 to $650,000. EWG identified two recent examples of well water projects funded under the American Recovery and Reinvestment Act (data provided by the U.S. EPA Office of Ground Water and

Drinking Water on August 25, 2011). In one case, the community of Rio, Wis., (population 986) rehabilitated a well affected by increasing nitrate levels at a cost of $420,823, or $427 per resident. In another, the community of Stevens Point, Wis. (population 1,743) drilled a new well in a location with lower nitrate levels at a cost of $517,332, or $297 per resident.

But drilling deeper wells is only a temporary solution that postpones tackling the fundamental problem. As a 2010 USGS report pointed out, "nitrate concentrations in water in deep aquifers are likely to increase during the next decade as shallow groundwater with elevated concentrations moves downward."[80] The report added

Table 11: Removing nitrate with ion exchange is very costly.

Source	Basis of estimate	Population served	Actual or estimated construction cost	Cost per resident
State EPA Nutrient Innovations Task Group (2009)[1]	EPA cost estimate model	500	$280,000	$560
Minnesota Dept. of Health and Dept. of Agriculture (2004)[2]	Case studies of systems installed in Adrian, Ellsworth, Edgerton, and Clear Lake, Minn.	400-1,200	$360,000-$600,000	$350-$970
U.S. EPA funding under American Recovery and Reinvestment Act (2011)[3]	Proposed system for Amherst, Wis.	1,058	$1.2-$1.7 million (for one or two wells)	$1,092-$1,606
Iowa Dept. of Natural Resources Drinking Water Loan program (2011)[4]	Proposed system for Epworth, Iowa	1,600	$600,000 (for one well)	$375
Iowa Dept. of Natural Resources Drinking Water Loan program (2011)[4]	Proposed system for Manchester, Iowa	5,300	$4.7 million (for three wells)	$886
Illinois EPA (2011)[5]	Streator, Ill. system built in 2002	13,700	$1.6 million	$117
Illinois EPA (2011)[5]	Decatur, Ill. system built in 2002	79,000	$7.5 million	$96

1. State-EPA Nutrient Innovations Task Group. 2009. An Urgent Call to Action. Available: http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/doing.cfm
2. Minnesota Department of Health & Minnesota Department of Agriculture. 2004. Nitrate Contamination – What is the Cost? Available: http://www.mda.state.mn.us/protecting/waterprotection/drinkingwater.aspx
3. U.S. Environmental Protection Agency Office of Ground Water and Drinking Water Drinking Water State Revolving Fund Team on Sept. 25, 2011; Wisconsin Department of Natural Resources. 2009. State Of Wisconsin Safe Drinking Water Loan Program Intended Use Plan for EPA FFY 2009, Capitalization Grant and American Recovery & Reinvestment Act of 2009. SRF Grant For Funding During State Fiscal Year 2010. Available: http://dnr.wi.gov/org/caer/cfa/EL/Section/sdwlpiup.pdf.
4. Drinking Water State Revolving Fund projects, Iowa Department of Natural Resources. 2011. Drinking Water Loan Program. Available: http://www.iowasrf.com/program/drinking_water_loan_program/
5. Illinois Environmental Protection Agency Division of Public Water Supplies on July 13, 2011; Stanmar G. 2002. Streator council OKs water improvements. The Pantagraph (Bloomington, IL) June 5, 2002.

that this "downward movement of shallow groundwater with nitrate concentrations exceeding the MCL could potentially result in deterioration of drinking water supplies in the future."

Table 12: Reverse osmosis water treatment costs millions.

System	Year completed	Cost	Population served
Lincoln-Pipestone Rural Water – Holland well field (Minnesota)[1]	1999	$1,706,650	4,100
Central Iowa Water Association, Waverly, Iowa[2]	2009	$9 million	1,000+ households
Hartley, Iowa[3]	2010	$3.1 million	1,700
Fort Madison, Iowa[4]	2010	$17 million	10,700

1. Minnesota Department of Health, Minnesota Department of Agriculture. 2004. Nitrate Contamination – What is the Cost? Available: http://www.mda.state.mn.us/protecting/waterprotection/drinkingwater.aspx
2. Heinselman K. 2007. Rural utility breaks ground Wednesday on water treatment plant in Waverly. Waterloo-Cedar Falls Courier (Waterloo, Iowa) June 19, 2007.
3. City of Hartley. 2011. Reverse Osmosis Water Treatment Facility. Available: http://www.hartleyiowa.com/reverseosmosis.asp
4. Iowa League of Cities. 2011. All Star Community Awards. Available: http://www.iowaleague.org/Pages/AllStarCommunityAwards.aspx

The most common treatment for nitrate removal is ion exchange. Table 11 summarizes the cost of nitrate removal for several completed and currently planned water treatment systems.

Some water systems in agricultural areas must install treatment systems capable of addressing multiple water quality problems, such as removing minerals in addition to nitrate. Reverse osmosis treatment is one alternative to ion exchange, but it is much more expensive.

Such costs can be overwhelming for small communities. A Wisconsin Department of Natural Resources review of 22 water utilities serving 144,000 people reported a total cost of $24 million for measures ranging from the least expensive well reconstruction to the most expensive options of both drilling new wells and installing water treatment.[81] The average per capita cost was about $160, but in many communities it rose to $400-to-$700 per person. For two communities with fewer than 500 residents, the cost reached $1,300-to-$2,000 per person.

The cost of cyanotoxins

A major problem for water utilities trying to eradicate cyanobacterial blooms in their reservoirs is that in the short term, at least, such efforts can make the situation worse. That's because when the algae die, either after exhausting the nutrients in the water or as a result of chemical treatment of the water, the cells break open and release cyanotoxins.

That's exactly what happens when utilities try to get rid of algal blooms with copper sulfate or other standard "algicides." It's preferable to remove the cyanobacterial cells intact because that also removes most of the stored toxins, so some utilities apply permanganate at the water intake. Permanganate is a weak oxidant that is less likely to break open algal cells, but it's expensive.[82] The cost of copper sulfate can reach $60,000 a year for a large water system, compared with $100,000 a year for permanganate.[83]

Once cyanotoxins have been released into the water supply, getting rid of them is a complex and expensive process. These toxins are fairly resistant to chlorine, and several types cannot be eliminated with conventional chlorination.[84] Water treatment with activated carbon, which utilities frequently use to address taste and odor problems, also removes some cyanotoxins, but at a cost.[85] In a recent outbreak of algal blooms in Ohio, the

Table 13: Algal toxin treatment costs for a water plant serving up to 100,000 people

Treatment technology	Construction cost[1]	Annual operating and maintenance costs
Powdered activated carbon	$4.4 million	$500,000
Ozone	$12.2 million	$700,000
Granular activated carbon	$19.7 million	$1 million
Ultraviolet/hydrogen peroxide	$21 million	$3.2 million
Nanofiltration and reverse osmosis	$56.6 million	$5.6 million

1. Costs were determined for a 20 million gallon per day water treatment plant. A facility of this size can serve a community of around 100,000 residents.

Source: Alvarez M, Rose J, Bellamy B. 2010. Treating Algal Toxins Using Oxidation, Adsorption, and Membrane Technologies. Water Research Foundation Project # 2839. Available: http://www.waterrf.org additional cost of more intensive treatment with activated carbon reached $300,000.[86]

Other methods that can remove cyanotoxins, such as membrane filtration or ultraviolet (UV) treatment combined with advanced oxidation, are also expensive.[87] A 2010 study by the Water Research Foundation estimated the costs of several technologies for algal toxin treatment (Table 13).

In addition to these estimates, EWG identified several water treatment plants either already built or currently under construction to cope with algal blooms, disinfection byproducts and poor tasting drinking water, which provide real-life examples of the costs:

- Charleston, Ill. – $8.5 million for a new water treatment plant serving 21,000 people;[88]
- Mattoon, Ill. – $15 million for a new plant serving 19,000 people;[89]
- Rend Lake Conservancy District, Ill. – $24.9 million for a water treatment project, currently under construction, that will serve more than100,000 people in more than 30 communities;[90]
- Fairmont, Minn. – $31.8 million for a new treatment plant serving 11,000.[91]

The situation of the Fairmont, Minn. water utility is instructive. It recently started a full restructuring of its surface water treatment plant to address cyanobacteria in Budd Lake, its primary water source. The lake is in an agricultural area with intense crop and livestock farming – 95 percent of the county's land is being used for row crops.[92] Runoff flowing into the lake has resulted in nutrient overload, persistent algal blooms and high levels of disinfection byproducts in the city's treated water, prompting officials to seek advanced treatment systems. The full cost of the project is anticipated to be $31.8 million for a 5.4 million-gallon-per-day facility to serve 10,000-12,000 residents.[93] The per-resident cost is nearly $3,000.

CONCLUSION

For far too long, governments and water utilities have paid scant attention to the problem of source water pollution, especially from agricultural sources. They have focused instead on strategies for treating contaminated water to make it safe for human use. Unfortunately, this approach is ultimately ineffective, self-defeating and far too costly to be sustainable. The only reasonable alternative is to prevent the problem in the first place by preventing contamination of source water.

For the nation's rich agricultural regions, this is a particularly urgent issue. As this paper documents, agricultural pollution, largely unregulated, is endangering vast quantities of drinking water by overloading surface water and groundwater sources with nutrients. This nutrient overload sets off a cascade of problems that degrade source water, increase the costs of treatment and confront utilities with ever-more-difficult challenges as they seek to provide safe drinking water. Since far too little is being done to confront the problem of contaminated source water, water managers and owners of private wells must confront the problems on their own at the back end of the water supply system.

The expense of removing agricultural contaminants from drinking water is already staggering and will inevitably grow unless significant steps are taken to prevent source water pollution. These costs are especially hard to bear for smaller rural communities, where utilities and private well owners face the highest per-person costs to either treat contaminated water or find alternative sources.

Because agricultural pollution typically comes from multiple sources, even in small watersheds, utilities or individuals have little ability, and even fewer resources, to protect their source water on their own. Only a concerted national effort to implement strong source water protections, energetically enforced, can guarantee that Americans will continue to have access to the high quality, safe and good tasting water they have a right to expect.

Source Water and the Farm Bill

This year's debate over renewing the federal farm bill is a referendum on America's commitment to protecting our drinking water supplies at the source.

With the exception of large animal feeding operations, farm businesses are exempt from the pollution control requirements of the federal Clean Water Act, and few states have authority to compel farm businesses to adopt practices that reduce the amount of farm pollution reaching our rivers, lakes and bays.

As a result, the farm bill, which is renewed every five years, serves as the primary tool for addressing the environmental damage caused by polluted runoff from agricultural operations. The farm bill affects the fate our nation's waters in two ways: by providing subsidies to the producers of feed grains and oilseeds that encourage all-out production which incentivizes increased pollution and habitat destruction and by providing incentives for farmers to protect the environment.

In exchange for federal subsidies, farmers since 1985 have agreed to adopt soil conservation measures to minimize erosion and protect wetlands. As a result of this "conservation compact" between farmers and taxpayers, soil erosion on highly erodible land fell by 40 percent in recent decades, and the nation met the long-sought goal of no net loss of wetlands.

Now, however, some lobbyists and legislators want to end this compact, opposing proposals to re-link "conservation compliance" to farm insurance subsidies, which are the government's chief form of income support for farm businesses. To finance those subsidies, many of the same lobbyists and legislators have proposed to cut USDA programs that help farmers pay for implementing conservation measures. This would reverse a gradual trend in recent decades that has seen annual spending on conservation increase from $2 billion to more than $4 billion, including greater incentives for farmers to take steps to reduce water pollution

We cannot afford to give up the gains we've made in reducing agricultural pollution, so Congress should:

Reform Farm Subsidies – Congress should end direct payments, reduce subsidies for farm insurance programs and refuse to create new farm entitlement programs that encourage all-out production. Instead, lawmakers should help farmers when they suffer deep losses in yields and provide options for them to purchase additional crop and revenue insurance at their own expense.

Renew the Conservation Compact -- Congress should renew the "conservation compliance" provisions of the 1985 farm bill by relinking wetland and soil protection requirements to crop insurance programs. In addition, legislators should require farm businesses who receive subsidies to update their conservation plans and should strengthen the government's enforcement tools.

Strengthen Conservation Incentive Programs – Congress should strengthen programs that reward farmers who take steps to protect sources of drinking water. In addition to providing adequate funding, Congress should expand "collaborative conservation" tools that award funds to groups of farmers working together to protect drinking water sources. Greater focus should be placed on restoring buffers and wetlands that filter runoff contaminated with farm pollutants.

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