Blending Water from Wells

Drinking water pumped from the ground or from surface supplies such as rivers is often contaminated and needs to be purified before it is consumed. In the western United States, arsenic is present in many groundwater supplies. Arsenic is dissolved into groundwater from naturally occurring minerals or ores. It can also be introduced into water sources from industrial sources.

Arsenic is tasteless and odorless. Despite this innocuous appearance, it has been linked to several form of cancer. Long term exposure to arsenic leads to other severe effects such as thickening and discoloration of the skin, stomach pain, nausea, vomiting, diarrhea, numbness in hands and feet, partial paralysis, and blindness. In 2006, new federal standards went into effect that dropped the maximum contaminant level (MCL) from 50 parts per billion to 10 parts per billion.

This new standard resulted in many communities having water systems that did not meet the required MCL. These water systems were required to purify their drinking water using several existing technologies. Many of these technologies are expensive. The Arsenic Treatment Technology Handbook published by the Environmental Protection Agency

estimates that an arsenic treatment system for a well producing 2 to 3 million liters of water per day can cost as much as $1 million. Many water systems may have several wells that require treatment compounding costs even more. The initial cost is not the only prohibitive cost to consider. Operating and maintaining an arsenic treatment system can cost more than $100,000 annually. These costs, as well as the disposal of arsenic collected by the treatment systems, lead many communities to seek less expensive options for purifying drinking water.

An option that many communities adopt is blending. If a community has another well (or several wells) that falls beneath the federal standard of 10 part per billion, they may decide to abandon wells that fall above the standard. If these wells do not provide enough capacity for the water system, it may be possible to blend the water with water from the contaminated well to yield water with an arsenic level of 10 parts per billion or less. For instance, suppose we blend 750,000 liters of water containing 5 parts per billion of arsenic with 250,000 liters of water containing 15 parts per billion. We can calculate the amount of arsenic in each volume of water by understanding the meaning of parts per billion.

Contaminant levels are usually given in parts per billion (ppb) or parts per million (ppm). Since there are 1 billion micrograms (μg) in 1 kilogram (kg), a microgram is 1 part per billion of a kilogram. One liter (L) of pure water at 4 ºC and 1 standard atmosphere pressure weighs exactly 1 kilogram. This means that a contaminant level in water of 1 part per billion is

$$1\ \text{ppb} = \frac{1\ \mu\text{g}}{1\ \text{kg}} = \frac{1\ \mu\text{g}}{1\ \text{L}}$$

Similarly, a contaminant level in water of 1 part per million is

$$1\ \text{ppm} = \frac{1\ \text{mg}}{1\ \text{kg}} = \frac{1\ \text{mg}}{1\ \text{L}}$$

Note the difference in units in the numerator. Since a microgram is a thousand times smaller than a milligram, a concentration of 1 ppb is a thousand times smaller than 1 ppm.

We can use the fact that 1 ppb is equal to 1 μg per liter to calculate the amount of arsenic in 750,000 liters of well water with an arsenic concentration of 5 ppb:

$$(750{,}000 \text{ liters})\left(\frac{5\ \mu\text{g}}{\text{liter}}\right) = 3{,}750{,}000\ \mu\text{g} = 3.75 \text{ grams}$$

The prefix μ or micro is equivalent to a factor of 10^{-6}. The amount of arsenic in 250,000 liters of well water with an arsenic concentration of 15 parts per billion is

$$(250{,}000 \text{ liters})\left(\frac{15\ \mu\text{g}}{\text{liter}}\right) = 3{,}750{,}000\ \mu\text{g} = 3.75 \text{ grams}$$

Because of the higher concentration in this amount of water, a smaller volume of water contains the exact same amount of arsenic.

If we combine these two volumes of water, we get a total amount of $750,000 + 250,000 = 1,000,000 \text{ liters}$ of contaminated water with a total volume of $3,750,000 + 3,750,000 = 7,500,000 \ \mu\text{g}$ of arsenic. If we divide the total amount of contaminant by the total amount of contaminated water, we find the fraction of the total volume that is arsenic:

$$\frac{\text{Total amount of arsenic}}{\text{Total amount of contaminated water}} = \frac{7,500,000 \ \mu\text{g}}{1,000,000 \text{ liters}} = 7.5 \text{ ppb}$$

Remember, micrograms per liter are the same as parts per billion. This combination of water yields a blend that is below the federal standard. The concentration of contaminant has been diluted to an acceptable level.