America's Children and the Environment, Third Edition

DRAFT Indicators

Environments and Contaminants: Drinking Water Contaminants

EPA is preparing the third edition of *America's Children and the Environment* (ACE3), following the previous editions published in December 2000 and February 2003. ACE is EPA's compilation of children's environmental health indicators and related information, drawing on the best national data sources available for characterizing important aspects of the relationship between environmental contaminants and children's health. ACE includes four sections: Environments and Contaminants, Biomonitoring, Health, and Special Features.

EPA has prepared draft indicator documents for ACE3 representing 23 children's environmental health topics and presenting a total of 42 proposed children's environmental health indicators. This document presents the draft text, indicators, and documentation for the drinking water contaminants topic in the Environments and Contaminants section.

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For more information on America's Children and the Environment, please visit www.epa.gov/ace. For instructions on how to submit comments on the draft ACE3 indicators, please visit www.epa.gov/ace/ace3drafts/.

Drinking Water Contaminants

Drinking water sources may contain a variety of contaminants that are associated with increased risk of a range of diseases in children, including acute diseases such as gastrointestinal illness, developmental effects such as learning disorders, and cancer.[1,2] Because children tend to take in more water relative to their body weight than adults do, children are likely to have higher exposure to drinking water contaminants.

Public drinking water sources include surface water, such as rivers, lakes, and reservoirs;[3] and groundwater aquifers, which are subsurface layers of porous soil and rock that contain large collections of water.[4] Groundwater and surface water are not isolated systems and are continually recharged by each other as well as by rain and other natural precipitation.[5]

Several types of drinking water contaminants are of concern for children's health. Examples include microorganisms, (e.g., *Giardia)*, inorganic chemicals (e.g., lead, arsenic, nitrates, and nitrites), organic chemicals (e.g., atrazine and glyphosate), and disinfection byproducts (e.g., chloroform). EPA sets enforceable drinking water standards for public water systems, including maximum contaminant levels and treatment technique requirements for more than 90 chemical, radiological, and microbial contaminants, designed to protect people, including sensitive populations such as children, against adverse health effects.[1,6]

Children are particularly sensitive to microbial contaminants, such as *Giardia, Cryptosporidium,* and *E. coli*, because their immune systems are less developed than those of most adults.[7-12] Microbial contaminants include bacteria, viruses, and protozoa that may cause severe gastrointestinal illness.[1]

Children are also very sensitive to lead and other contaminants that affect brain development due to their rapidly developing nervous systems.[13-20] Drinking water can be a source of lead exposure due to the historical use of lead in pipes and pipe solder.

Fertilizer, livestock manure, and human sewage are significant contributors of nitrates and nitrites in groundwater sources of drinking water.[21,22] Nitrates and nitrites can cause the blood disorder methemoglobinemia (blue baby syndrome)[23-25] and have been linked to thyroid dysfunction in children[26,27] and pregnant women.[26,28-30] Moderate deficits in maternal thyroid hormone levels during early pregnancy have been linked to reduced childhood IQ scores and other neurodevelopmental effects, as well as unsuccessful or complicated pregnancies.[31]

Arsenic, which is odorless and tasteless, enters drinking water sources from natural deposits in the earth, which vary widely from one region to another, or from agricultural and industrial sources where it is used as a wood preservative and a component of fertilizers, animal feed, and a variety of industrial products.[32] Long-term consumption of arsenic-contaminated water has been linked to the development of skin conditions and circulatory system problems, as well as increased risk of cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate.[30,32] In many cases, long-term exposure to arsenic begins during prenatal development or

childhood, which increases the risk of mortality and morbidity among young adults exposed to arsenic long-term.[33] Recent reports indicate an association between exposure to arsenic and abnormal pregnancy outcomes, such as spontaneous abortion, still-births, reduced birth weight, and infant mortality, as well as associations between early-life exposure to arsenic and reduced cognitive function and increased incidence of childhood cancer.[34] These concerns—both cancer and non-cancer—are based primarily on studies of populations in other countries, such as Bangladesh, Taiwan, and Chile, where arsenic levels in drinking water are generally higher than in the United States due to high levels of naturally occurring arsenic in groundwater.[35]

Disinfection of drinking water to reduce water-borne infectious disease is one of the major public health advances of the 20th century.[36] The method by which infectious agents are removed or chemically deactivated depends on the type and quality of the drinking water source. Surface water systems are more exposed than groundwater systems to weather and runoff; therefore, they may be more susceptible to contamination.[37,38] Surface and groundwater systems use various filtration methods to physically remove dissolved particles, such as dust, parasites, viruses, and bacteria. Disinfectants, such as chlorine and chloramine, are also added to drinking water to kill or neutralize microbial contaminants.[37] However, an unavoidable consequence of this process is the production of disinfection byproducts, which form when chemical disinfectants react with naturally occurring organic matter in water.[30] The most common of these disinfection byproducts are chloroform and other trihalomethanes. Long-term exposure to disinfection byproducts has been associated with bladder cancer and possible reproductive effects.[39] Some individual epidemiological studies have found an association between the presence of disinfection byproducts in drinking water and increased risk of birth defects, especially neural tube defects and oral clefts.[40-42] Recent reviews of published studies, however, found that due to inconsistent findings among multiple studies, there was not enough evidence to conclude that there is an association between exposure to disinfection byproducts and birth defects.[43,44]

Some of the most widely used agricultural pesticides in the United States, such as atrazine and glyphosate, are also drinking water contaminants.[45,46] Pesticides can enter drinking water sources as runoff from crop production in agricultural areas.[47] Epidemiological studies in the United States have found associations between prenatal exposure to atrazine and birth defects, reduced birth weight, and preterm birth.[48-52] However, due to inconsistencies in the results of these studies, conclusions about the effects of atrazine exposure in pregnant women cannot be made at this time.

The use of glyphosate, an herbicide used to kill weeds, has increased dramatically in recent years because of the growing popularity of Roundup Ready® crops, which have been genetically modified to survive glyphosate treatment.[53] Previous safety assessments have concluded that glyphosate does not affect fertility or reproduction in laboratory animal studies.[54,55] However, more recent studies in laboratory animals have found that male rats exposed to high levels of glyphosate, either during prenatal or pubertal development, may suffer from reproductive problems, such as delayed puberty, decreased sperm production, and decreased testosterone production.[56,57] Very few epidemiological human studies have investigated effects of glyphosate exposure on reproductive endpoints. In contrast to the results of animal studies, one such

epidemiological study of women living in regions with different levels of exposure to glyphosate found no associations between glyphosate exposure and delayed time to pregnancy.[58]

A variety of other chemical contaminants can enter the water supply after use in industry.[46] Examples include trichloroethylene (TCE) and tetrachloroethylene (also known as perchloroethylene or PCE), which are solvents widely used in industry as degreasers, dry cleaning agents, paint removers, chemical extractors, and components of adhesives and lubricants.[59,60] A recent report summarizing epidemiological and laboratory studies concluded that there is substantial evidence that TCE in drinking water, at levels currently found in the environment, might cause impaired fetal growth.[59] A study conducted in Massachusetts found associations between birth defects and maternal exposure to drinking water contaminated with PCE around the time of conception.[61] An additional study found that older mothers or mothers who had previously miscarried, and who were exposed to PCE, had a higher risk of delivering a baby with reduced birth weight.[62] However, other studies failed to find associations between maternal exposure to PCE and pregnancy loss, gestational age, or birth weight.[63,64] Studies in laboratory animals indicate that mothers exposed to high levels of PCE can have spontaneous abortion, and their fetuses can suffer from altered growth and birth defects.[60]

Personal care products, such as cosmetics, sunscreens, and fragrances; and pharmaceuticals, including prescription, over-the-the counter, and veterinary medications, can enter water systems after use by humans or domestic animals[65] and have been measured in drinking water.[66] Concentrated animal feeding operations treat livestock with hormones and antibiotics and are one significant source of pharmaceuticals in water.[67] Other major sources of pharmaceuticals in water are human waste, manufacturing plants and hospitals, and other human activities such as showering and swimming.[65] The potential health implications of long-term exposure to levels of pharmaceuticals and personal care products found in drinking water are unclear at this point, and these products are not currently regulated in drinking water.

Perchlorate is a naturally occurring and man-made chemical that has been found in surface and groundwater in the United States.[68-70] Perchlorate is used in the manufacture of fireworks, explosives, flares, and rocket fuel.[70] Perchlorate was detected in just over 4% of public water systems in a nationally representative monitoring study conducted from 2001–2005.[70] Some infant formulas have been found to contain perchlorate, and the perchlorate content of the formula is increased if it is prepared with perchlorate-contaminated water.[71-74] Exposure to perchlorate inhibits iodide uptake into the thyroid gland, disrupting the functions of the thyroid and potentially leading to a reduction in the production of thyroid hormone.[75,76] As noted above, thyroid hormones are particularly important for growth and development of the central nervous system in fetuses and infants.

In January 2009, EPA issued an interim health advisory level to help state and local officials manage local perchlorate contamination issues in a health-protective manner, in advance of a final EPA regulatory determination.[70,77] EPA has decided to move forward with development of a federal drinking water standard for perchlorate, based on the concern for effects on thyroid hormones and the development and growth of fetuses, infants and children.[70] The process will

include receiving input from key stakeholders as well as submitting any formal rule to a public comment process.

The two indicators that follow use the best data currently available to EPA to characterize the performance of water systems in meeting EPA's health-based drinking water standards and in reporting monitoring results.

Indicator E6 estimates the percentage of children served by community water systems that did not meet all applicable health-based drinking water standards. Indicator E7 estimates the percentage of children served by systems with violations of drinking water monitoring and reporting requirements. Monitoring and reporting violations occur when a water system does not monitor, does not report monitoring results, or was late in reporting results.[78] Such violations in monitoring and reporting may mean that some health-based violations were not reported; this could cause the percentages shown in Indicator E6 to be underestimated.

Indicator E6: Percentage of children ages 0 to 17 years served by community water systems that did not meet all applicable health-based drinking water standards, 1993–2009

Indicator E7: Percentage of children ages 0 to 17 years served by community water systems with violations of drinking water monitoring and reporting requirements, 1993–2009

Overview

Indicators E6 and E7 estimate the percentage of children served by community water systems that did not meet all health-based drinking water standards or failed to adhere to monitoring and reporting requirements. The data are from an EPA database that compiles drinking water violations reported by public water systems. Indicator E6 shows the change in the estimated percentage of children served by community water systems that did not meet health-based drinking water standards over time. Indicator E7 shows the change in the estimated percentage of children served by community water systems that did not adhere to monitoring and reporting requirements over time.

SDWIS/FED

These indicators use data from EPA's Safe Drinking Water Information System, Federal Version (SDWIS/FED). Public drinking water systems in the United States are required to monitor the presence of certain individual contaminants at specific time intervals and locations to assess whether they are complying with drinking water standards. These standards include Maximum Contaminant Levels (MCLs), which are numerical limits on how much of a contaminant may be present in drinking water; as well as mandatory treatment techniques and processes, such as those intended to prevent microbial contamination of drinking water. When a violation of a drinking water standard is detected, the public water system is required to report the violation to the state, which in turn reports to the federal government. All health-based violations are compiled in SDWIS/FED. SDWIS/FED was created in 1995 and includes data from various precursor database systems that have violation and inventory data going back to 1976. SDWIS/FED also reports the number of people served by each water system.

The following indicators consider only children ages 0 to 17 years whose homes are served by community water systems. Community water systems are public water systems that serve water to the same residential population year-round.[79]

Health-Based Drinking Water Standard Violations

Indicator E6 presents statistics on violations of drinking water standards grouped into several categories:

The "Surface water treatment" category includes violations of requirements in the Surface Water Treatment Rule and Interim Enhanced Surface Water Treatment Rule that specify the type of treatment and maintenance activities that systems must use to prevent microbial contamination of drinking water.

The "Chemical and radionuclide" category includes violations of the MCLs for organic and inorganic chemicals, such as atrazine, glyphosate, trichloroethylene, tetrachloroethylene, arsenic, cadmium, and mercury, in addition to radionuclide contaminants, such as radium and uranium.

The "Lead and copper" category includes violations of treatment technique requirements for systems to control the corrosiveness of their water.[1]

The "Total coliforms" category covers all violations of the MCL for total coliform bacteria, which is an indicator of the presence of various fecal pathogens, including *E.Coli*.[80,81]

The "Nitrate/nitrite" category takes account of all violations of the MCLs for nitrates and nitrites.

The "Disinfectants and disinfection byproducts" category covers violations of standards for several disinfectants—chlorine, chloramine, and chlorine dioxide—and disinfectant byproducts—total trihalomethanes, haloacetic acids, chlorite, and bromate.[82]

Monitoring and Reporting Violations

Indicator E7 presents statistics on violations of monitoring and reporting requirements. Monitoring and reporting violations occur when a water system does not monitor, does not report monitoring results, or was late in reporting results.[78] All monitoring and reporting violations are compiled from SDWIS/FED.

Data Presented in the Indicators

Indicator E6 estimates the percentage of children served by community water systems that did not meet all applicable health-based drinking water standards between 1993 and 2009. The indicator is calculated by identifying all community water systems with violations in SDWIS/FED each year, then summing the number of people served by those systems with violations. Census data are then used to adjust these estimates of the total population served to estimate the percentage of children served by systems with violations in relation to all children served by community water systems.

Indicator E7 estimates the percentage of children served by community water systems with violations of drinking water monitoring and reporting requirements. This indicator is based on data reported to SDWIS/FED for violations between 1993 and 2009. Violations of monitoring and reporting requirements for Indicator E7 were grouped into the same categories as in Indicator E6, except for the Nitrate/nitrite category.

Violations of health-based standards (as represented in Indicator E6) may be under-reported as a result of monitoring and reporting violations. An EPA audit of drinking water data from 2002–2004 found that only 62% of health-based standards violations were reported to SDWIS.[78]

Therefore, the data on systems reporting no violations of health based standards include a number of systems that have not gathered or reported all of the required data needed to make this determination.

Indicators E6 and E7 are not intended as indicators of children's exposure to drinking water contaminants or of risk to children. Indicator E6 does not take into account the duration of a violation. A large water system with a single violation of short duration during the year may significantly affect the indicator value. Nor does the indicator reflect the extent to which a water system's distribution system may not have been affected by a violation.

The ability to examine children's potential exposure to contaminated drinking water is limited by the type of information collected and stored in the SDWIS/FED database. Public water systems are not required to report the actual contaminant levels measured to SDWIS/FED; instead, they report when standards are not met. As a result, SDWIS/FED data cannot be used to analyze national or local trends in contaminant concentrations.[i] EPA is working with states to develop a new drinking water data system that will compile and make available actual measurements of contaminant levels.

Trend analysis is further complicated by the periodic addition or modification of drinking water standards. Changes over time in the values shown in Indicator E6 may be related to both changes in standards and changes in water quality. For example, a new standard for disinfection byproducts was implemented in 2002 for larger drinking water systems, and in 2004 for smaller systems.[83] Revisions to the surface water treatment standard were finalized in 2002.[82] A revised standard for radionuclides went into effect in 2003, and for arsenic (included in the chemical and radionuclide category) in 2006.[84] An analysis of the statistical significance of changes over time in indicators E6 and E7 has not been conducted because of these changes in regulatory standards between 1993 and 2009.

Indicators E6 and E7 are based on drinking water provided to residences served by community water systems, and therefore do not account for all sources of children's drinking water. Some drinking water comes from other types of public water systems, including those that may not serve residences, or may not operate year-round (e.g., schools, factories, office buildings, and hospitals that have their own water systems; gas stations and campgrounds); and bottled water, which EPA does not regulate.[85,86]

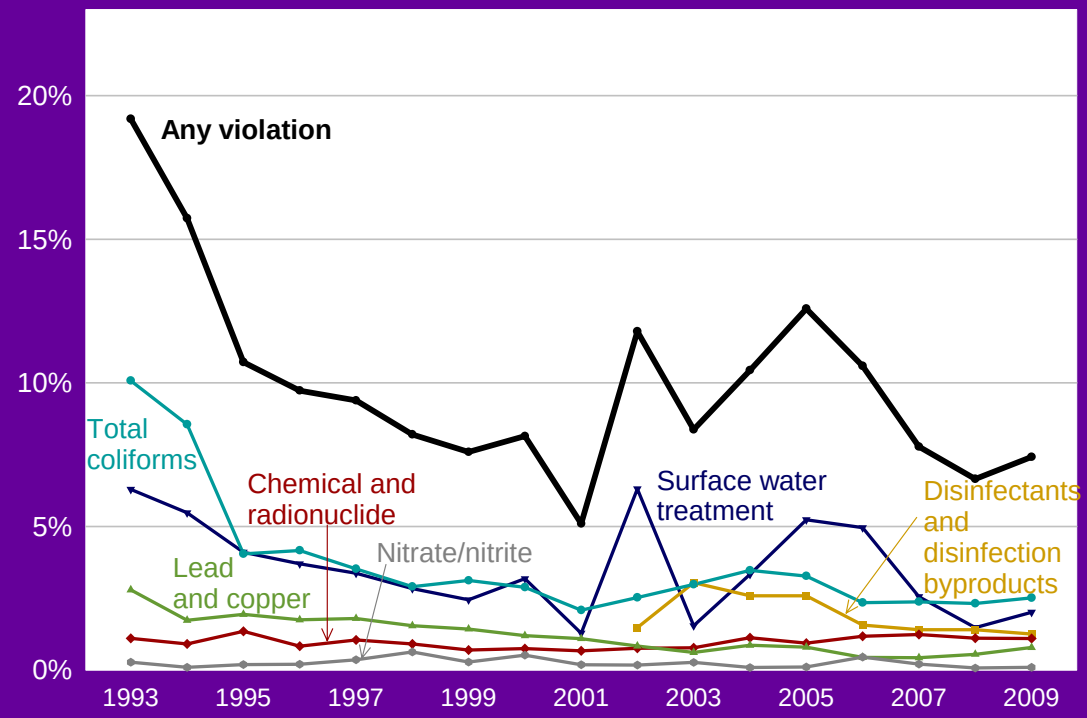
In addition, many homes are not served by community water systems and instead obtain their drinking water from private wells.[86,87] EPA does not have the authority under the Safe Drinking Water Act to regulate private wells. Thus the SDWIS/FED database does not contain data on non-public water systems, such as privately owned household wells, that are not required to monitor or report the quality of drinking water to EPA.[85,88] In 2000, approximately 15% of the total U.S. population was served by non-public water systems[88] and more than 90,000 new

[i] EPA requires community water systems to provide annual drinking water quality reports to their customers. These reports summarize the contaminants measured in each system's drinking water over the course of a year, providing much more detail than the information reported to SDWIS. The drinking water quality reports for many systems can be found at: http://water.epa.gov/lawsregs/rulesregs/sdwa/ccr/index.cfm.

domestic wells are installed every year.[89] Separate data collection activities have found that the contaminants in groundwater are generally at lower levels than the MCL; however, more than 20% of wells sampled by the U.S. Geological Survey between 1991 and 2004 contained at least one contaminant at a level of potential health concern.[90] Approximately 4% of the 2,167 sampled wells exceeded the nitrate MCL, and 7% exceeded the arsenic MCL.[90] Nitrate concentrations above the MCL were more frequently detected in agricultural regions than any other land-use setting.[90] Groundwater-sourced wells in rural and agricultural regions may be at an increased risk for nitrate and nitrite contamination due to local fertilizer use and animal waste runoff.[91]

Indicator E6

Percentage of children ages 0 to 17 years served by community water systems that did not meet all applicable health-based drinking water standards, 1993-2009



DRAFT Indicator for Third Edition of America's Children and the Environment

DATA: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System, Federal Version

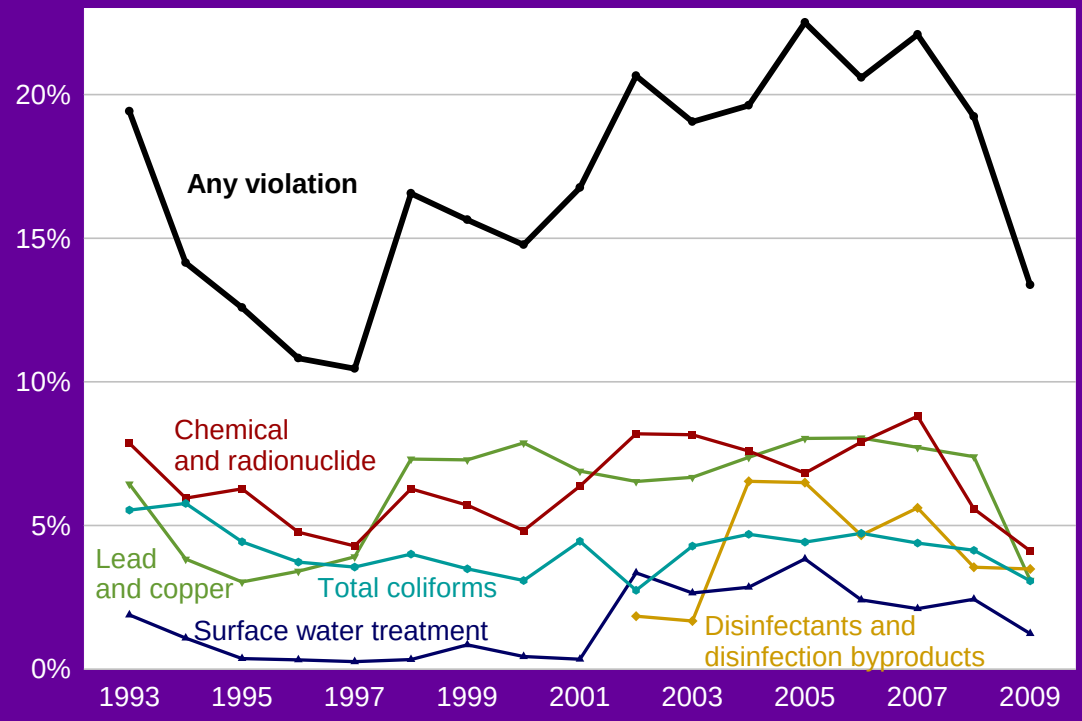
- The estimated percentage of children served by community drinking water systems that did not meet all applicable health-based standards declined from 19% in 1993 to about 8% in 1999. Since 1999, this percentage has fluctuated between 5% and 13%, and was 7% in 2009.

- Total coliforms indicate the potential presence of harmful bacteria associated with infectious illnesses. The estimated percentage of children served by community drinking water systems that did not meet the health-based standard for total coliforms was about 10% in 1993 and about 3% in 2009.

- A new standard for disinfection byproducts was adopted in 2001. The estimated percentage of children served by community water systems that had violations of the disinfection byproducts standard has steadily declined from 3% in 2003 to about 1% in 2009.

Indicator E7

Percentage of children ages 0 to 17 years served by community water systems with violations of drinking water monitoring and reporting requirements, 1993-2009



DRAFT Indicator for Third Edition of America's Children and the Environment

DATA: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System, Federal Version

- Between 1993 and 2009, the estimated percentage of children served by community water systems that had at least one monitoring and reporting violation fluctuated between about 11% and 23%, and was 13% in 2009.

- In 1993, approximately 6% of children served by community water systems lived in an area with significant monitoring and reporting violations for lead and copper. This figure dropped to about 3% in 2009.

- The estimated percentage of children served by community water systems with a chemical and radionuclide monitoring violation has varied between 4 and 9%, and was 4% of children in 2009.

Data Tables

Table E6: Percentage of children ages 0 to 17 years served by community water systems that did not meet all applicable health-based drinking water standards, 1993-2009

1993-1997					
Type of standard violated	**1993**	**1994**	**1995**	**1996**	**1997**
Lead and copper†	2.8%	1.7%	1.9%	1.8%	1.8%
Total coliforms	10.1%	8.6%	4.0%	4.2%	3.5%
Chemical and radionuclide	1.1%	0.9%	1.3%	0.8%	1.0%
Nitrate/nitrite	0.3%	0.1%	0.2%	0.2%	0.4%
Surface water treatment#	6.3%	5.5%	4.1%	3.7%	3.4%
All health-based violations	19.2%	15.7%	10.7%	9.7%	9.4%

1998-2003						
Type of standard violated	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Lead and copper†	1.5%	1.4%	1.2%	1.1%	0.8%	0.6%
Total coliforms	2.9%	3.1%	2.9%	2.1%	2.5%	3.0%
Chemical and radionuclide	0.9%	0.7%	0.8%	0.7%	0.8%	0.8%
Nitrate/nitrite	0.6%	0.3%	0.5%	0.2%	0.2%	0.3%
Surface water treatment#	2.8%	2.4%	3.2%	1.3%	6.3%	1.5%
Disinfectants and disinfection byproducts	NA	NA	NA	NA	1.5%	3.0%
All health-based violations	8.2%	7.6%	8.1%	5.1%	11.8%	8.4%

2004-2009						
Type of standard violated	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Lead and copper†	0.9%	0.8%	0.4%	0.4%	0.5%	0.8%
Total coliforms	3.5%	3.3%	2.3%	2.4%	2.3%	2.5%
Chemical and radionuclide	1.1%	0.9%	1.2%	1.2%	1.1%	1.1%
Nitrate/nitrite	0.1%	0.1%	0.5%	0.2%	0.1%	0.1%
Surface water treatment#	3.3%	5.2%	5.0%	2.6%	1.5%	2.0%
Disinfectants and disinfection byproducts	2.6%	2.6%	1.6%	1.4%	1.4%	1.3%
All health-based violations	10.4%	12.6%	10.6%	7.8%	6.7%	7.4%

DATA: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System Federal Version

† Lead and copper represents the lead and copper rule, which is a set of standards and implementation measures.[92]

"Surface water treatment" includes violations of the Surface Water Treatment Rule and of the Interim Enhanced Surface Water Treatment Rule.

NOTE: A new standard for disinfection byproducts was implemented beginning in 2002 for larger drinking water systems and 2004 for smaller systems.[93] Revisions to the standard for surface water treatment took effect in 2002.[94] A revised standard for radionuclides went into effect in 2003.[95] A revised standard for arsenic went into effect in 2006.[96] No other revisions to the standards have taken effect during the period of trend data (beginning with 1993).

Table E7: Percentage of children ages 0 to 17 years served by community water systems with violations of drinking water monitoring and reporting requirements, 1993-2009

1993-1997					
Type of standard violated	**1993**	**1994**	**1995**	**1996**	**1997**
Lead and copper	6.4%	3.8%	3.0%	3.4%	3.9%
Total coliforms	5.5%	5.8%	4.4%	3.7%	3.6%
Chemical and radionuclide	7.9%	5.9%	6.3%	4.8%	4.3%
Surface water treatment#	1.9%	1.1%	0.4%	0.3%	0.3%
Any violation	19.4%	14.1%	12.6%	10.8%	10.5%

1998-2003						
Type of standard violated	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Lead and copper	7.3%	7.3%	7.9%	6.9%	6.5%	6.7%
Total coliforms	4.0%	3.5%	3.1%	4.4%	2.7%	4.3%
Chemical and radionuclide	6.3%	5.7%	4.8%	6.4%	8.2%	8.2%
Surface water treatment#	0.3%	0.8%	0.4%	0.3%	3.3%	2.6%
Disinfectants and disinfection byproducts	NA	NA	NA	NA	1.8%	1.7%
Any violation	16.6%	15.6%	14.8%	16.8%	20.6%	19.1%

2004-2009						
Type of standard violated	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Lead and copper	7.4%	8.0%	8.0%	7.7%	7.4%	3.1%
Total coliforms	4.7%	4.4%	4.7%	4.4%	4.1%	3.1%
Chemical and radionuclide	7.6%	6.8%	7.9%	8.8%	5.6%	4.1%
Surface water treatment#	2.9%	3.8%	2.4%	2.1%	2.4%	1.2%
Disinfectants and disinfection byproducts	6.5%	6.5%	4.7%	5.6%	3.5%	3.5%
Any violation	19.6%	22.5%	20.6%	22.1%	19.2%	13.4%

DATA: U.S. Environmental Protection Agency, Office of Water, Safe Drinking Water Information System Federal Version

"Surface water treatment" includes violations of the Surface Water Treatment Rule and of the Interim Enhanced Surface Water Treatment Rule.

NOTE: A new standard for disinfection byproducts was implemented beginning in 2002 for larger drinking water systems and 2004 for smaller systems.[93] Revisions to the standard for surface water treatment took effect in 2002.[94] A revised standard for radionuclides went into effect in 2003.[95] A revised standard for arsenic went into effect in 2006.[96] No other revisions to the standards have taken effect during the period of trend data (beginning with 1993).

References

1. U.S. Environmental Protection Agency. 2008. *National Primary Drinking Water Regulations*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/drink/contaminants/index.cfm.

2. U.S. Geological Survey. 2010. *Source Water-Quality Assessment (SWQA) Program*. Retrieved November 25, 2010 from http://water.usgs.gov/nawqa/swqa/.

3. U.S. Environmental Protection Agency. 2010. *Drinking Water Glossary: Surface Water*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://owpubauthor.epa.gov/aboutow/ogwdw/glossary.cfm#slink.

4. U.S. Environmental Protection Agency. 2010. *Drinking Water Glossary: Ground Water*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/aboutow/ogwdw/glossary.cfm#glink.

5. Winter, T.C., J.W. Harvey, O.W. Franke, and W.M. Alley. 1998. *Ground Water and Surface Water: A Single Resource*. Reston, VA: U.S. Geological Survey. http://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf.

6. U.S. Environmental Protection Agency. 1992. *Secondary Drinking Water Regulations: Guidance for Nuisance Chemicals*. U.S. EPA, Office of Water. Retrieved November 26, 2010 from http://water.epa.gov/drink/contaminants/secondarystandards.cfm.

7. Dietert, R.R. 2009. Developmental immunotoxicology: focus on health risks. *Chemical Research in Toxicology* 22 (1):17-23.

8. Garcia, A.M., S.A. Fadel, S. Cao, and M. Sarzotti. 2000. T cell immunity in neonates. *Immunologic Research* 22 (2-3):177-90.

9. Thompson, S.C. 1994. Giardia lamblia in children and the child care setting: a review of the literature. *Journal of Paediatrics and Child Health* 30 (3):202-9.

10. Woodruff, T., L. Zeise, D. Axelrad, K.Z. Guyton, S. Janssen, M. Miller, G. Miller, J. Schwartz, G. Alexeeff, H. Anderson, L. Birnbaum, F. Bois, J. Cogliano, K. Crofton, S.Y. Euling, P. Foster, D. Germolec, G. Ginsberg, E. Gray, D. Hattis, D. Kyle, R. Luebke, M. Luster, C. Portier, D. Rice, G. Solomon, C. Steinmaus, J. Vandenberg, and T. Zoeller. 2008. Moving Upstream: A workshop on evaluating adverse upstream endpoints for improved risk assessment and decision making. *Environmental Health Perspectives* 116 (11):1568–1575.

11. Yoder, J.S., and M.J. Beach. 2010. Cryptosporidium surveillance and risk factors in the United States. *Experimental Parasitology* 124 (1):31-9.

12. Yoder, J.S., C. Harral, and M.J. Beach. 2010. Giardiasis Surveillance---United States, 2006--2008. *Morbidity and Mortality Weekly Report* 59 (SS06):15-25.

13. Bellinger, D., A. Leviton, C. Waternaux, H. Needleman, and M. Rabinowitz. 1987. Longitudinal analyses of prenatal and postnatal lead exposure and early cognitive development. *New England Journal of Medicine* 316 (17):1037-43.

14. Calderon, J., M.E. Navarro, M.E. Jimenez-Capdeville, M.A. Santos-Diaz, A. Golden, I. Rodriguez-Leyva, V. Borja-Aburto, and F. Diaz-Barriga. 2001. Exposure to arsenic and lead and neuropsychological development in Mexican children. *Environmental Research* 85 (2):69-76.

15. Mendelsohn, A.L., B.P. Dreyer, A.H. Fierman, C.M. Rosen, L.A. Legano, H.A. Kruger, S.W. Lim, and C.D. Courtlandt. 1998. Low-level lead exposure and behavior in early childhood. *Pediatrics* 101 (3):E10.

16. Minder, B., E.A. Das-Smaal, E.F. Brand, and J.F. Orlebeke. 1994. Exposure to lead and specific attentional problems in schoolchildren. *Journal of Learning Disabilities* 27 (6):393-9.

17. Needleman, H.L. 1990. What can the study of lead teach us about other toxicants? *Environmental Health Perspectives* 86:183-9.

18. Needleman, H.L., J.A. Riess, M.J. Tobin, G.E. Biesecker, and J.B. Greenhouse. 1996. Bone lead levels and delinquent behavior. *Journal of the American Medical Association* 275 (5):363-9.

19. Needleman, H.L., A. Schell, D. Bellinger, A. Leviton, and E.N. Allred. 1990. The long-term effects of exposure to low doses of lead in childhood. An 11-year follow-up report. *New England Journal of Medicine* 322 (2):83-8.

20. Tuthill, R.W. 1996. Hair lead levels related to children's classroom attention-deficit behavior. *Archives of Environmental Health* 51 (3):214-20.

21. Hunter, W.J. 2008. Remediation of Drinking Water for Rural Populations. In *Nitrogen in the Environment: Sources, Problems, and Management, Second Edition*, edited by J. L. Hatfield and R. F. Follett. Boston, MA: Academic Press/Elsevier.

22. U.S. Environmental Protection Agency. 2009. *Consumer Factsheet on: Nitrates/Nitrites*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://www.epa.gov/safewater/pdfs/factsheets/ioc/nitrates.pdf.

23. Gupta, S.K., R.C. Gupta, A.K. Seth, A.B. Gupta, J.K. Bassin, and A. Gupta. 2000. Methaemoglobinaemia in areas with high nitrate concentration in drinking water. *National Medical Journal of India* 13 (2):58-61.

24. Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. 2000. Blue babies and nitrate-contaminated well water. *Environmental Health Perspectives* 108 (7):675-8.

25. U.S. Environmental Protection Agency. 2010. *Basic Information About Nitrate in Drinking Water*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/drink/contaminants/basicinformation/nitrate.cfm.

26. Gatseva, P.D., and M.D. Argirova. 2008. High-nitrate levels in drinking water may be a risk factor for thyroid dysfunction in children and pregnant women living in rural Bulgarian areas. *International Journal of Hygiene and Environmental Health* 211 (5-6):555-9.

27. Tajtakova, M., Z. Semanova, Z. Tomkova, E. Szokeova, J. Majoros, Z. Radikova, E. Sebokova, I. Klimes, and P. Langer. 2006. Increased thyroid volume and frequency of thyroid disorders signs in schoolchildren from nitrate polluted area. *Chemosphere* 62 (4):559-64.

28. Haddow, J.E., G.E. Palomaki, W.C. Allan, J.R. Williams, G.J. Knight, J. Gagnon, C.E. O'Heir, M.L. Mitchell, R.J. Hermos, S.E. Waisbren, J.D. Faix, and R.Z. Klein. 1999. Maternal thyroid deficiency during pregnancy and subsequent neuropsychological development of the child. *New England Journal of Medicine* 341 (8):549-55.

29. Pop, V.J., E.P. Brouwers, H.L. Vader, T. Vulsma, A.L. van Baar, and J.J. de Vijlder. 2003. Maternal hypothyroxinaemia during early pregnancy and subsequent child development: a 3-year follow-up study. *Clinical Endocrinology* 59 (3):282-8.

30. U.S. Environmental Protection Agency. 2008. *Drinking Water Contaminants: Disinfection Byproducts*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/drink/contaminants/#Byproducts.

31. Morreale de Escobar, G., M.J. Obregon, and F. Escobar del Rey. 2000. Is Neuropsychological Development Related to Maternal Hypothyroidism or to Maternal Hypothyroxinemia? *The Journal of Clinical Endocrinology and Metabolism* 85 (11):3975-87.

32. U.S. Environmental Protection Agency. 2008. *Arsenic in Drinking Water*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/index.cfm.

33. Smith, A.H., G. Marshall, Y. Yuan, C. Ferreccio, J. Liaw, O. von Ehrenstein, C. Steinmaus, M.N. Bates, and S. Selvin. 2006. Increased mortality from lung cancer and bronchiectasis in young adults after exposure to arsenic in utero and in early childhood. *Environmental Health Perspectives* 114 (8):1293-6.

34. Smith, A.H., and C.M. Steinmaus. 2009. Health effects of arsenic and chromium in drinking water: recent human findings. *Annual Review of Public Health* 30:107-22.

35. Sambu, S., and R. Wilson. 2008. Arsenic in food and water--a brief history. *Toxicology and Industrial Health* 24 (4):217-26.

36. U.S. Environmental Protection Agency. 2004. *Drinking Water Treatment*. Washington, DC: U.S. EPA, Office of Water. http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_treatment_web.pdf.

37. Centers for Disease Control and Prevention. 2009. *Water Treatment*. CDC Healthy Water Site. Retrieved November 25, 2010 from http://www.cdc.gov/healthywater/drinking/public/water_treatment.html.

38. U.S. Environmental Protection Agency. 2010. *Surface Water Contamination*. U.S. EPA, Office of Solid Waste and Emergency Response. Retrieved November 25, 2010 from http://www.epa.gov/superfund/students/wastsite/srfcspil.htm.

39. Federal Register. 2006. *National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule*. Washington, DC: U.S. EPA. January 4, 2006. http://www.epa.gov/fedrgstr/EPA-WATER/2006/January/Day-04/w03.pdf.

40. Bove, F., Y. Shim, and P. Zeitz. 2002. Drinking water contaminants and adverse pregnancy outcomes: a review. *Environmental Health Perspectives* 110 (Suppl 1):61-74.

41. Hwang, B.F., J.J. Jaakkola, and H.R. Guo. 2008. Water disinfection by-products and the risk of specific birth defects: a population-based cross-sectional study in Taiwan. *Environmental Health* 7:23.

42. Hwang, B.F., P. Magnus, and J.J. Jaakkola. 2002. Risk of specific birth defects in relation to chlorination and the amount of natural organic matter in the water supply. *American Journal of Epidemiology* 156 (4):374-82.

43. Nieuwenhuijsen, M.J., D. Martinez, J. Grellier, J. Bennett, N. Best, N. Iszatt, M. Vrijheid, and M.B. Toledano. 2009. Chlorination disinfection by-products in drinking water and congenital anomalies: review and meta-analyses. *Environmental Health Perspectives* 117 (10):1486-93.

44. Wigle, D.T., T.E. Arbuckle, M.C. Turner, A. Berube, Q. Yang, S. Liu, and D. Krewski. 2008. Epidemiologic evidence of relationships between reproductive and child health outcomes and environmental chemical contaminants. *Journal of Toxicology and Environmental Health Part B: Critical Reviews* 11 (5-6):373-517.

45. U.S. Environmental Protection Agency. 2004. *Pesticides Industry Sales and Usage: 2000-2001 Market Estimates*. Washington, DC: U.S. EPA, Office of Pesticide Programs. http://www.epa.gov/opp00001/pestsales/01pestsales/market_estimates2001.pdf.

46. U.S. Environmental Protection Agency. 2010. *Basic Information about Regulated Drinking Water Contaminants*. U.S. EPA, Office of Water. Retrieved November 26, 2010 from http://water.epa.gov/drink/contaminants/basicinformation/index.cfm.

47. U.S. Geological Survey. 2006. *The Quality of Our Nation's Waters—Pesticides in the Nation's Streams and Ground Water, 1992–2001*. Reston, VA: U.S.G.S., National Water-Quality Assessment Program. http://pubs.usgs.gov/circ/2005/1291/pdf/circ1291_front.pdf.

48. Bukowski, J., G. Somers, and J. Bryanton. 2001. Agricultural contamination of groundwater as a possible risk factor for growth restriction or prematurity. *Journal of Occupational and Environmental Medicine* 43 (4):377-83.

49. Munger, R., P. Isacson, S. Hu, T. Burns, J. Hanson, C.F. Lynch, K. Cherryholmes, P. Van Dorpe, and W.J. Hausler, Jr. 1997. Intrauterine growth retardation in Iowa communities with herbicide-contaminated drinking water supplies. *Environmental Health Perspectives* 105 (3):308-14.

50. Ochoa-Acuna, H., J. Frankenberger, L. Hahn, and C. Carbajo. 2009. Drinking-water herbicide exposure in Indiana and prevalence of small-for-gestational-age and preterm delivery. *Environmental Health Perspectives* 117 (10):1619-24.

51. Villanueva, C.M., G. Durand, M.B. Coutte, C. Chevrier, and S. Cordier. 2005. Atrazine in municipal drinking water and risk of low birth weight, preterm delivery, and small-for-gestational-age status. *Occupational and Environmental Medicine* 62 (6):400-5.

52. Waller, S.A., K. Paul, S.E. Peterson, and J.E. Hitti. 2010. Agricultural-related chemical exposures, season of conception, and risk of gastroschisis in Washington State. *American Journal of Obstetrics & Gynecology* 202 (3):241 e1-6.

53. U.S. Geological Survey. 2010. *Glyphosate Herbicide Found in Many Midwestern Streams, Antibiotics Not Common*. U.S.G.S., Toxic Substances Hydrology Program. Retrieved November 25, 2010 from http://toxics.usgs.gov/highlights/glyphosate02.html.

54. Williams, G.M., R. Kroes, and I.C. Munro. 2000. Safety evaluation and risk assessment of the herbicide Roundup and its active ingredient, glyphosate, for humans. *Regulatory Toxicology and Pharmacology* 31 (2 Pt 1):117-65.

55. U.S. Environmental Protection Agency. 1990. *Glyphosate (CASRN 1071-83-6).* U.S. EPA, Integrated Risk Information System (IRIS). Retrieved November 25, 2010 from http://www.epa.gov/ncea/iris/subst/0057.htm#studoral.

56. Dallegrave, E., F.D. Mantese, R.T. Oliveira, A.J. Andrade, P.R. Dalsenter, and A. Langeloh. 2007. Pre- and postnatal toxicity of the commercial glyphosate formulation in Wistar rats. *Archives of Toxicology* 81 (9):665-73.

57. Romano, R.M., M.A. Romano, M.M. Bernardi, P.V. Furtado, and C.A. Oliveira. 2010. Prepubertal exposure to commercial formulation of the herbicide glyphosate alters testosterone levels and testicular morphology. *Archives of Toxicology* 84 (4):309-17.

58. Sanin, L.H., G. Carrasquilla, K.R. Solomon, D.C. Cole, and E.J. Marshall. 2009. Regional differences in time to pregnancy among fertile women from five Colombian regions with different use of glyphosate. *Journal of Toxicology and Environmental Health* 72 (15-16):949-60.

59. National Research Council. 2006. *Assessing the Human Health Risks of Trichloroethylene: Key Scientific Issues*. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=11707.

60. National Research Council. 2010. *Review of the Environmental Protection Agency's Draft IRIS Assessment of Tetrachloroethylene*. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=12863.

61. Aschengrau, A., J.M. Weinberg, P.A. Janulewicz, L.G. Gallagher, M.R. Winter, V.M. Vieira, T.F. Webster, and D.M. Ozonoff. 2009. Prenatal exposure to tetrachloroethylene-contaminated drinking water and the risk of congenital anomalies: a retrospective cohort study. *Environmental Health* 8:44.

62. Sonnenfeld, N., I. Hertz-Picciotto, and W.E. Kaye. 2001. Tetrachloroethylene in drinking water and birth outcomes at the US Marine Corps Base at Camp Lejeune, North Carolina. *American Journal of Epidemiology* 154 (10):902-8.

63. Aschengrau, A., J. Weinberg, S. Rogers, L. Gallagher, M. Winter, V. Vieira, T. Webster, and D. Ozonoff. 2008. Prenatal exposure to tetrachloroethylene-contaminated drinking water and the risk of adverse birth outcomes. *Environmental Health Perspectives* 116 (6):814-20.

64. Aschengrau, A., J.M. Weinberg, L.G. Gallagher, M.R. Winter, V.M. Vieira, T.F. Webster, and D.M. Ozonoff. 2009. Exposure to Tetrachloroethylene-Contaminated Drinking Water and the Risk of Pregnancy Loss. *Water Quality, Exposure, and Health* 1 (1):23-34.

65. U.S. Environmental Protection Agency. 2010. *Pharmaceuticals and Personal Care Products: Frequent Questions*. U.S. EPA, Office of Research and Development. Retrieved November 25, 2010 from http://www.epa.gov/ppcp/faq.html.

66. Focazio, M.J., D.W. Kolpin, K.K. Barnes, E.T. Furlong, M.T. Meyer, S.D. Zaugg, L.B. Barber, and M.E. Thurman. 2008. A national reconnaissance for pharmaceuticals and other organic wastewater contaminants in the United States--II) untreated drinking water sources. *Science of the Total Environment* 402 (2-3):201-16.

67. Burkholder, J., B. Libra, P. Weyer, S. Heathcote, D. Kolpin, P.S. Thorne, and M. Wichman. 2007. Impacts of waste from concentrated animal feeding operations on water quality. *Environmental Health Perspectives* 115 (2):308-12.

68. California Department of Public Health. *History of Perchlorate in California Drinking Water*. California Department of Public Health, Drinking Water Program. Retrieved November 25, 2010 from http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Perchloratehistory.aspx.

69. Rao, B., T.A. Anderson, G.J. Orris, K.A. Rainwater, S. Rajagopalan, R.M. Sandvig, B.R. Scanlon, D.A. Stonestrom, M.A. Walvoord, and W.A. Jackson. 2007. Widespread natural perchlorate in unsaturated zones of the southwest United States. *Environmental Science and Technology* 41 (13):4522-8.

70. U.S. Environmental Protection Agency. 2011. *Perchlorate*. U.S. EPA, Office of Water. Retrieved February 11, 2011 from http://water.epa.gov/drink/contaminants/unregulated/perchlorate.cfm.

71. Blount, B.C., and L. Valentin-Blasini. 2007. Biomonitoring as a method for assessing exposure to perchlorate. *Thyroid* 17 (9):837-41.

72. Centers for Disease Control and Prevention. 2009. *Perchlorate in Baby Formula Fact Sheet*. CDC. Retrieved August 13, 2009 from http://cdc.gov/nceh/features/perchlorate_factsheet.htm.

73. Pearce, E.N., A.M. Leung, B.C. Blount, H.R. Bazrafshan, X. He, S. Pino, L. Valentin-Blasini, and L.E. Braverman. 2007. Breast milk iodine and perchlorate concentrations in lactating Boston-area women. *Journal of Clinical Endocrinology & Metabolism* 92 (5):1673-7.

74. Schier, J.G., A.F. Wolkin, L. Valentin-Blasini, M.G. Belson, S.M. Kieszak, C.S. Rubin, and B.C. Blount. 2010. Perchlorate exposure from infant formula and comparisons with the perchlorate reference dose. *Journal of Exposure Science and Environmental Epidemiology* 20 (3):281-7.

75. Greer, M.A., G. Goodman, R.C. Pleus, and S.E. Greer. 2002. Health effects assessment for environmental perchlorate contamination: the dose response for inhibition of thyroidal radioiodine uptake in humans. *Environmental Health Perspectives* 110 (9):927-37.

76. National Research Council. 2005. *Health Implications of Perchlorate Ingestion*. Washington, DC: National Academies Press. http://www.nap.edu/catalog.php?record_id=11202.

77. U.S. Environmental Protection Agency. 2008. *Interim Drinking Water Health Advisory for Perchlorate*. Washington, DC: U.S. EPA, Office of Water. EPA 822-R-08-025. http://www.epa.gov/ogwdw/contaminants/unregulated/pdfs/healthadvisory_perchlorate_interim.pdf.

78. U.S. Environmental Protection Agency. 2008. *2006 Drinking Water Data Reliability Analysis and Action Plan*. Washington, DC. EPA 816-R-07-010. http://www.epa.gov/ogwdw/databases/pdfs/report_data_datareliability_2006.pdf.

79. U.S. Environmental Protection Agency. 2009. *Factoids: Drinking Water and Ground Water Statistics for 2009*. Washington, DC: U.S. EPA, Office of Water. EPA 816-K-09-004. http://www.epa.gov/safewater/databases/pdfs/data_factoids_2009.pdf.

80. U.S. Environmental Protection Agency. 1989. Drinking Water; National Primary Drinking Water Regulations; Total Coliforms (Including Fecal Coliforms and E. Coli) Final Rule. *Federal Register* 54 (124):27544-68.

81. U.S. Environmental Protection Agency. 2010. *Total Coliform Rule: Basic Information*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/lawsregs/rulesregs/sdwa/tcr/basicinformation.cfm.

82. U.S. Environmental Protection Agency. 2010. *Microbial and Disinfection Byproducts Rules: Microbials and Disinfection Byproducts*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/lawsregs/rulesregs/sdwa/mdbp/index.cfm.

83. U.S. Environmental Protection Agency. 2006. National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule. *Federal Register* 71 (2):387-493.

84. U.S. Environmental Protection Agency. 2001. National Primary Drinking Water Regulations; Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. *Federal Register* 66 (14):6975-7066.

85. U.S. Environmental Protection Agency. 2010. *Public Drinking Water Systems Programs*. U.S. EPA, Office of Water. Retrieved November 25, 2010 from http://water.epa.gov/infrastructure/drinkingwater/pws/index.cfm.

86. U.S. Environmental Protection Agency. 2005. *Water Health Series: Bottled Water Basics*. Washington, DC: U.S. EPA, Office of Water. 816-K-05-003. http://www.epa.gov/safewater/faq/pdfs/fs_healthseries_bottlewater.pdf.

87. U.S. Environmental Protection Agency. 2010. *Private Drinking Water Wells*. U.S. EPA, Office of Water. Retrieved January 10, 2011 from http://water.epa.gov/drink/info/well/index.cfm.

88. U.S. Geological Survey. 2004. Estimated Use of Water in the United States in 2000. In *USGS Circular 1268*. Denver, CO.

89. Focazio, M.J., D. Tipton, S. Dunkle Shapiro, and L.H. Geiger. 2006. The Chemical Quality of Self-Supplied Domestic Well Water in the United States. *Ground Water Monitoring and Remediation* 26 (3):92-104.

90. DeSimone, L.A. 2009. *Quality of Water from Domestic Wells in Principal Aquifers of the United States, 1991–2004: U.S. Geological Survey Scientific Investigations Report*. Reston, VA: U.S.G.S. SIR 2008–5227. http://pubs.usgs.gov/sir/2008/5227.

91. U.S. Environmental Protection Agency. 2009. *Potential Environmental Impacts of Animal Feeding Operations*. U.S. EPA, Ag Center. Retrieved January 10, 2011 from http://www.epa.gov/agriculture/ag101/impacts.html.

92. U.S. Environmental Protection Agency. 2010. *Lead and Copper Rule*. U.S. EPA, Office of Water. Retrieved January 10, 2011 from http://water.epa.gov/lawsregs/rulesregs/sdwa/lcr/index.cfm.

93. U.S. Environmental Protection Agency. 2010. *Fact Sheet on the Federal Register Notice for Stage 1 Disinfectants and Disinfection Byproducts Rule*. U.S. EPA, Office of Water. Retrieved January 10, 2011 from http://water.epa.gov/lawsregs/rulesregs/sdwa/stage1/factsheet.cfm.

94. U.S. Environmental Protection Agency. 2010. *Fact Sheet on the Interim Enhanced Surface Water Treatment Rule*. U.S. EPA, Office of Water. Retrieved January 10, 2011 from http://water.epa.gov/lawsregs/rulesregs/sdwa/ieswtr/factsheet.cfm.

95. U.S. Environmental Protection Agency. 2001. *Radionuclides Rule: A Quick Reference Guide*. Washington, DC: U.S. EPA, Office of Water. EPA 816-F-01-003. http://www.epa.gov/ogwdw/radionuclides/pdfs/qrg_radionuclides.pdf.

96. U.S. Environmental Protection Agency. 2009. *Technical Fact Sheet: Final Rule for Arsenic in Drinking Water*. U.S. EPA, Office of Water. Retrieved January 10, 2011 from http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/regulations_techfactsheet.cfm.

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2 # Metadata

Metadata for	Safe Drinking Water Information System Federal Version (SDWIS/FED)
Brief description of the dataset	SDWIS/FED is EPA's national database that manages and collects public water system information from states, including reports of drinking water standard violations, reporting and monitoring violations, and other basic information, such as water system location, type, and population served. (http://water.epa.gov/scitech/datait/databases/drink/sdwisfed/basicinformation.cfm)
Who provides the data set?	U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water.
How are the data gathered?	Violation data for all public water systems are provided by states and EPA regions. Public water systems are required to follow treatment and reporting requirements, to measure contaminant levels, and to report violations of standards.
What documentation is available describing data collection procedures?	Information is available at http://water.epa.gov/scitech/datait/databases/drink/sdwisfed/basicinformation.cfm
What types of data relevant for children's environmental health indicators are available from this database?	Violations of national standards for drinking water, either due to contaminant levels exceeding allowable levels, violations of treatment requirements, or violations of monitoring and reporting requirements. Total population served by each public water system.
What is the spatial representation of the database (national or other)?	SDWIS/FED includes data for all public water systems in the United States.
Are raw data (individual measurements or survey responses) available?	Separate reports for each violation of drinking water standards or monitoring and reporting requirements for individual public water systems are available; measured contaminant levels are not available in SDWIS/FED.
How are database files obtained?	SDWIS/FED violation and inventory data were obtained from OGWDW staff who compiled the data into a dataset listing the water system, state, violation type and code, chemical contaminant code, violation dates, and the population served
Are there any known data quality or data analysis concerns?	The estimated number of people served by each public water system is approximate. Estimates are updated when there is a significant change in a water system's population. Some water systems serve more than one state (the primary state is reported) and water systems often serve more than one county. Many people obtain drinking water from more than one public water system. Although the data are largely accurate, EPA is aware of underreporting of some violation data in SDWIS/FED. Several states have recently found and corrected

Metadata for	**Safe Drinking Water Information System Federal Version (SDWIS/FED)**
	significant errors in their violation databases.
What documentation is available describing QA procedures?	EPA routinely evaluates drinking water programs by conducting data verification audits, which evaluate state compliance decisions and reporting to SDWIS/FED. Every three years, the agency prepares summary evaluations based on the data verification. These evaluations are available at: http://www.epa.gov/safewater/databases/sdwis/datareliability.html.
For what years are data available?	1976 – present.
What is the frequency of data collection?	Quarterly.
What is the frequency of data release?	Quarterly.
Are the data comparable across time and space?	Violations across time are often not comparable because of changes in regulations and changes in drinking water standards (maximum contaminant levels), and variability over time in monitoring and reporting violations. Data may not be geographically comparable due to variations in state enforcement and database quality.
Can the data be stratified by race/ethnicity, income, and location (region, state, county or other geographic unit)?	Data can be stratified by state and county, with some uncertainty because boundaries of public water systems do not coincide with state and county boundaries. The state and county reported in SDWIS/FED are the primary state and county served by the water system. Data cannot be stratified by demographic characteristics because SDWIS/FED reports only the total population served by a public water system, without any demographic information.

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Methods

Indicator E6. Percentage of children ages 0 to 17 years served by community water systems that did not meet all applicable health-based drinking water standards, 1993–2009.

Indicator E7. Percentage of children ages 0 to 17 years served by community water systems with violations of drinking water monitoring and reporting requirements, 1993–2009.

Summary

EPA's Safe Drinking Water Information System Federal Version (SDWIS/FED) includes information on populations served and violations of maximum contaminant levels or required treatment techniques by the nation's 160,000 public water systems. For each calendar year, SDWIS/FED violation data for the nation's 50,000 community water systems were obtained from EPA Office of Ground Water and Drinking Water (OGWDW), listing all violations that occurred during part or all of that year. For Indicator E6, health-based violations were grouped into different types based on the violation code and chemical contaminant code. For Indicator E7, violations of monitoring and reporting requirements were grouped into different types based on the violation code. For each state and type of violation, the fraction of the population served by violating systems was estimated as the total population served by community water systems with one or more violations divided by the total population served by all community water systems. For each state and type of violation, the number of children served by violating systems was estimated as the fraction of the population served by violating systems multiplied by the total population of children ages 17 years and under in the state. Indicators E6 and E7 are the percentages of children served by violating systems in relation to all children served by community water systems, estimated by summing the numbers of children served by violating systems across all states and dividing this total by the national total population of children ages 17 years and under.

Overview of Data Files

The following files are needed to calculate this indicator:

- SDWIS/FED violation data. This file contains the public water system identification code (PWSID), violation code, contaminant code, contaminant type, state (primary state served by the water system), population served, and calendar year. The SDWIS/FED database records the PWSID and start and end date of each violation. This file has one row for each calendar year and violation where the violation starts on or before December 31 and ends on or after January 1. This file only contains violations by Community Water Systems (as defined by OGWDW).[ii] The population served is the current (fourth quarter

[ii] Community Water Systems have at least 15 service connections or serve 25 or more of the same population year-round.

2009) estimate of the population served by that water system. This file was obtained directly from OGWDW staff.

- SDWIS/FED inventory data. This file contains the total population served by all community water systems in each state and year. The data for 2009, fourth quarter, frozen as of January 2010, were used for these analyses. This file was obtained directly from OGWDW staff.

- Census data. This file contains the state FIPS codes, year, and children's population. For 1993-1999, we obtained this information from the U.S. Census Bureau files:

  > "Estimates of the Population of Counties by Age and Sex: 1990-1999," August 30, 2000, http://www.census.gov.

  For 2000-2009, we obtained this information from the bridged-race Vintage 2009 postcensal population files:

  > National Center for Health Statistics. Postcensal estimates of the resident population of the United States for July 1, 2000-July 1, 2009, by year, county, age, bridged race, Hispanic origin, and sex (Vintage 2009). Prepared under a collaborative arrangement with the U.S. Census Bureau; released June 20, 2010. Available from: http://www.cdc.gov/nchs/nvss/bridged_race.htm as of July 23, 2010.

The children's populations by year and state were obtained by summing across all counties and across the ages 0 to 17 years inclusive.

Drinking Water Standards Violation Data

Drinking water standards violation data from the EPA Safe Drinking Water Information System Federal Version (SDWIS/FED) were obtained directly from OGWDW[iii]. The file was extracted from SDWIS/FED in November 2010. This file contains the public water system identification code (PWSID), violation code, contaminant code, state (primary state served by the water system), population served, and calendar year. The SDWIS database records the PWSID and start and end date of each violation. This file has one row for each calendar year and violation where the violation starts on or before December 31 and ends on or after January 1. Violations that start and end in different calendar years are included for each of the calendar years that intersect the violation period. This file only contains violations by Community Water Systems. The population served is the current (fourth quarter 2009) estimate of the population served by that water system. Violations by systems not assigned to one of the 50 U.S. States or Washington DC were excluded. Therefore, we did not include violations in Puerto Rico and other U.S. territories that are not states. We also excluded violations on tribal lands which are assigned to the EPA regions. Finally, we excluded a single SWTR TT for PWSID CA1910067 determined to be invalid by OGWDW staff.

[iii] http://water.epa.gov/drink/contact.cfm

For Indicator E6, health-based violations were grouped into the following violation types using the violation and contaminant codes:

- All health-based: Violation codes 20, 48 (Ground water rule), 40 (Filter backwash recycling rule), or any of the following violations
- Lead and copper: Violation codes 57, 58, 59, 63, 64, 65
- Total coliforms: Violation codes 21 and 22 with all contaminant codes. Violation codes 1 and 2 with contaminant code 3000 (Coliform pre-TCR) only
- Chemical and radionuclide: Violation codes 1, 2 and 7 with all applicable contaminant codes*
- Surface water treatment: Violation codes 33, 41-44 and 47 with all contaminant codes. Violation code 37 with contaminant code 0300 only
- Nitrate/nitrite: Violation codes 1 and 2 with contaminant codes 1038, 1040, and 1041
- Disinfectants and disinfection byproducts: Violation codes 11, 12, 13, and 46 with all contaminant codes. Violation code 2 with contaminant codes 1009, 1011, 2456, 2941, 2942, 2943, 2944 and 2950. Violation code 37 with contaminant code 0400.

* The applicable contaminant codes for Chemical and radionuclide are as follows:

Volatile organic chemicals: 2378, 2380, 2955, 2964, 2968, 2969, 2976, 2977, 2979, 2980, 2981, 2982, 2983, 2984, 2985, 2987, 2989, 2990, 2991, 2992, 2996
Synthetic organic contaminants: 2005, 2010, 2015, 2020, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2039, 2040, 2041, 2042, 2046, 2050, 2051, 2063, 2065, 2067, 2105, 2110, 2274, 2298, 2306, 2326, 2383, 2388, 2390, 2392, 2394, 2396, 2400, 2931, 2946, 2959

Inorganic chemicals: 1005, 1010, 1015, 1020, 1024, 1025, 1035, 1045, 1074, 1075, 1085, 1094
Radiological contaminants: 4000, 4006, 4010, 4100, 4101, 4102

For Indicator E7, monitoring and reporting violations were grouped into the following violation types using the violation codes:

- Any violation: Violation codes 19, 34 (Ground water rule), 39 (Filter backwash recycling rule), or any of the following violations
- Lead and copper: Violation codes 51, 52, 53, 56, and 66
- Total coliforms: Violation codes 23, 24, 25, and 26
- Chemical and radionuclide: Violation codes 3 and 4
- Surface water treatment: Violation codes 29, 31, 32, 36 and 38 with all contaminant codes. Violation code 37 with contaminant code 0800 only
- Disinfectants and disinfection byproducts: Violation codes 27, 30, and 35.

In a calendar year, a PWSID may have one or more violations of a given violation type. Only the first such violation is selected. For each violation type, state, and calendar year, the total population served by all violating PWSIDs was calculated by summing across the PWSIDs, counting each violating PWSID once only.

For each state, the total population served by community water systems was obtained from the SDWIS/FED inventory files. OGWDW staff provided this summary file. The data for 2009, fourth quarter, frozen as of January 2010, were used for these analyses. Only the 50 U.S. States or Washington DC, identified by their postal code abbreviations, were included.

Census Data

We obtained children's populations by state for each year from 1993-2009.

For 1993-1999, the source was U.S. Census Bureau files:

> "Estimates of the Population of Counties by Age and Sex: 1990-1999," August 30, 2000. The file headers are "(C0-99-9) Population Estimates for Counties by Age and Sex: Annual Time Series July 1, 1990 to July 1, 1999."
> http://www.census.gov/popest/archives/1990s/CO-99-09.html

These files give county populations by age and sex for 1990 to 1999. We summed these populations by year and state across all counties in the state, all ages 17 years and under, and both sexes.

For 2000-2009, we used the bridged-race Vintage 2009 postcensal populations files obtained from the CDC website:

> National Center for Health Statistics. Postcensal estimates of the resident population of the United States for July 1, 2000-July 1, 2009, by year, county, age, bridged race, Hispanic origin, and sex (Vintage 2009). Prepared under a collaborative arrangement with the U.S. Census Bureau; released June 20, 2010. Available from: http://www.cdc.gov/nchs/nvss/bridged_race.htm as of July 23, 2010.

The bridged Vintage 2009 postcensal population files contains estimates of the resident population of the United States as of July 1, 2000, July 1, 2001, July 1, 2002, July 1, 2003, July 1, 2004, July 1, 2005, July 1, 2006, July 1, 2007, July 1, 2008, and July 1, 2009 by county, single-year of age (0, 1, 2,..., 85 years and over), bridged-race category (White, Black or African American, American Indian or Alaska Native, Asian or Pacific Islander), Hispanic origin (not Hispanic or Latino, Hispanic or Latino), and sex. There is one file for each year. Files are available in SAS dataset and text formats; we used the SAS dataset format for these analyses.

We extracted the variables: state, county, age, racesex, hisp, and pop. The racesex variable is a single coded value for each combination of race and sex, e.g., racesex = 1 denotes White males. The value pop gives the population as of July 1 of the calendar year for a given state, county, age, racesex combination, and ethnicity. The state children's populations for each year 2000-2009 were obtained by summing the variable pop over all counties in a state, ages <= 17, all values of "racesex" and all values of "hisp."

Calculation of Indicator

Indicators E6 and E7 are calculated as follows.

Using the water quality violation data, the PWSIDs violating a given type of violation during each calendar year were listed. For each type of violation and calendar year, only the first violation by a PWSID was selected.

1. For each state, type of violation, and year, the populations served by violating systems were obtained by summing the populations served across the violating PWSIDs:

Violating population (state, violation type, year) = Σ Population served

where this sum is taken over all violating community water systems in the state for the given calendar year.

2. The fractions of the populations served by violating systems were obtained by dividing the violating population by the total population served by all community water systems in the state for that year. The total populations served by community water systems in each state were obtained from the SDWIS/FED inventory data:

State population fraction affected (state, violation type, year) =
Violating population (state, violation type, year) /
Total population served (state, year)

3. The number of affected children in each state was estimated by multiplying the state population fraction affected by the state children's population. This estimate assumes an even geographic distribution over water systems of individuals under the age of 18 in each state for each year. This estimate also assumes that all children are served by community water systems; see below for a discussion of this assumption. This estimate also makes no adjustment for children in one state that are served by water systems that primarily serve another state:

State children affected (state, violation type, year) =
State population fraction affected (state, violation type, year) ×
Children 0-17 (state, year)

4. The national number of children served by violating systems was obtained by summing the state numbers of children served by violating systems:

National children affected (violation type, year) =
Σ State children affected (state, violation type, year)

5. The percentage of children served by violating water systems was obtained by dividing the national number of children served by violating water systems by the total number of children in the 50 U.S. states and Washington DC:

Percentage children affected (violation type, year) =

[National children affected (violation type, year) /
Σ Children 0-17 (state, year)] × 100%

where the sum is across all states.

In Step 3, an assumption is made that all children ages 0 to 17 years are served by community water systems. In fact, some of the U.S. population, and hence some children ages 0 to 17 years, are not served by community water systems, so this assumption is unrealistic. To address this issue, suppose instead that a fraction g of children are served by community water systems, where g is approximately the same for every state, but could vary by year. In Step 3, the number of children affected in a given state is given by:

State children affected (state, violation type, year) =
State population fraction affected (state, violation type, year) ×
Children 0-17 (state, year) × g(year),

since there are Children 0-17 (state, year) × g(year) children ages 0 to 17 years that are served by community water systems in that state and year. Step 4 is unchanged. In Step 5, the percentage of children served by violating systems in relation to the children served by community water systems is obtained by dividing the national number of children served by violating water systems by the total number of children served by community water systems:

Percentage children affected (violation type, year) =
[National children affected (violation type, year) /
Σ Children 0-17 (state, year) × g(year)] × 100%.

Because the same fraction g(year) appears in both the numerator and denominator, it cancels out. Therefore, even though not all children are served by community water systems, Indicators E6 and E7 estimate the percentage of children served by violating systems in relation to the children served by community water systems.

Questions and Comments

Questions regarding these methods, and suggestions to improve the description of the methods, are welcome. Please use the "Contact Us" link at the bottom of any page in the America's Children and the Environment website.