

CONVERSIONS

All concentrations are measured in:

milligrams per liter (mg/l)

micrograms per liter ($\mu\text{g/l}$)

To convert between the two:

$1,000 \mu\text{g/l} = 1 \text{ mg/l}$

Also used to measure concentration are the units parts per billion (ppb) and parts per million (ppm). For general purposes, one can use the following very simple conversion:

$1 \text{ ppb} \approx 1 \mu\text{g/l}$

$1 \text{ ppm} \approx 1 \text{ mg/l}$

To convert TDS to electrical conductivity (a measure of salinity):

The TDS concentration in mg/l is approximately 65 percent of the electrical conductivity value in $\mu\text{S/cm}$ or in $\mu\text{mho/cm}$. For example:

$65 \text{ mg/l} \approx 100 \mu\text{mho/cm}$

$130 \text{ mg/l} \approx 200 \mu\text{mho/cm}$

$260 \text{ mg/l} \approx 400 \mu\text{mho/cm}$

$520 \text{ mg/l} \approx 800 \mu\text{mho/cm}$

$650 \text{ mg/l} \approx 1 \text{ mmho/cm}$

are more cations and anions in the water. With more ions in the water, the water's electrical conductivity (EC) increases. By measuring the water's electrical conductivity, we can indirectly determine its TDS concentration. At a high TDS concentration, water becomes saline. Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA secondary drinking water guidelines). Water with a TDS above 1,500 to 2,600 mg/l (EC greater than 2.25 to 4 mmho/cm) is generally considered problematic for irrigation use on crops with low or medium salt tolerance.

Except for natural organic matter originating from topsoils, all of these naturally occurring dissolved solids are *inorganic* constituents: minerals, nutrients, and trace elements, including trace metals. In most cases, trace elements occur in such low concentrations that they are not a threat to human health. In fact many of the trace elements are considered essential for the human metabolism. In Europe, water from springs and wells with certain levels of trace elements has long been considered a remedy for ailments. Popular health spas usually are located near such areas. High concentrations of trace metals can also be found in ground water near contaminated sources, however, posing serious health threats. Some trace constituents that are associated with industrial pollution, such as arsenic and chromium, may also occur in completely pristine ground water at concentrations that are high enough to make that water unsuitable as drinking water.

Microbial matter is also a natural constituent of ground water. Just as microbes are ubiquitous in the environment around us, they are very common in the subsurface, including ground water. Hydrogeologists increasingly rely on these, for instance, for subsurface bioremediation of contaminated ground water.

Human activities can alter the natural composition of ground water through the disposal or dissemination of chemicals and microbial matter at the land surface and into soils, or through injection of wastes directly into ground water. *Groundwater pollution* (or *groundwater contamination*) is defined as an undesirable change in groundwater quality resulting from human activities (for more information on nonpoint source pollution from agricultural activities, see *Nonpoint Sources of Pollution in Irrigated Agriculture* [UC ANR Publication 8055]).

The EPA's drinking water program (<http://www.epa.gov/ogwdw/>) defines acceptable levels of both inorganic and organic groundwater constituents and of microbial matter, as well as other groundwater quality factors.

Groundwater pollution works differently from surface water pollution, although they have many sources in common, such as fertilizers, pesticides, and animal wastes. Several important concepts should be kept in mind:

1. Unlike surface water, ground water does not typically flow toward a single outlet at the topographic bottom of the watershed, where the cumulative effect of watershed pollution and of improvements in watershed management can be directly measured. Groundwater discharge depends on topography (mountainous, hilly, or flat), hydrogeology (confined or unconfined aquifers, fractured rock or sediments, aquifer geometry), the sources of groundwater recharge

(precipitation; percolation of irrigation water; seepage from streams, lakes, and canals), and the amount of ground water pumped in wells. Groundwater discharge may be exclusive to wells that are distributed throughout a given watershed or groundwater basin, or it may discharge to down-gradient stream segments and lakes, springs, or (via the underground) directly to neighboring groundwater basins.

Of most interest to us is the effect of farm practices on groundwater pollution in wells (irrigation wells, domestic wells, municipal wells) and on groundwater quality in seepage to streams. As we consider the link between groundwater sources and groundwater uses, we can look at this in two ways:

- *Farmer's view.* From the point of view of a farmer whose water is percolating from the farm into ground water, the main concern is one of *stewardship*, protection of water quality in the percolating waters that recharge the ground water. This water will travel to many destinations (wells, streams, and lakes) nearby and, potentially, far away, and may impact many different users (domestic water users, irrigation water users, stream water users).
- *User's view.* From the perspective of water users (including farmers), the main concerns are about *assessment* and *protection*: the quality of water in the well, spring, or stream, and who it is whose activities have an impact on it. Ground water that is pumped from someone's well or ground water discharging into springs and streams may have originated nearby or may have traveled several miles, or it may be a mix of both. It generally has many sources. A careful, professional hydrogeologic assessment is typically necessary to determine the extent of the exact source area of these groundwater discharges. Depending on the depth and pumping rate of the well and depending on local hydrogeologic conditions, the size of the source area may range from a few acres to many tens of square miles, and it often includes many potential nonpoint and point sources of groundwater pollution (see the California Department of Health Services *Drinking Water Source Assessment and Protection Program* (<http://www.dhs.ca.gov/ps/ddwem/dwsap/DWSAPindex.htm>)).

2. The most prevalent forms of groundwater pollution from nonpoint sources are salt and nitrate contamination, which adversely affect approximately 10 to 15 percent of California's water wells, followed by pesticide and industrial contamination. Pathogens are also frequently detected in ground water. These contaminants, often associated with septic systems and animal wastes, are transported by water percolating from the soil to the water table, where they enter the ground water. The degree of groundwater pollution depends on a number of factors:

- *NPS sources.* The number and intensity or strength of NPS pollution activities within the source area of a well or a spring. A large number of low-grade NPS pollution sources may have a cumulative effect similar to that of a few more-intense NPS pollution sources.
- *Percolation rate.* The rate of percolation from the land surface to ground water. A significant amount of chemicals or pathogens may reach ground water when the water percolation rate is high.
- *Natural attenuation.* The ability of the soil or aquifer to retain or degrade the chemical before it reaches a well, spring, stream, or lake. The more a chemical is degraded or retained in the subsurface, the less likely it will be to reach a nearby well or stream.

3. Groundwater pollution occurs on a different time scale than surface water pollution. Ground water naturally flows at a speed that may range from a few tens of feet per year in poorly producing aquifers to a few thousand feet per year in very productive aquifers. In very sandy or gravelly aquifers and in some highly porous or cavernous volcanic and karstic aquifers, groundwater speed may be 10,000 feet (roughly 2 miles) per year or more. Nonpoint source pollution therefore does not typically appear in domestic or irrigation wells until years or even decades after it was released from its source. By the same token, groundwater cleanup takes a matter of years or decades, during which expensive treatment methods must be applied to render the ground water useable, especially if it is used as drinking water. The large time spans involved in groundwater pollutant transport must be kept in mind when assessing groundwater pollution sources and defining monitoring programs.
4. As with surface water pollution, there is a large natural variability in the generation and fate of groundwater NPS pollution. As a result, concentrations of NPS pollutants typically vary significantly from well to well, making it difficult to delineate the contamination plumes.

Whether contaminant concentrations change quickly over time is a function of the well type. Large production wells (municipal wells or irrigation wells) mix water from a large cross-section of the aquifer and concentrations stay relatively stable over periods of months to years. Small domestic wells and monitoring wells that intersect only short thicknesses of an aquifer may vary significantly in pollutant concentrations over a period of less than 6 months, particularly if a strong but variable source is nearby.

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Protecting Groundwater Quality in Citrus Production, publication 21521

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