What are safe exposure limits for PFAS compounds in drinking water and why the wide range of MCLs?

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Summary

- A Maximum Contaminant Level (MCL) is the amount of a substance that is allowed in public drinking water. Federal Maximum Contaminant Levels are produced by EPA. The EPA has not developed a MCL for any PFAS, but it did publish Health Advisories of 70 ppt for PFOS and PFOA in 2016. These are guidance values and are not federally enforceable or require monitoring of public water systems, however, they have been adopted by many states. Other states have developed their own standard or guidelines.
- The Unregulated Contaminants Monitoring Regulation (UCMR3), collected analytical data on 6 PFAS chemicals during 2013-2015, including PFOA and PFOS, from 4920 mostly large water supplies covering the majority of the population on public water systems. PFAS were detected in a fraction of 1% at ppt levels. UCMR5 has been initiated and it will analyze for 29 PFAS chemicals in all of the large systems as well as a greater number of smaller systems.
- The EPA and individual states may use similar methodology to develop MCLs and guidance values, but the resulting values often differ due to differing assumptions and opinions. Despite the variation in MCLs, each is designed to protect public health with sizable margins of safety.
- To date, eight states have developed MCLs or guidance values for some of the PFAS. For PFOS, the values range from 2 – 35 ppt, and for PFOA, the values range from 6.5 – 20 ppt. Some other states are in the process of developing MCLs or guidance values, and other states will simply use the guidance value of 70 ppt that EPA published. If a state establishes an MCL, it must be the same or lower than that set by the EPA.
- International values are over even a broader range covering several orders of magnitude. Having a plethora of different values can undermine public confidence in the state of the science, the objectivity of the processes and in the safety of their water.

What is an MCL and a Guidance Value?

A Maximum Contaminant Level (MCL) is the limit on the amount of a substance that is allowed in public water systems. A Federal MCL is developed by the United States Environmental Protection Agency (EPA) under the provisions of the Safe Drinking Water Act (SDWA). Individual states can also develop their own MCLs, but they cannot be less stringent that the EPA MCLs (e.g., they must be lower). Some states have developed their own MCLs that sometimes differ from EPA MCLs. Other states might develop MCLs for chemicals that do not have a federal MCL. Exceeding an MCL for some period of time does not mean that the water is not safe to drink. It means that the usually large margin of safety built into the MCL is somewhat smaller. EPA advises when the extent of exceedance of an MCL warrants avoidance of the water.

The SDWA includes a process that EPA must follow to identify and determine whether a national drinking water standard is warranted. Most substances sometimes detected in some drinking waters do not reach the point where a national drinking water regulation is needed. States can regulate contaminants of concern in their water systems due to more localized presence, such as from geologic presence. For a national regulation, EPA must consider whether 1) the chemical might cause health effects in humans, 2) the chemical is actually found in public water systems often enough and at levels that may be a concern for human health, and 3) that regulation of the chemical will actually reduce the potential health concerns. This process ensures that the appropriate chemicals are regulated, but it can take many years to complete.

After reviewing all the data, the regulatory agency may decide to regulate a specific chemical and then begin the rule making process to establish the MCL. In contrast, the regulatory agency may decide that either there isn't enough information to warrant a MCL or the information does not indicate that a MCL is necessary to protect health. In this situation, the EPA or the state can develop a health advisory (HA) or guidance value for the specific chemical. This provides valuable benchmark information for states and water suppliers with respect to whether corrective actions are appropriate. These HAs are sometimes inappropriately treated as MCLs by states or water suppliers. Rather they provide useful information for decision making with regard to appropriate actions.

Thus, the difference between a MCL and Health Advisory guidance value is that Federal MCLs are enforceable and require monitoring of public water systems.

Has EPA Established an MCL for PFAS?

Although EPA recently announced its intent to regulate some PFAS in drinking water[1], to date, EPA has not established a MCL for any PFAS. In 2016, EPA published drinking water health advisories for two PFAS – PFOS and PFOA. The Health Advisories for each and their sum were 70 ppt[2]. They incorporated appropriate margins of safety from the available toxicology data.

[1] https://www.epa.gov/newsreleases/epa-takes-action-address-pfas-drinking-water

[2] https://www.epa.gov/ground-water-and-drinking-water/drinking-water-health-advisories-pfoa-and-pfos

In the absence of a Federal MCL, several individual states have derived MCLs for several PFAS for their own particular state. This has resulted in a range of values and has caused confusion as to why the MCLs differ among states and differ from the EPA's health advisory. These differences can lead to significant disruptions and economic impacts.

How is an MCL or Guidance Value Established?

The EPA first develops the maximum contaminant level goal (MCLG). The MCLG is the maximum level of a contaminant in drinking water at which "no known or anticipated adverse effect on the health of persons would occur, allowing an adequate margin of safety". MCLs are based upon the MCLGs but take into account technology and costs; MCLs are as close as is feasible to the MCLG as the technology and costs allow. EPA states the MCLs are safe and protective of public health.

MCLGs and health advisories are developed using similar but not necessarily identical methodology. In general, this includes consideration of potential health effects and exposure to the chemical via drinking water. A variety of toxicology studies are utilized to determine whether a chemical has the potential to cause health effects in humans. Generally, the studies are conducted in laboratory animals and these studies assess a variety of potential effects such as cancer or effects on the liver or kidney, the reproductive system, or the developing fetus. These are referred to as toxicology studies. Occasionally, there may also be epidemiological studies of people that may have been exposed to the chemical of interest. The EPA MCLGs (aspirational goals) are determined differently for chemicals that cause cancer by a genotoxic process versus chemicals that cause other kinds of health effects, usually referred to as noncancer effects. For PFAS, EPA concluded that establishing the low exposure MCLs or guidance values based on noncancer effects will also be protective of possible cancer concerns since they do not cause cancer by a genotoxic process. For genotoxic carcinogens, the MCLG is conservatively set at zero as an aspirational goal, (not 0) because it is not quantifiable) and the MCL is set at the lowest level that is technically and economically feasible, and EPA concludes that these MCLs are safe and protective of public health.

The first step in the development of a MCLG or health advisory is to evaluate the toxicology studies to determine whether the chemical actually causes a health outcome, and if so, how much of the compound is required and for how long. This is known as the hazard and dose-response assessment. As shown in the Figure 1, the incidence and/or severity of a particular health effect increases as the amount of exposure to the chemical increases. The minimum amount of chemical that is required to elicit a response in animals under the test conditions, is called the "lowest-observed – adverse- effect- level" (LOAEL) and the maximal amount of chemical that does not cause the health outcome is called the no- observed-adverse-effect-level" (NOAEL). Sometimes, the data can be statistically modeled to refine the estimates of the LOAEL and NOAEL to calculate a benchmark dose (BMD or BMDL), which is typically the dose at which there is believed to be a ten percent increase in the risk of the health outcome. In addition, more sophisticated modeling may be done to simulate the metabolism and toxicity mechanisms relative amounts of a chemical inside the body of the animal model and how that would extrapolate to a human; this is known as pharmacokinetic modeling. The values of the NOAEL, LOAEL, BMD or BMDL are referred to as the Point of Departure (POD).

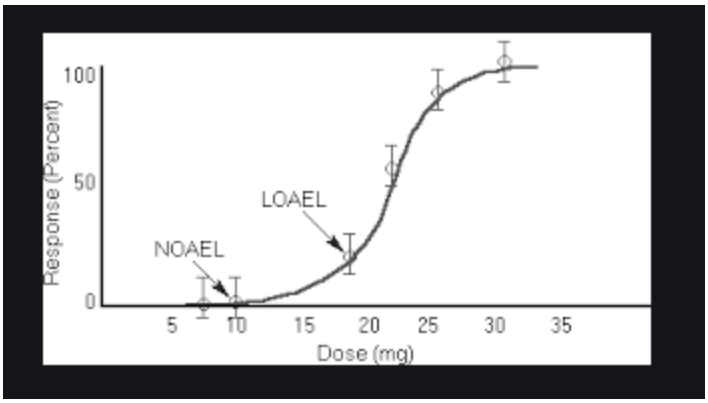

Figure 1. Example of a dose-response curve with the NOAEL and LOAEL

The second step in the development of a MCL or guidance value is the development of a Reference Dose. A Reference Dose (RfD) is defined as the daily dose to humans which is likely to be without appreciable risk of deleterious effects over a lifetime. It is calculated as:

$$\text{Reference Dose (RfD)} = \frac{\text{Point of Departure (POD)}}{\text{Uncertainty Factors}}$$

The uncertainty factors (UF) are used to account for a variety of considerations including differences among humans, differences between humans and animal models, whether a study established a NOAEL, whether the toxicology study used to establish the POD represents a lifetime exposure (chronic) and whether there are any substantial deficiencies in the health effects data. The judgmental uncertainty factors generally have a value of 10, and if the information is sufficient the value can be decreased generally to a value of 3 or 1, or in rare circumstances the values could be increased or decreased. The uncertainty factors considered are:

1) Human variability – intraspecies UF
2) Animal to human variability – interspecies UF
3) LOAEL to NOAEL extrapolation
4) Less than lifetime (chronic) exposure
5) Deficiencies in the database – database UF

The uncertainty factors are multiplied to increase the conservatism of the resulting value. For example if the above factors were: 10 x 10 x 10 x 3 x 1 in this example would be 3000. Typically, the derived factors are 1000 or less because higher values would indicate significant limitations in understanding the toxicology of the substance regarding possible risk. The evaluation of the toxicological data and the development of the RfD involves considerable scientific judgment so it is not unusual that different groups produce different values. It is not a "cookbook" and different scientists may come to different conclusions on what the appropriate POD is and what the value of the various uncertainty factors should be. In addition, RfDs reflect the data available at the time of derivation. For these reasons, it more appropriate that a recognized (perhaps international) expert group is assembled to provide a single value, that is subjected to external peer review before acceptance. The World Health Organization provides an international perspective on values of contaminants to assure safe drinking water, in their Guidelines for Drinking Water Quality. It

should be understood that risk assessors constitute part of the regulatory development process, they are not the decision makers.

Table 1. Hypothetical Example of a RfD Derivation by Two groups

	Example 1	Example 2
POD	Increased liver weight from mouse study; NOAEL = 1 mg/kg/day	Decrease immune function from mouse study; LOAEL = 3 mg/kg/day
Intraspecies UF	10	10
Interspecies UF	10	10
LOAEL/NOAEL UF	1	10
Chronic UF	1	1
Database UF	1	3
RfD (mg/kg/day)	0.01	0.001

The next two steps in the development of a MCLG or guidance value involve consideration of exposure to drinking water. This includes determination of the daily water consumption and the relative source contribution which refers to the percentage of exposure that is due to drinking water as opposed to other exposures like food or air. Thus, the MCLG or guidance value is calculated as:

$$\text{MCLG or Health Advisory(mg/L)} = \frac{\text{RfD (mg/kg/day) X Relative Source Contribution (\%)}}{\text{Water ingestion rate (L/kg/day}}$$

The choice of the specific water ingestion rate can also vary among decision makers. The default drinking water daily consumption value is usually 2 liters per day, However, the average consumption in the US is about 1 liter per day. Typically, the MCL will be established for the target population. This will be determined by what woman – 0.054 L/kg/day; and 3) child, 0-1 years old – 0.175 L/kg/day. These can vary by country, location, climate, and physical activity. In the hypothetical example in Table 1, the liver weight effect used by EPA is an effect that is observed in adult mice. Thus, it would use a water ingestion rate that is typical for adults. In contrast, the decrease in immune function used by the alternate group is an effect that was observed in mice who were exposed via nursing. Therefore, it decided to use a water ingestion rate that is typical for a lactating woman. Examples of water ingestion rates for target populations include: 1) adult – 0.029 L/kg/day; 2) lactating woman – 0.054 L/kg/day; and 3) child, 0-1 years old – 0.175 L/kg/day.

The relative source contribution is the percentage of exposure to the chemical that comes from drinking water as opposed to other exposures from all other pathways like food or consumer products. The sum of all the sources of exposure (i.e., drinking water, food, consumer products etc.) should not exceed the RfD. If the sources of the chemical are well known, it may be possible to actually calculate a representative relative source contribution from drinking water. In the absence of such information, a default value is used. Again, the value used may differ among decision makers. Typically, the defaults are 10 or 20% if drinking water is not likely to be a major contributing source, or 80% if drinking water is a major source.

Thus, there are many possibilities in the development of a MCLG that can lead to differing scientific conclusions and therefore different MCLGs for the same chemical. These include, choice of the most sensitive health effect and uncertainty factors used to calculate the RfD, choice of target population and the resulting water ingestion rate, and choice of the relative source contribution. Almost all MCLGs are designed to be health protective with several orders of magnitude of safety built into them.

What are "Safe" Levels of Various PFAS in Drinking Water?

The EPA has not developed a MCL yet for any PFAS. They have published a Health Advisory in 2016 for two PFAS, PFOS and PFOA which were considered to be the predominant PFAS chemicals in the environment, drinking water is one source. Their uses in many consumer products have been curtailed in the early 2000's and exposure levels had declined since then. However, some ground waters have been contaminated and the chemicals are persistent in those locations. Some states will simply follow the Health Advisory. Other states have developed, or are in the process of developing, their own MCLs or guidance values. Thus, at this time there is no universal or international agreement on what the most appropriate MCLs or guidance values for various PFAS are. Some examples of MCLs that have been developed by some states are provided in Table 2. As can be seen above, relatively minor differences in assumptions can result in different guidance values. The state guideline values range from 5.1-35 ng/L (a 7-fold range) for PFOA and range from 6.5-20 ng/L for PFOS (a 3-fold range).

In addition, there are several values produced by other countries. For example, the 2019 Canadian Guidelines are: 600 ppt for PFOS and 200 ppt for PFOA. The United Kingdom declined to establish a health-based guidance but recommended that if a water supply exceeded 100 ppt some type of action should be considered. The World Health Organization is preparing their recommendations in their Guidelines for Drinking-water Quality that will be released shortly.

Table 2. Examples of Guidance Values for Various PFAS (ppt or ng/L)

	Perfluorooctanoic acid (PFOA)	Perfluorooctane sulfonic acid (PFOS)	Perfluorononanoic acid (PFNA)	Perfluorohexane sulfonic acid (PFHxS)	Type of Guidance Value
EPA	70	70			Health Advisory
CA[3]	5.1	6.5			Notification Level
MA[4]	20	20	20	20	MCL
MI[5]	8	16	6	51	MCL
MN[6]	35	15		47	Guidance Value

[3] https://www.waterboards.ca.gov/publications_forms/publications/factsheets/docs/pfoa_pfos_guidelines_faq_factsheet.pdf

[4] https://www.mass.gov/service-details/per-and-polyfluoroalkyl-substances-pfas-in-drinking-water

[5] https://www.michigan.gov/som/0,4669,7-192-47796-534660--,00.html

[6] https://www.health.state.mn.us/communities/environment/hazardous/topics/pfcs.html#safelevels

NH[7]	12	15	11	18	MCL
NJ[8]	14	13	13		MCL
NY[9]	10	10			MCL
VT[10]	20	20	20	20	MCL

[7] https://www.natlawreview.com/article/new-hampshire-adopts-aggressive-pfas-drinking-water-bill

[8] https://www.nj.gov/health/ceohs/documents/pfas_drinking%20water.pdf

[9] https://www.health.ny.gov/environmental/water/drinking/docs/water_supplier_fact_sheet_new_mcls.pdf

[10] https://dec.vermont.gov/water/drinking-water/water-quality-monitoring/pfas#:~:text=On%20March%2017%2C%202020%2C%20a,water%20monitoring%20frequencies%20for%20PFAS.&text=The%20sum%20of%20these%20five,part%20per%20trillion%20(ppt)

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