What are Iowa's Statewide Groundwater Standards and How are they Determined?

Chapter 137 of the Iowa DNR voluntary cleanup rules prescribes statewide standards (SWSs) for groundwater. Two classes of statewide groundwater standards are prescribed: protected groundwater sources and non-protected groundwater sources. The two classes are distinguished by the hydraulic conductivity (K) of the aquifer and the naturally occurring total dissolved solids (TDS) content. In simple terms, groundwater in a useable aquifer ($K \geq 0.44$ m/day, TDS < 2,500 mg/L) has a higher level of protection than groundwater that is not likely to be used ($K < 0.44$ m/day, TDS $\geq$ 2,500 mg/L). Most of the following discussion addresses SWSs for groundwater in a protected groundwater source, although non-protected groundwater SWSs are discussed near the end.

There is a hierarchy for applicable SWSs for groundwater contaminants. If the contaminant has an enforceable drinking-water standard (Maximum Contaminant Level or MCL), this standard is used. If a contaminant does not have an MCL, the lifetime health advisory level (HAL) is used. If neither an MCL nor a HAL exists, the SWS is calculated in a manner similar to that used to establish MCLs and HALs. The method used to calculate a SWS is based on a contaminant's cancer-causing potential, that is whether a contaminant is classified as a known or probable carcinogen, a possible carcinogen, or there is no evidence of human carcinogenicity.

SWS for Non-Carcinogens

SWSs for contaminants with no evidence of cancer-causing potential are based on the contaminant's oral reference dose (RfD). An RfD is an estimate of a daily oral exposure to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure. An RfD has the units of mg/kg/day: milligrams per day of an orally ingested contaminant per kilogram of body weight of the exposed individual. An RfD is usually determined from animal studies where animals are exposed to varying doses of the contaminant and possible adverse effects are observed.

Uncertainty/safety factors are factored into RfDs to account for things like extrapolating from animal studies to humans, ensuring protection of sensitive human subpopulations (e.g., infants and elderly), and recognizing potential deficiencies in the animal studies (e.g., the lowest dose had an adverse effect). Uncertainty factors for contaminants typically range from 3 to 10, with a factor of 10 most frequently used. When there are multiple uncertainties for a contaminant, the uncertainty factors are multiplied together.

The SWS for a contaminant with no evidence of carcinogenicity is based on ingestion of 2 liters of water a day (L/day) by a 70-kilogram (kg) person. Only 20% of the acceptable exposure to the contaminant is allowed to come from drinking water with the remaining 80% assumed to come from other sources, like food and air. The SWS is determined as follows. SWS (in mg/L) = 0.2 x RfD (mg/kg/day) ÷ 2 L/day x 70 kg or simplified as:

SWS (mg/L) = 7 x RfD (SWS based on non-cancer risk) (1)

As an example, consider ethylbenzene that has shown no evidence being a carcinogen. The RfD for ethylbenzene is 0.1 (http://www.epa.gov/iris/), so the SWS is 7 x 0.1 = 0.7 mg/L. (In the case of ethylbenzene, the SWS is the same as the MCL and the MCL is actually the SWS by default.)

It is worthwhile to consider the factors of safety built into the RfD. The RfD for ethylbenzene is based on a study where rats were given various contaminant doses and certain levels of exposure were found to cause adverse effects to the liver and kidney. A collective uncertainty factor of 1,000 was assigned: 10 for use of animal data, 10 to protect sensitive human subpopulations, and 10 due to shortcomings in the study. With the 5 times factor (i.e., only 20% of contaminant allowed from water), the resultant SWS represents a dose that is 5,000 times less than the highest dose found not to have an adverse effect in the rat study.

SWSs for Known or Probable Carcinogens

SWSs for contaminants that are known or probable human carcinogens are based on the cancer slope factor (CSF). The CSF is based on studies where laboratory animals are fed

various doses of the contaminant and the CSF is then determined using the dose that causes cancer in 10% of the laboratory animals (Dose10): CSF = 0.1 ÷ Dose10. Dose has units of mg/kg/day and CSF has units of $(mg/kg/day)^{-1}$.

Cancer risk can be calculated for any contaminant dose by multiplying the exposure dose (ED) by the CSF (Cancer Risk = ED x CSF). SWSs are based on a prescribed acceptable cancer risk of 5×10^{-6} (five cases of cancer in a million people exposed) and an assumed lifetime ingestion of 2 liters per day by a person weighing 70 kilograms. The exposure dose (ED) from an assumed lifetime exposure to water containing a contaminant at a concentration equal to the SWS is: ED = SWS (mg/L) x 2 L/day ÷ 70 kg. Substituting "SWS (mg/L) x 2 L/day ÷ 70 kg" for "ED" in the above cancer risk equation yields:

$$5 \times 10^{-6} \text{ (unitless)} = \text{SWS (mg/L)} \times 2 \text{ L/day} \div 70 \text{ kg} \times \text{CSF } (mg/kg/day)^{-1}$$

Solving for SWS yields: SWS (mg/L) = 5×10^{-6} x 70 kg ÷ 2 L/day ÷ CSF $(mg/kg/day)^{-1}$ which can be simplified to:

$$\textbf{SWS (mg/L)} = \mathbf{1.75 \times 10^{-4} \div CSF} \quad \text{(SWS based on cancer risk)} \qquad (2)$$

For example, DDT is a probable human carcinogen and does not have an MCL or a HAL. The CSF for DDT is 0.34 $(mg/kg/day)^{-1}$ (http://www.epa.gov/iris/). The SWS for DDT can be calculated as follows. SWS = $1.75 \times 10^{-4} \div 0.34 = 5.1 \times 10^{-4}$ mg/L

For known or probable carcinogens, MCLs and SWSs are different. The EPA typically sets non-enforceable MCL goals (MCLGs) at zero for cancer-causing contaminants. However, this standard is technically impracticable so the EPA takes into account the ability of laboratory analyses to detect the contaminant and limitations in the technical ability to remove a contaminant from water. As a result, the cancer risk associated with MCLs varies among contaminants, ranging from about 4.3×10^{-4} (arsenic) to 1×10^{-6} (methylene chloride) (average = 6×10^{-5}). There is a provision in Chapter 137 that SWSs can be no lower than the practical quantification limit (laboratory detection limit), which has a similar effect.

SWSs for Possible Carcinogens

SWSs for contaminants classified as possible human carcinogens that do not have an MCL or a HAL and do not have a CSF are calculated based on non-cancer impacts using Equation 1. SWSs for contaminants classified as possible human carcinogens that do not have an MCL or a HAL but do have a CSF are calculated as the larger of a SWS using Equation 2 or $1/10^{th}$ of the SWS determined by using Equation 1. The $1/10^{th}$ factor replicates how MCLs have been established for this class of contaminant.

SWSs for Groundwater in a Non-Protected Groundwater Source

SWSs for non-protected groundwater sources are based on minor modifications to the formulae used for protected groundwater sources. Formula 1 is adjusted by omitting the 20% factor used to account for contaminant sources other than drinking water. This results in non-protected standards being 5 times larger than protected standards. For non-protected SWSs, Formula 2 is based on a 1×10^{-4} acceptable cancer risk in lieu of the 5×10^{-6} acceptable cancer risk prescribed for protected standards. This results in 20 times larger SWSs for non-protected groundwater sources. While non-protected groundwater is assumed to be unusable, consumption of that groundwater with contaminant levels equal to the non-protected groundwater SWSs would still be safe.

Source of Toxicity Values

Values of drinking water MCLs and HALs can be found at the following Internet address: http://water.epa.gov/drink/standards/hascience.cfm

The primary source of RfDs and CSFs is EPA's Integrated Risk Information System (IRIS) which, as previously indicated, can be assessed at: http://www.epa.gov/iris/

If an RfD and/or CSF is not available from IRIS, the DNR consults with the Iowa Department of Public Health who recommends appropriate toxicity values.