Water Treatment
NOTES

Cornell Cooperative Extension, College of Human Ecology

Drinking water Standards and the Health Effects of Drinking Contaminated Water

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When you fill a glass with water from your tap, you expect to drink water that is safe and pure. However, suspended or dissolved gases, minerals, bacteria, metals, or chemicals may influence the quality of your water. Contaminated drinking water can adversely affect your health.

Drinking Water Standards

As authorized by the 1974 Safe Drinking Water Act and its amendments, the U.S. Environmental Protection Agency (EPA) has established limits, or standards, on the concentrations of certain contaminants that are allowed in public drinking water supplies. These standards are set to protect public health by ensuring good water quality. EPA standards for drinking water fall into two categories: primary standards and secondary standards.

Primary Standards

Primary standards protect consumers from microbial contaminants, radioactive elements, and toxic chemicals. Primary standards set a limit, the maximum contaminant level (MCL), on the highest allowable concentration of a contaminant in public drinking water supplies. The MCL, which is enforced by the EPA, is set as close as possible to the maximum contaminant level goal (MCLG), a preliminary standard set but not enforced by the EPA. The MCLG is based entirely on health considerations; as a health goal, it is set at a level at which no adverse health effects should occur. The nonenforceable MCLG is used to establish the enforceable MCL, which also takes into consideration the feasibility and cost of analysis and treatment of the regulated contaminant.

Secondary Standards

Secondary standards regulate contaminants that cause offensive taste, odor, color, corrosivity, foaming, or staining. The concentration limit is called the secondary maximum contaminant level (SMCL). Secondary standards are not enforced; they are guidelines for water treatment plant operators and state governments attempting to provide communities with the best quality water possible.

How Standards Are Set

Primary standards for drinking water contaminants are based on three criteria:

- The contaminant causes adverse health effects.
- The contaminant is detectable in drinking water.
- The contaminant is known to occur in drinking water.

In setting primary standards for a drinking water contaminant, the EPA first looks at all the toxicological data on that contaminant, usually obtained from acute and chronic animal studies. (Human clinical or epidemiological data are used when they are available, but scientific data linking human health to drinking water contaminants are limited.) Experts use this information to estimate the concentration of the contaminant that may be toxic and the concentration level, if any, at which the contaminant causes no adverse health effects.

Acute and Chronic Health Effects

Toxic doses of chemicals cause either acute or chronic health effects. An acute effect usually follows a large dose of a chemical and occurs almost immediately.

Examples of acute health effects are nausea, lung irritation, skin rash, vomiting, dizziness, and even death. The levels of contaminants found in drinking water are seldom high enough to cause acute health effects. They are most likely to cause chronic health effects, which occur long after exposure to small amounts of a contaminant. Examples of chronic health effects include cancer, birth defects, organ damage, disorders of the nervous system, and damage to the immune system.

Acceptable Daily Intake

If a chemical does not cause cancer, drinking water standards are calculated from the acceptable daily intake (ADI). The ADI is the daily dose of a substance (including a safety margin) that a person can ingest over a lifetime without suffering adverse health effects. The ADI is used to establish the MCLG for a contaminant, which in turn is used to set the enforceable MCL.

Risk Estimate

If a contaminant causes cancer, it is assumed that no concentration is safe. Consequently, the MCLG is set at zero, a level that is not always possible to achieve. However, at very low concentrations the risk of cancer becomes so small that it is considered negligible. Therefore, regulatory officials must decide what level of risk is acceptable. The concentration of a chemical estimated to cause this "acceptable level" of risk is the risk estimate.

Current Drinking Water Standards

Regulations governing drinking water have more than tripled since the passage of the Safe Drinking Water Act Amendments in 1986. Although the EPA oversees community drinking water quality, regulatory officials in each state ultimately set and enforce drinking water standards for EPA-regulated and other contaminants. States are permitted to set standards that are stricter, but not less stringent, than the MCLs set by the EPA. When a standard is exceeded, the EPA, through the designated state agency, requires that the contaminant level be reduced to the MCL. The corrective treatment is left to the individual water supply system.

Drinking Water Standards Are Not Absolute

Setting drinking water standards is an imperfect process influenced by economic, political, and social considerations, in addition to scientific data. In fact, data relating human health effects to chemicals in drinking water are limited, and scientists have difficulty predicting the effects of drinking small amounts of chemicals for many years. Furthermore, standards do not take into account the presence of multiple chemicals, which may increase or decrease the toxicity of a particular contaminant.

For these reasons, it is important to understand that primary drinking water standards do not guarantee that water with a contaminant level below the standard is risk free, nor do they indicate that water with a higher level is unsafe. Drinking water standards represent conservative judgments of scientists and regulatory officials, which are based on all available information on the health effects of drinking water contaminants.

Therefore, although current drinking water standards do not guarantee that the glass of water you draw from your tap is absolutely safe and pure, they do provide monitoring guidelines for public water supply systems and concerned individuals with private water supplies. Current drinking water standards reflect sound scientific judgment and are based on all the knowledge that is available at the time they are set.

Regulated Contaminants

The following tables are adapted from EPA National Primary Drinking Water Standards tables.

Inorganic Contaminants

Inorganic contaminants occur naturally in soil and rocks and often contaminate water during mining processes. Additional sources include refining and other industrial processes, sewage treatment, waste incineration, landfills, and industrial waste sites.

Contaminant	EPA Standards	Possible Health Effects
Antimony	MCL: 0.006 MCLG: 0.006	Decreases longevity; alters glucose and cholesterol levels
Arsenic	MCL:0.010 (1/23/06) MCLG:0.0	Skin and lung cancer; liver and kidney damage
Asbestos (fibers > 10 micrometers)	MCL:7.0 MFL MCLG: 7.0 MFL	Lung cancer; gastrointestinal cancer when swallowed fibers exceed 10 micrometers in length
Barium	MCL: 2.0 MCLG: 2.0	Hypertension; heart damage
Beryllium	MCL: 0.004 MCLG: 0.004	Cancer; liver and kidney damage; intestinal lesions
Cadmium	MCL: 0.005 MCLG: 0.005	Kidney damage
Chromium (total)	MCL: 0.1 MCLG: 0.1	Liver, kidney and lung damage
Copper	MCL: TT[1] Al: 1.3 MCLG: 1.3	Liver and kidney damage; digestive disturbances; anemia
Cyanide (as free cyanide)	MCL:0.2 MCLG: 0.2	Spleen and liver damage, brain damage
Fluoride	MCL: 4.0 MCLG: 4.0	Mottling of teeth; bone damage
Lead	MCL:TT[1] AL: 0.015 MCLG:1.3	Brain and nerve damage (especially in children); kidney damage; digestive disturbances; blood disorders; hypertension
Mercury (inorganic0	MCL: 0.002 MCLG:0.002	Brain and nerve damage; kidney damage; birth defects and skin rash
Nitrate (as N)	MCL:10.0 MCLG: 10.0	Methemoglobinemia in infants (blue-baby syndrome)
Nitrite (as N)	MCL: 1.0 MCLG: 1.0	Methemoglobinemia in infants (blue-baby syndrome)
Selenium	MCL: 0.05 MCLG: 0.05	Growth inhibition; skin discoloration; dental and digestive problems; liver damage and psychological disorders
Thallium	MCL: 0.002 MCLG: 0.0005	Kidney, liver, brain, and intestinal damage

Note. Unless otherwise noted, EPA standards are measured in milligrams per liter. MCL = maximum contaminant level; MCLG = maximum contaminant level goal; MFL = million fibers per liter; TT = treatment technique; AL = action level. 1Treatment technique is a required process intended to reduce the level of a contaminant in drinking water. Lead and copper are regulated by a treatment technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level (AL), water systems must take additional steps. For copper, the AL is 1.3 mg/L, and for lead it is 0.015 mg/L.

Organic Contaminants

Organic contaminants originate from industrial manufacturing processes, the manufacture and application of agricultural chemicals, and municipal and hazardous waste sites.

Contaminant	EPA Standards	Possible Health Effects
Acrylamide	MCL: TT[1] MCLG: 0.0	Cancer; nervous system damage
Alachlor	MCL:0.002 MCLG:0.0	Cancer; eye and liver damage
Atrazine	MCL:0.003 MCLG: 0.003	Dermatitis; cardiovascular system or reproductive problems
Benzene	MCL: 0.005 MCLG: 0.0	Leukemia and other cancers; nerve, lung kidney, and reproductive organ damage; blood disorders.
Benzo(a)pyrene (PAHs)	MCL: 0.0002 MCLG: 0.0	Cancer
Carbofuran	MCL: 0.04 MCLG: 0.04	Reproductive and immune system damage; cholinesterase inhibition
Carbon tetrachloride	MCL: 0.005 MCLG: 0.005	Central nervous system depression; liver and kidney damage; cancer
Chlordane	MCL: 0.002 MCLG: 0.0	Cancer; nerve and liver damage
2,4-D	MCL: 0.07 MCLG: 0.07	Liver, kidney, and muscle damage; skin irritations
Chlorobenzene	MCL: 0.1 MCLG: 0.1	Liver or kidney problems
Dalapon	MCL: 0.2 MCLG: 0.2	Kidney and liver damage
1,2-Dibromo-3-chloropropane (DBCP)	MCL: 0.0002 MCLG: 0.0	Kidney and liver damage; cancer; infertility
o-Dichlorobenzene	MCL:0.6 MCLG: 0.6	Liver and kidney damage; eye and nose irritation
p-Dichlorobenzene	MCL: 0.075 MCLG: 0.075	Liver and kidney damage; blood disorders
1,2-Dichloroethane	MCL: 0.005 MCLG: 0.0	Cancer; lung, heart, kidney, and liver damage; central nervous system depression
1,1-Dichloroethylene	MCL: 0.007 MCLG:0.007	Heart, kidney, and liver damage; central nervous system depression
cis-1,2-Dichloroethylene	MCL:0.07 MCLG: 0.07	Central nervous system depression; liver and kidney damage
trans-1,2-Dichloroethylene	MCL: 0.1 MCLG: 0.1	Central nervous system depression; liver and kidney damage
Dichloromethane	MCL: 0.005 MCLG: 0.0	Liver problems; increased risk of cancer
1,2-Dichloropropane	MCL: 0.005 MCLG: 0.0	Liver and kidney damage
Di (2-ethylhexyl) adipate	MCL: 0.4 MCLG: 0.4	Liver and testes damage
Di (2-ethylhexyl) phtalate	MCL: 0.006 MCLG: 0.0	Cancer
Dinoseb	MCL: 0.007 MCLG: 0.007	Thyroid and reproductive organ damage

Organic Contaminants *continued*.

Contaminant	EPA Standards	Possible Health Effects
Diquat	MCL: 0.02 MCLG: 0.02	Liver, kidney, and gastrointestinal tract damage; cataracts
Endothall	MCL: 0.1 MCLG: 0..1	Liver kidney, gastrointestinal tract, and reproductive organ damage
Endrin	MCL:0.002 MCLG:0.002	Liver and nervous system damage; birth defects
Epichlorohydrin	MCL: TT[1] MCLG: 0.0	Cancer; central nervous system, lung, liver, testes, and kidney damage
Ethylbenzene	MCL: 0.07 MCLG: 0.07	Nerve, brain, liver and kidney damage
Ethylene dibromide	MCL: 0.00005 MCLG: 0.0	Cancer; liver, kidney, central nervous system, gastrointestinal and reproductive organ damage
Glyphosphate	MCL: 0.7 MCLG: 0.7	Liver and kidney damage
Heptachlor	MCL: 0.0004 MCLG: 0.0	Cancer; liver and central nervous system damage
Heptachlor epoxide	MCL: 0.0002 MCLG: 0.0	Cancer; liver and central nervous system damage
Hexachlorobenzene	MCL: 0.001 MCLG: 0.0	Cancer
Hexachlorocyclopentadiene	MCL: 0.05 MCLG: 0.05	Stomach and kidney damage
Lindane	MCL: 0.0002 MCLG: 0.0002	Liver and kidney damage
Methoxychlor	MCL: 0.04 MCLG: 0.04	Central nervous system, liver, and kidney damage
Oxamyl (Vydate)	MCL:0.2 MCLG: 0.2	Kidney damage
Pentachlorophenol (PCP)	MCL: 0.001 MCLG: 0.0	Liver, kidney, nervous system, immune system, and reproductive organ damage; blood disorders
Picloram	MCL: 0.5 MCLG: 0.5	Liver and kidney damage
Polychlorinated biphenyls (PCBs)	MCL: 0.0005 MCLG:0.0	Cancer; liver damage
Simazine	MCL:0.004 MCLG: 0.004	Cancer
Styrene	MCL: 0.1 MCLG: 0.1	Liver damage
Tetrachloroethylene	MCL: 0.005 MCLG: 0.0	Cancer; liver and kidney damage; central nervous system depression
Toluene	MCL: 1.0 MCLG: 1.0	Central nervous system depression; kidney damage
Toxaphene	MCL: 0.003 MCLG: 0.0	Cancer; liver and kidney damage
2,4,5-TP (Silvex	MCL: 0.05 MCLG: 0.05	Liver and kidney damage
1,2,4-Trichlorobenzene	MCL: 0.07 MCLG: 0.07	Liver and kidney damage

Organic Contaminants *continued*.

Contaminant	EPA Standards	Possible Health Effects
1,1,1-Trichloroethane	MCL: 0.2 MCLG: 0.2	Central nervous system depression; liver and cardiovascular damage
1,1,2-trichloroethane	MCL: 0.005 MCLG: 0.003	Kidney and liver damage
2,3,7,8-TCDD (dioxin)	MCL:3 x 10^{-8} MCLG: 0.0	Cancer
Trichloroethylene (TCE)	MCL:0.005 MCLG: 0.0	Cancer; central nervous system depression; heart, liver, and kidney damage
Vinyl chloride	MCL:0.002 MCLG: 0.0	Cancer; central nervous system depression; liver, reproductive, and digestive tract damage; birth defects
Xylenes (total)	MCL:10.0 MCLG: 10.0	Central nervous system and reproductive organ damage

Note: Unless otherwise noted, EPA standards are measured in milligrams per liter. MCL = maximum contaminant level; MCLG = maximum contaminant level goal; TT = treatment technique. 1Treatment technique is a required process intended to reduce the level of a contaminant in drinking water. Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified as follows: acrylamide = 0.05% dosed at 1 mg/L (or equivalent); epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

Microbial Contaminants

Microbial contaminants are usually present in sewage and also in animal waste. The major sources of microbial contamination are septic systems and agricultural practices such as manure spreading.

Contaminant	EPA Standards	Possible Health Effects
Cryptosporidium	MCL:TT[1] MCLG: 0.0	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)
Giardia lamblia	MCL:TT[1] MCLG: 0.0	Giardiasis: gastrointestinal infection causing fatigue, diarrhea, abdominal cramps, and gas
Heterotrophic plate count (HPC)	MCL:TT[1] MCLG:n/a	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water
Legionella	MCL:TT[1] MCLG: 0.0	Legionnaires' disease; Pontiac fever
Total coliforms (including fecal coliform and E. coli)	MCL: 5%[2] Positive MCLG:0.0	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[3]
Turbidity	MCL:TT[1] MCLG: n/a	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g. whether disease-causing organisms are present)
Viruses (enteric)	MCL:TT[1] MCLG: 0.0	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)

Note: Unless otherwise noted, EPA standards are measured in milligrams per liter. MCL = maximum contaminant level; MCLG = maximum contaminant level goal; TT = treatment technique. 1Treatment technique is a required process intended to reduce the level of a contaminant in drinking water. The EPA's surface water treatment rules require systems using surface water or ground-water under the direct influence of surface water to (1) disinfect their water and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium*: 99% removal
- *Giardia lamblia*: 99.9% removal/inactivation.

Microbial Contaminants *continued*

• Viruses: 99.99% removal/inactivation
• *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* also will be controlled• Viruses: 99.99% removal/inactivation
• *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* also will be controlled• Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelometric turbidity units (NTU); systems that filter must ensure that the turbidity goes no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of 1/1/02, for systems serving >10,000 people, and 1/14/05, for systems serving < 10,000 people, turbidity may never exceed 1 NTU and must not exceed 0.3 NTU in 95% of daily samples in any month.
• HPC: No more than 500 bacterial colonies per milliliter.
• Long Term 1 Enhanced Surface Water Treatment (effective 1/14/05): Surface water systems or (GWUDI) systems serving <10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g., turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfi ltered systems). The new Long Term 2 Enhanced Surface Water Treatment Rule is being developed and will require additional water treatment.
• Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state. 2No more than 5.0% of samples can be total coliform (TC)-positive in a month. (For water systems that collect <40 routine samples per month, no more than one sample can be TC-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliform or *E. coli*. If there are two consecutive TC-positive samples and one is also positive for *E.coli* or fecal coliforms, the system has an acute MCL violation.
[3]Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

Disinfectants

Disinfectants are added to water to treat microbial contaminants

Contaminants	EPA Standards	Possible Health risks
Chloramines (as CL_2)	MRDL[1]: 4.0 MRDLG[2]: 4.0	Eye/nose irritation; stomach discomfort, anemia
Chlorine (as Cl_2)	MRDL[1]: 4.0 MRDLG[2]: 4.0	Eye/nose irritation; stomach discomfort
Chlorine dioxide (as CLO_2)	MRDL[1]: 0.8 MRDLG[2]: 0.8	Anemia; infants and young children: nervous system effects

Note: Unless otherwise noted, EPA standards are measured in milligrams per liter. MRDL = maximum residual disinfectant level; MRDLG = maximum residual disinfectant level goal.
[1]The MRDL is the highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
[2]The MRDLG is the level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.

Disinfection Byproducts

Disinfection byproducts are created from the reaction of disinfectants and organic matter in water.

Contaminants	EPA Standards	Possible Health risks
Bromate	MCL: 0.010 MCLG: 0.0	Increased risk of cancer
Chlorite	MCL: 1.0 MCLG: 0.8	Anemia; infants and young children: nervous system effects
Haloacetic acid (HAA5)	MCL: 0.060 MCLG: n/a[1]	Increased risk of cancer
Total trihalomethanes (TTHMs)	MCL: 0.080 MCLG: n/a[1]	Liver, kidney or central nervous system problems; increased risk of cancer

Disinfection Byproducts *continued*

Note: Unless otherwise noted, EPA standards are measured in milligrams per liter. MCL = maximum contaminant level; MCLG = maximum contaminant level goal.
[1]Although there is no collective MCLG for this group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- • Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

Radionuclide Contaminants

The primary source of radio nuclides is the natural decay of uranium in rocks and soil.

Contaminants	EPA Standards	Possible Health risks
Alpha particles	MCL: 15 pCi/L MCLG: 0.0	Increased risk of cancer
Beta particles and photon emitters	MCL: 4 mrem/yr MCLG: 0.0	Increased risk of cancer
Radium-226 +228	MCL: 5 pCi/L MCLG: 0.0	Bone cancer; kidney damage; birth defects
Uranium	MCL: 30 µg/L MCLG: 0.0	Increased risk of cancer, kidney toxicity

Note: MCL = maximum contaminant level; MCLG = maximum contaminant level goal; mrem = millirem (measure of radiation); pCi/L = picocuries per liter.

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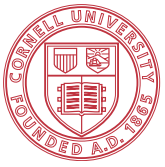

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