Drinking water contaminants and known health effects

EPA currently regulates **over 90 contaminants** in public drinking water, and WHO's drinking-water guidelines continue to update and add chemicals as evidence develops.

1) Major known drinking-water contaminants with known health effects

A. Microbial contaminants

This is the highest public-health risk category globally. It includes **pathogenic bacteria, viruses, and parasites/protozoa**, typically from fecal contamination. Health effects include **acute gastrointestinal disease**, diarrhoea, cholera, dysentery, typhoid, hepatitis A, polio, and in some cases severe disease in vulnerable groups. WHO states that microbiologically contaminated drinking water poses the greatest risk to drinking-water safety. (Världshälsoorganisationen)

Key examples:

- **Bacteria:** *E. coli* pathotypes, *Vibrio cholerae*, *Salmonella Typhi*, *Shigella*, *Campylobacter*
- **Viruses:** norovirus, rotavirus, hepatitis A virus, enteroviruses
- **Protozoa/parasites:** *Giardia*, *Cryptosporidium*, helminths in some settings

B. Inorganic chemical contaminants

These are among the best-established chemical hazards in drinking water, especially in groundwater.

- **Arsenic:** strongly linked to **skin lesions**, and increased risk of **skin, lung, and bladder cancer**, as well as cardiovascular and other chronic effects. (Världshälsoorganisationen)
- **Fluoride:** at appropriate intake can reduce dental caries, but excess exposure can cause **dental fluorosis** and **skeletal fluorosis**; higher exposures have also been associated in recent evaluations with **lower IQ in children**. (Världshälsoorganisationen)
- **Nitrate / nitrite:** classically linked to **methemoglobinemia** in infants; evidence also supports concern for **colorectal cancer** under some exposure conditions involving endogenous N-nitroso compound formation. (PMC)
- **Lead:** causes **neurodevelopmental harm**, especially reduced cognition and behavioral effects in children; can also affect cardiovascular and renal systems. Lead in water often comes from plumbing rather than the source water itself. (Världshälsoorganisationen)

- **Chromium (especially hexavalent chromium, Cr(VI))**: associated with **gastrointestinal, liver, developmental, hematological, immune, and male reproductive toxicity**; EPA's recent IRIS review says oral Cr(VI) is likely carcinogenic to the human GI tract.
- **Manganese:** excess exposure, particularly in children, has been associated with **adverse neurodevelopmental and behavioral outcomes**. (Världshälsoorganisationen)
- **Cadmium:** linked to **kidney toxicity** and bone effects; recognized by WHO and EPA in drinking-water frameworks. (Världshälsoorganisationen)
- **Mercury:** associated with **neurological toxicity**, especially developmental neurotoxicity. (Världshälsoorganisationen)
- **Selenium:** excess can cause **hair/nail changes and neurological or gastrointestinal effects**. (Världshälsoorganisationen)
- **Copper:** high levels can cause **gastrointestinal irritation** and, in severe or prolonged exposure, liver effects. (US EPA)

C. Radiological contaminants

These include **uranium, radium, gross alpha emitters, beta/photon emitters**, and related radionuclides. Health effects include **cancer risk from radiation exposure**, while uranium also has important **chemical nephrotoxicity** independent of radioactivity. WHO and EPA both treat radiological contaminants as a core drinking-water category. (US EPA)

D. Disinfectants and disinfection by-products (DBPs)

Chlorination is essential for infection control, but it can form by-products such as **trihalomethanes (THMs)** and **haloacetic acids (HAAs)**. The best-established long-term concern is an association with **bladder cancer**, with some evidence also for colorectal cancer in recent analyses. (US EPA)

E. Volatile organic compounds (VOCs) and industrial solvents

This group includes **trichloroethylene (TCE), tetrachloroethylene (PCE), benzene, vinyl chloride**, and others. These contaminants are well known in contaminated groundwater and distribution contexts.

- **TCE:** sufficient evidence for **kidney cancer**, **non-Hodgkin lymphoma**, and **cardiac defects**. (atsdr.cdc.gov)
- **PCE:** sufficient evidence for **bladder cancer**. (atsdr.cdc.gov)

- **Benzene:** sufficient evidence for **leukemias** and **non-Hodgkin lymphoma**. (atsdr.cdc.gov)
- **Vinyl chloride:** sufficient evidence for **liver cancer**. (atsdr.cdc.gov)

F. Pesticides and herbicides

This group includes compounds such as **atrazine** and many other agricultural chemicals. Health effects vary by compound, but concerns include **endocrine disruption, reproductive effects, developmental effects, and some cancer associations**. WHO includes many pesticides in its chemical fact sheets, and EPA regulates multiple pesticide-related contaminants in drinking water. (US EPA)

G. PFAS ("forever chemicals")

PFAS are a large, evolving contaminant class. Current EPA summaries state that exposure to certain PFAS may lead to **reproductive effects, developmental effects in children, reduced immune response, endocrine interference, elevated cholesterol, and increased risk of some cancers including kidney and testicular cancer**. (US EPA)

H. Cyanobacterial toxins

These include **microcystins, cylindrospermopsins, saxitoxins, anatoxin-a analogues**. WHO added or updated guidance for several of these in recent guideline updates. Health effects include **acute poisoning**, with **liver toxicity** particularly central for microcystins; other cyanotoxins can affect gastrointestinal, neurological, and other systems. (Världshälsoorganisationen)

I. Emerging / unregulated contaminants

This bucket includes substances that may occur in drinking water and are under active review, such as some **pharmaceutical residues, endocrine-disrupting compounds, newer PFAS, perchlorate, 1,4-dioxane, microplastics**, and others depending on jurisdiction and evidence maturity. EPA explicitly maintains an unregulated contaminant monitoring and candidate-list process because this category is dynamic. (US EPA)

2) Key scientific papers and reviews by contaminant group

This is **not every paper ever published**. It is a curated list of the most useful starting set: landmark cohort studies, systematic reviews, meta-analyses, and authoritative technical reviews.

Microbial contamination

- **Ashbolt NJ (2004), "Microbial contamination of drinking water and disease outcomes in developing regions."** A highly cited review on waterborne pathogens and disease burden. (PMC)
- **WHO, "Microbial aspects" chapter in the Guidelines for Drinking-water Quality.** Not a journal article, but an authoritative synthesis of outbreak evidence and pathogen risk management.

Arsenic

- **Argos et al. (2010), "Arsenic exposure from drinking water, and all-cause and chronic-disease mortalities in Bangladesh (HEALS): a prospective cohort study."** A landmark prospective cohort study linking chronic arsenic exposure to increased mortality. (PubMed)
- Use this together with WHO/EPA toxicological summaries for the broader cancer and chronic-disease picture. (Världshälsoorganisationen)

Fluoride

- **NTP Monograph, "Fluoride Exposure: Neurodevelopment and Cognition."** The U.S. National Toxicology Program concluded with moderate confidence that higher fluoride exposure, such as drinking water above 1.5 mg/L, is associated with lower IQ in children. (ntp.niehs.nih.gov)
- **Taylor et al. (2025), "Fluoride Exposure and Children's IQ Scores."** A recent systematic review and meta-analysis in *JAMA Pediatrics*. (JAMA Network)
- **WHO background document on fluoride in drinking-water.** Important for dental and skeletal fluorosis evidence. (Världshälsoorganisationen)

Nitrate / nitrite

- **Ward et al. (2018), "Drinking Water Nitrate and Human Health: An Updated Review."** This is one of the most useful modern syntheses; it identifies the strongest evidence beyond infant methemoglobinemia as being for colorectal cancer, thyroid disease, and some adverse reproductive outcomes under specific conditions. (PMC)
- **Chambers et al. (2024), systematic review/meta-analysis on nitrate-nitrite and colorectal cancer.** Useful for the cancer-specific evidence base. (PMC)

Lead

- **Lee et al. (2022), "Childhood lead exposure is associated with lower cognitive functioning more than 50 years later."** Important for long-run consequences of childhood exposure, including exposure through drinking water. (PMC)

- Broader interpretation should still sit alongside established toxicology that no safe level of lead exposure in children is known. (Världshälsoorganisationen)

Chromium (especially Cr(VI))

- **Zhitkovich (2011), "Chromium in Drinking Water: Sources, Metabolism, and Cancer Risks."** A core review for the chromium-in-water literature. (PMC)
- **EPA IRIS Toxicological Review of Hexavalent Chromium (2024).** This is now one of the most authoritative evidence syntheses on oral Cr(VI) toxicity and carcinogenicity.

Manganese

- **Rodríguez-Barranco et al. (2013), systematic review and meta-analysis** on manganese and child neurodevelopment, cited by WHO as showing significant negative effects in most included studies. (Världshälsoorganisationen)
- **Schullehner et al. (2020), "Exposure to Manganese in Drinking Water during Childhood …"** useful for epidemiologic evidence linking water manganese with neurodevelopmental outcomes. (PMC)
- **Iyare (2019), review of manganese exposure from drinking water on children's cognition.** (ScienceDirect)

Uranium / radionuclides

- **Kurttio et al. (2002), "Renal effects of uranium in drinking water."** A landmark human study on uranium-associated kidney effects. (PMC)
- **WHO/EPA radiological drinking-water guidance** for the broader framework on radionuclide monitoring and health risk. (US EPA)

Disinfection by-products

- **Xie et al. (2025), review/meta-analysis on drinking-water disinfection by-products and bladder cancer.** Reports a statistically significant positive correlation between long-term exposure to chlorinated drinking water and bladder cancer. (ScienceDirect)
- **Freeman et al. (2022), "Disinfection By-Products in Drinking Water and Bladder Cancer."** Helpful for more recent epidemiologic evidence. (PubMed)
- **Meta-analysis review chapter on DBPs and cancer** gives the historical synthesis context. (pubs.acs.org)

VOCs / industrial solvents

- **EPA/ATSDR assessments for TCE, PCE, benzene, vinyl chloride.** These are not single cohort papers, but they are high-authority evidence syntheses on causation. (atsdr.cdc.gov)
- **National Research Council / contaminated-water epidemiology review** is useful for historical epidemiologic context for TCE/PCE community exposures. (ncbi.nlm.nih.gov)
- **Recent TCE review (2026)** summarizes the current scientific consensus on TCE-related cancers and neurological toxicity. (pubs.acs.org)

Pesticides / herbicides

- **ATSDR Toxicological Profile for Atrazine.** Useful official review of the human and animal evidence; notes slightly increased non-Hodgkin lymphoma risk among exposed farmers and suggestive evidence for some other cancers. (ncbi.nlm.nih.gov)
- **WHO Atrazine in Drinking-water background document.** Useful for guideline context and toxicology. (cdn.who.int)

PFAS

- **Fenton et al. (2020), "Per- and Polyfluoroalkyl Substance Toxicity and Human Health Review."** One of the best broad scientific reviews on PFAS toxicology and health outcomes. (PMC)
- **EPA PFAS human-health risk page.** Best current official synthesis of the major health endpoints linked to certain PFAS. (US EPA)
- For drinking-water-specific policy context, EPA's PFAS rulemaking and health-risk updates are important companion sources. (US EPA)

Cyanotoxins

- **Hitzfeld et al. (2000), "Cyanobacterial toxins: removal during drinking water treatment, and human risk."** A foundational review in the drinking-water context. (PMC)
- **EPA Health Effects Support Document for Microcystins (2015).** Strong technical synthesis for toxicology, epidemiology, and risk assessment. (US EPA)
- **WHO Microcystin-LR in Drinking-water background document.** Useful for classical toxicology and health effects framing. (Världshälsoorganisationen)

A **summary table for contaminant, source, health effects, WHO/EPA status, and key papers**.

Contaminant class	Example contaminants	Main known health effects	Key research papers / reviews
Microbial contaminants	Pathogenic bacteria, viruses, protozoa (*E. coli*, *Vibrio cholerae*, *Giardia*, *Cryptosporidium*, norovirus, hepatitis A)	Diarrhoea, cholera, dysentery, typhoid, hepatitis, acute gastrointestinal illness; potentially severe disease in children and immunocompromised people	**Ashbolt NJ (2004)** – *Microbial contamination of drinking water and disease outcomes in developing regions*; **WHO Guidelines for Drinking-water Quality** – microbial aspects (Världshälsoorganisationen)
Arsenic	Arsenic in groundwater	Skin lesions, skin cancer, bladder cancer, lung cancer, cardiovascular and chronic systemic effects	**Argos et al. (2010)** – *Arsenic exposure from drinking water and all-cause and chronic-disease mortalities in Bangladesh*; **WHO drinking-water guidance/reviews on arsenic** (Världshälsoorganisationen)
Fluoride	Fluoride in groundwater	Dental fluorosis, skeletal fluorosis; at higher exposure levels, evidence of neurodevelopmental harm in children	**NTP Monograph – Fluoride Exposure: Neurodevelopment and Cognition**; **Taylor et al. (2025)** – *Fluoride Exposure and Children's IQ Scores*; **WHO fluoride background documents** (Världshälsoorganisationen)
Nitrate / Nitrite	Nitrate, nitrite	Infant methemoglobinemia; evidence also links exposure with colorectal cancer risk and some	**Ward et al. (2018)** – *Drinking Water Nitrate and Human Health: An Updated Review*; **recent systematic reviews/meta-analyses on nitrate**

Contaminant class	Example contaminants	Main known health effects	Key research papers / reviews
		thyroid/reproductive concerns in certain settings	**and colorectal cancer** (Världshälsoorganisationen)
Lead	Lead from plumbing, service lines, fixtures	Neurodevelopmental harm in children, reduced IQ, behavioral impacts, cardiovascular and kidney effects	**Lee et al. (2022)** – *Childhood lead exposure is associated with lower cognitive functioning more than 50 years later*; WHO and EPA drinking-water guidance on lead (US EPA)
Chromium	Chromium, especially hexavalent chromium Cr(VI)	Gastrointestinal toxicity, liver and blood effects, developmental and reproductive concerns; oral carcinogenic concern for GI tract	**Zhitkovich (2011)** – *Chromium in Drinking Water: Sources, Metabolism, and Cancer Risks*; **EPA IRIS Toxicological Review of Hexavalent Chromium** (US EPA)
Manganese	Manganese in groundwater	Neurodevelopmental and behavioral effects, especially in children, at elevated exposure	**Rodríguez-Barranco et al. (2013)** systematic review/meta-analysis; **Schullehner et al. (2020)** childhood manganese exposure and neurodevelopment; WHO manganese review documents (Världshälsoorganisationen)
Cadmium	Cadmium	Kidney toxicity, bone effects	WHO drinking-water background documents; toxicological reviews used in guideline development (Världshälsoorganisationen)

Contaminant class	Example contaminants	Main known health effects	Key research papers / reviews
Mercury	Mercury	Neurological toxicity, especially developmental neurotoxicity	WHO drinking-water background documents; toxicological reviews used in guideline development (Världshälsoorganisationen)
Selenium	Selenium	Hair/nail changes, neurological and gastrointestinal effects at excess exposure	WHO drinking-water background documents and guideline fact sheets (Världshälsoorganisationen)
Copper	Copper from plumbing corrosion	Gastrointestinal irritation; possible liver toxicity at high exposure	EPA National Primary Drinking Water Regulations; WHO drinking-water guidance (US EPA)
Radiological contaminants	Uranium, radium, gross alpha emitters, beta/photon emitters	Increased cancer risk from radiation; uranium also linked to kidney toxicity	**Kurttio et al. (2002)** – *Renal effects of uranium in drinking water*; EPA radiological drinking-water regulations and guidance (US EPA)
Disinfectants	Chlorine, chloramine, chlorine dioxide	Irritation and chemical exposure concerns at elevated levels; regulated because they are necessary for microbial control but must be managed	EPA National Primary Drinking Water Regulations; WHO drinking-water chemical fact sheets (US EPA)
Disinfection by-products (DBPs)	Trihalomethanes (THMs), haloacetic acids (HAAs), bromate, chlorite	Long-term exposure linked especially with bladder cancer; some evidence for reproductive	**Freeman et al. (2022)** – *Disinfection By-Products in Drinking Water and Bladder Cancer*; **recent reviews/meta-analyses on**

Contaminant class	Example contaminants	Main known health effects	Key research papers / reviews
		and other chronic effects depending on compound	**DBPs and bladder cancer**; WHO THM fact sheets (Världshälsoorganisationen)
Volatile organic compounds (VOCs)	TCE, PCE, benzene, vinyl chloride, toluene, ethylbenzene	Cancer, liver toxicity, kidney toxicity, blood disorders, neurological effects depending on compound	**ATSDR / EPA toxicological assessments** for TCE, PCE, benzene, vinyl chloride; contaminated groundwater epidemiology reviews (US EPA)
Pesticides / herbicides	Atrazine, simazine, glyphosate-related compounds, others	Endocrine, reproductive, developmental, liver, or possible cancer effects depending on the chemical	**ATSDR Toxicological Profile for Atrazine**; **WHO Atrazine and pesticide drinking-water background documents** (US EPA)
PFAS	PFOA, PFOS, PFHxS, PFNA, GenX-related compounds and other PFAS	Developmental effects, immune effects, cholesterol changes, endocrine disruption, kidney/testicular cancer concerns for some PFAS	**Fenton et al. (2020)** – broad PFAS toxicity review; **EPA PFAS health-effects summary**; current EPA PFAS regulatory materials (US EPA)
Cyanobacterial toxins	Microcystins, cylindrospermopsins, saxitoxins, anatoxin-related toxins	Liver toxicity, gastrointestinal illness, neurotoxicity, acute poisoning depending on toxin	**Hitzfeld et al. (2000)** – cyanobacterial toxins and drinking water; **EPA Health Effects Support Document for Microcystins**; WHO cyanotoxin guidance (Världshälsoorganisationen)

Contaminant class	Example contaminants	Main known health effects	Key research papers / reviews
Emerging / unregulated contaminants	1,4-dioxane, perchlorate, pharmaceuticals, endocrine-disrupting compounds, microplastics, newer PFAS	Health effects vary widely; evidence is still developing for many of these contaminants	EPA unregulated contaminant and candidate-contaminant processes; compound-specific reviews needed case by case (US EPA)