

What does ppm or ppb mean?

Parts per million also can be expressed as milligrams per liter (mg/L). This measurement is the mass of a chemical or contaminate per unit volume of water. Seeing ppm or mg/L on a lab report means the same thing.

The University of Minnesota provides some other analogies that may help you visualize the scale involved with ppm and ppb. One ppm is like:

- one inch in 16 miles,
- one second in 11.5 days,
- one minute in two years, or
- one car in bumper-to-bumper traffic from Cleveland to San Francisco.

Is 1 mg/L equal to 1 ppm?

Metric system units go in steps of 10, 100, and 1,000. For example, a milligram is a thousandth of a gram (moving the decimal point three places to the left) and a gram is a thousandth of a kilogram (again a difference of three places to the left on the decimal point). Thus, a milligram is a thousandth of a thousandth, or a millionth of a kilogram moving the decimal point six places.

1,000.	kilogram	kg	10 ³
100.0	hectogram	hg	10 ²
10.00	dekagram	dag	10 ¹
1.000	gram	g	-
0.1	decigram	dg	10 ⁻¹
0.01	centigram	cg	10 ⁻²
0.001	milligram	mg	10 ⁻³
0.000,001	microgram	µg	10 ⁻⁶

So, a milligram is one ppm of a kilogram; therefore, one ppm is the same as one milligram per kilogram.

- milligram/kilogram or
- mg/kg or
- 0.001/1,000 or
- 10⁻³/10³

One milligram in a kg is 1 ppm (by mass). One liter (L) of pure water at 4°C and 1 standard atmosphere pressure weighs exactly 1 kg, so 1 mg/L is 1 ppm. Another way to say it is a liter of water weighs 1,000 grams or 1 million milligrams. Therefore, 1 mg in 1 liter is 1 mg in 1 million milligrams or 1 part per million.

What is ppb?

An even smaller concentration measurement is parts per billion (ppb). One ppb is one part in 1 billion. One drop of ink in one of the largest tanker trucks used to haul gasoline would be an ink concentration of 1 ppb. It is important to know the difference between ppm and ppb.

A common mistake is reporting a concentration as ppm when it is really ppb. This is a big difference, such as the difference between \$1 and \$1,000. As a ppm is equal to mg/L, then ppb is equal to microgram per liter (µg/L). A µg/L is 1 thousandth of a mg/L. Most water analysis will have the concentration reported in ppm or mg/L and/or ppb or µg/L. When reading the lab results, be careful as they could switch the units back and forth between contaminants. For example:

- 1 ppm = 1 mg/L =
1/1 million = 0.000001
- 1 ppb = 1 µg/L =
1/1 billion = 0.000000001

Some labs will report their analysis in ppb instead of ppm. Labs will do this to have the results in whole numbers instead of a bunch of zeros with a number on the end, because some people think that whole numbers are simpler to read and understand. EPA uses ppm in most of their literature for the National Primary Drinking Water Standards.



By **Zane Satterfield, P.E.**
NESCE Engineering Scientist

What is ppm and what does it mean?

Most contaminants are expressed as parts per million (ppm). This means that the concentration of a particular substance is very low even though the regulatory agency may consider it a significant amount.

One ppm is 1 part in 1 million or the value is equivalent to the absolute fractional amount multiplied by one million. A better way to think of ppm is to visualize putting four drops of ink in a 55-gallon barrel of water and mixing it thoroughly. This procedure would produce an ink concentration of 1 ppm. Would that be safe to drink? Well, that depends on what the ink is made of, and what was in the barrel before the water. ▶

Four drops of ink in one 55-gallon barrel of water (mixed thoroughly) would produce an ink concentration of 1 ppm.

Below are some examples of how important it is to pay attention to the units or the concentration amount.

Take the inorganic chemical arsenic, for example. On January 23, 2006, the maximum contamination level (MCL) will be 0.010 ppm or mg/L. The MCL also can be stated as 10 ppb or $\mu\text{g/L}$. It is important to get the units straight because it could possibly mean the difference between the system violating the MCL or not.

Another inorganic chemical, beryllium, has an MCL of 0.004 ppm or mg/L, where, again, the MCL can also be stated at 4 ppb or $\mu\text{g/L}$. If units are not correct, it could mean the possibility of intestinal lesions for the system's customers. The point is: Be sure of the units. If you are more comfortable seeing ppm instead ppb, request that the lab report the results in the units you want. If the results are going to be reported in the consumer confidence report (CCR), be sure to check with your state primacy agency. They may require a certain unit to be used. Therefore, be careful when converting from one unit to another. Moving the decimal the wrong way can make all the difference.

Because a ppb is a much lower concentration, other analogies would be:

- one silver dollar in roll stretching from Detroit to Salt Lake City,
- one sheet in a roll of toilet paper stretching from New York to London,
- one second in nearly 32 years, or
- one pinch of salt in 10 tons of potato chips.

Why are ppm and ppb important measures?

These measurements refer to exposure standards and guidelines created to protect the public from harmful substances that can cause serious health effects. Exposure standards and guide-

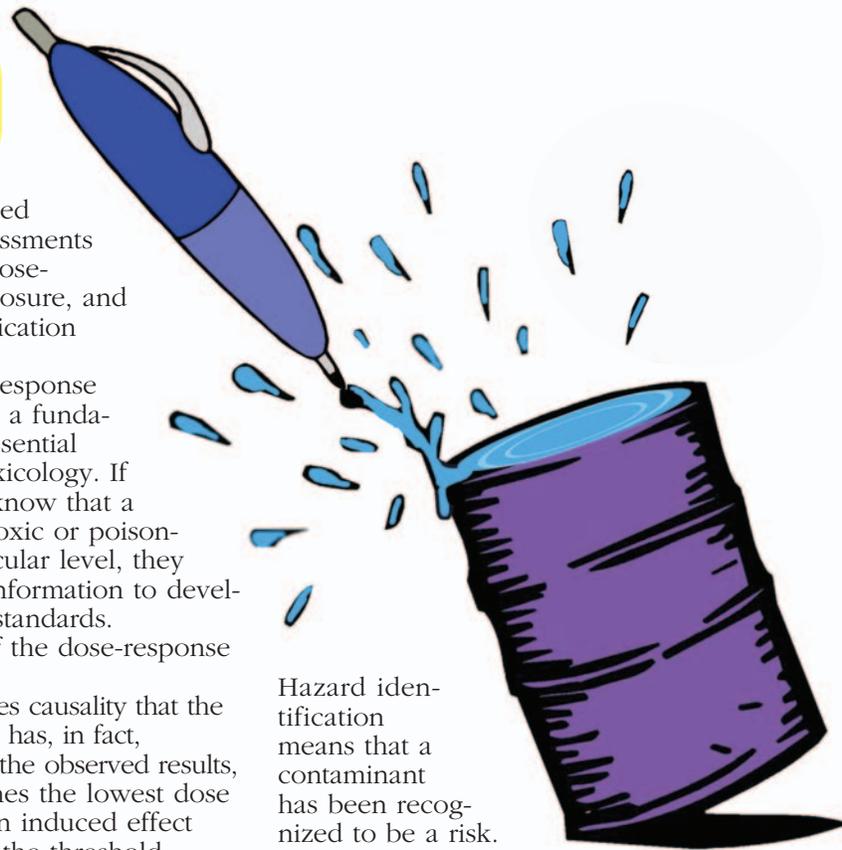
lines are created from risk assessments that include dose-response, exposure, and hazard identification assessments.

The dose-response relationship is a fundamental and essential concept in toxicology. If toxicologists know that a substance is toxic or poisonous at a particular level, they can use this information to develop exposure standards. Knowledge of the dose-response relationship:

- establishes causality that the chemical has, in fact, induced the observed results,
- determines the lowest dose where an induced effect occurs—the threshold effect, and
- verifies the rate at which injury builds up—the slope for the dose response.

The threshold effect refers to the point where the body's ability to detoxify itself has been exceeded. The slope for the dose response refers to the predictability of how toxic a substance will be at specific doses to a wide range of people. Major differences may exist not only in the point at which the threshold is reached in some people but also in the percent of the population responding to small changes in the dose.

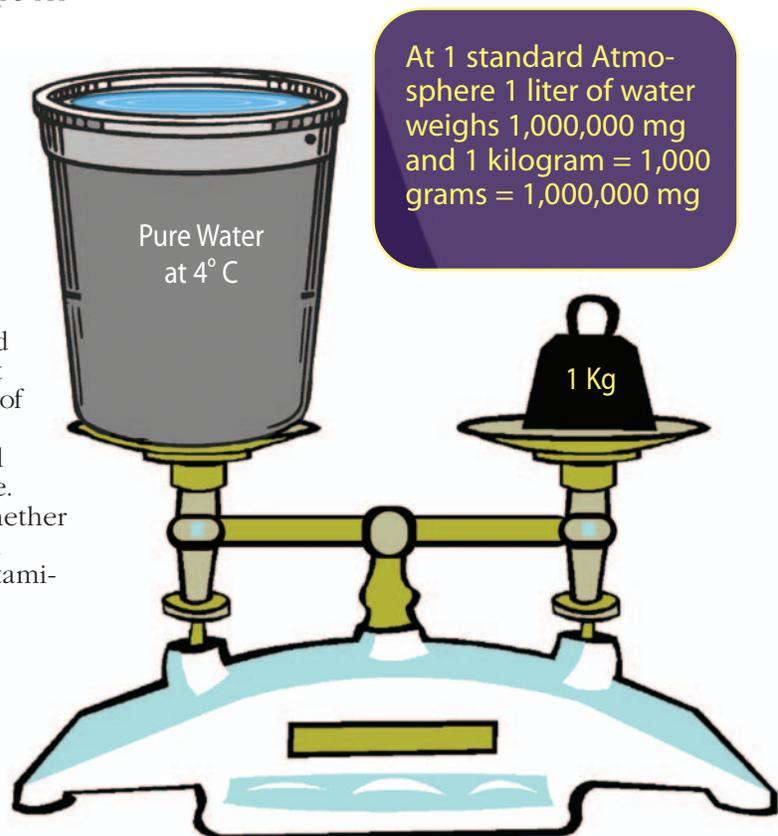
To uncover whether people have been exposed to a contaminant, researchers conduct tests to determine if a contaminant is present and at what levels.



Hazard identification means that a contaminant has been recognized to be a risk.

What are some other units that might be seen on a water analysis?

Other units or concentration that may be seen on a lab report besides ppm, mg/L, ppb, or $\mu\text{g/L}$, might be color units, threshold



At 1 standard Atmosphere 1 liter of water weighs 1,000,000 mg and 1 kilogram = 1,000 grams = 1,000,000 mg

One ppb is like adding a pinch of salt to a 10 ton bag of potato chips.



odor number, pH index, corrosive index number, and, for radionuclides, the units pCi/L [picocuries per liter] and millirems per year are used.

Pronounced py-coe-cure-ee, pCi/L is a measurement of radioactivity in water. Radioactivity is commonly measured in picocuries (pCi). This unit of measure is named for the French physicist Marie Curie, who was a pioneer in the research of radioactive elements and their decay. One pCi is equal to the decay of about two radioactive atoms per minute.

Because the level of radioactivity is directly related to the number and type of radioactive atoms present, radon and all other radioactive elements are measured in picocuries. A picocurie is 1 million millionth, or a trillionth, of a curie, and represents about 2.2 radioactive particle disintegrations per minute. One curie equals 3.7×10^{10} disintegrations per second.

A millirem is 1 thousandth (10^{-3}) of a Roentgen Equivalent Man (rem) and a rem is a radioactivity unit—a measure of radioactivity, which is the dosage of ionizing radiation that will cause the same amount of injury to human tissue as 1 roentgen of X-rays. The name Roentgen comes from Wilhelm Conrad Röntgen.

Röntgen's name is chiefly associated with his discovery of X-rays. In 1895 he

was studying the phenomenon accompanying the passage of an electric current through a gas of extremely low pressure. To give you a better idea of how much a millirem is a chest x-ray is about 6 millirem (mrem). The rem is the unit of absorbed dose measuring the energy imparted by ionizing radiation to matter. The Curie is not a measure of dose; it merely states the amount of radioactive disintegrations per unit time (radiation activity).

Using these analogies may help in understanding how the measurements ppm and ppb are used in water system laboratory reports.

For more information about how to decipher a lab report, call the National Environmental Services Center at (800) 624-8301 and ask for a technical assistant.

References:

The American Heritage Dictionary of the English language; fourth edition
www.bartleby.com/61/34/M0303450.html

The Cardinal Surveys Company
www.cardinalsurveys.com/glos.htm

The Free Dictionary dot com
www.thefreedictionary.com/REM

Informationsphere.com
www.informationphere.com/html/493.htm

Kimball's Biology Pages users.rcn.com/jkim
ball.ma.ultranet/BiologyPages/P/Ppm.html

Michigan State Department of Environmental Quality
www.michigan.gov/deq/0,1607,7-135-3310_4104_4196-10588--,00.html

Michigan State University Extension
www.msue.msu.edu/msue/imp/mod02/01500585.html

The National Safety Council Radiation
www.nsc.org/issues/rad/exposure.htm

The NOBEL e-MUSEUM
www.nobel.se/physics/laureates/1901/rontgen-bio.html

University of Minnesota Web site
www.seagrant.umn.edu/water/report/help/fulinformation/concentrations.pdf

The University of the West Indies, Chemistry Department, Dhanial De Lloyd
delloyd.50megs.com/photo.html

Water on the Web—understanding
www.nrri.umn.edu/wow/under/units.html

Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Parts_per_million



One ppb is like one sheet in a roll of toilet paper stretching from New York to London.

Zane Satterfield came to the National Environmental Services Center from the West Virginia Bureau of Public Health, where he worked as a system inspector. He also has worked for the Fairmont, West Virginia, engineering office, gaining valuable experience with water and wastewater treatment.



Julie Black has been the graphic designer of *On Tap* for more than three years. She also moonlights as a writer/photo journalist for an online magazine.

