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Evaluating Concurrent Exposures to Multiple Chemicals

In many situations a sample of groundwater contains multiple chemicals. Chemicals in combination may cause adverse effects that would not be predicted based on separate exposures to the individual concentrations of each chemical present. Therefore, evaluating the safety of a mixture of chemicals based on individual HRLs may not provide an adequate margin of safety. The procedures stated in the Health Risk Limits (HRLs) Rules for Groundwater for evaluating exposure to multiple chemicals are based on an additive model. The U.S. Environmental Protection Agency (EPA) uses this model as a reasonable approach given what is unknown about how chemicals interact in the body. Chemicals that share a common health endpoint are evaluated together. Chemicals for which no health endpoint is specified (e.g., None) are not included in any group. Similar health endpoints with or without the endocrine (E) designation are deemed equivalent (e.g., thyroid (E) = thyroid) and should be summed together in the Health Risk Index (HRI) calculation.

For each chemical sharing a health endpoint, a ratio is calculated by comparing the groundwater concentration of the chemical to the exposure duration-specific health-based guidance for that chemical. The ratios are grouped by duration and summed within each health endpoint group.

To determine whether the sum exceeds the multiple-chemical health index of one for noncancer, the chemicals are grouped according to their noncancer health endpoints, e.g., liver, kidney, nervous system. A ratio of the measured concentration of each chemical in groundwater to the corresponding health-based guidance value for the individual chemical is calculated for each exposure duration. For example:

$$\text{Noncancer HRI} = \frac{C_1}{nHRL_1} + \frac{C_2}{nHRL_2} + \dots \frac{C_N}{nHRL_N}$$

Where:

$C_1, C_2, \dots C_N$ = the concentration of the first, second, …, Nth chemical that has been detected in groundwater and that causes a specific noncancer effect (μg/L).

HRI = Health Risk Index. The noncancer HRI is determined by calculating, for each chemical with a similar health endpoint (such as liver effects), the concentration of the chemical in the water divided by the health risk limit for that chemical, and summing the resulting ratios (see below for an example). An HRI over one indicates possible exceedances.

$nHRL_1, nHRL_2, \dots nHRL_N$ = the duration-specific noncancer health risk limit of the first, second, …, N^{th} chemical with the same health endpoint that has been detected in groundwater (μg/L).

All carcinogens are treated as members of the same group. A ratio of the measured concentration of each individual carcinogen in groundwater to the health based

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guidance value for that carcinogen is calculated. Ratios are added and compared to the multiple-chemical health risk limit of one. For example:

$$\text{Cancer HRI} = \frac{C_1}{nHRL_1} + \frac{C_2}{nHRL_2} + \dots \frac{C_N}{nHRL_N}$$

Where:

$C_1, C_2, \dots C_N$ = the concentration of the first, second, …, N^{th}

HRI = Health Risk Index. The cancer HRI is determined by calculating, for each chemical in the water, the concentration of the chemical divided by the cancer health risk limit for that chemical and summing the resulting ratios (see below for an example). An HRI over one indicates possible exceedances.

$cHRL_1, cHRL_2, \dots cHRL_N$ = the cancer health risk limit of the first, second, …, N^{th} chemical that has been detected in groundwater (µg/L).

Example Health Risk Index Calculations:

To determine the health risks when benzene, chloroform and vinyl chloride are present, the duration-specific ratio for each health endpoint is added together to derive a duration-specific health risk index for each endpoint.

Chemical	Amount detected in water (µg/L)	Duration	HRL (µg/L)	Health Endpoint
Benzene	2.8	Acute	10	Developmental
		Short-term	10	Blood system; Immune system
		Subchronic	3	Blood system; Immune system
		Chronic	3	Blood system; Immune system
		Cancer	2	Cancer
Chloroform	1.5	Acute	ND	--
		Short-term	30	Developmental; Liver; Immune system
		Subchronic	30	Developmental; Liver; Immune system; Male reproductive system
		Chronic	30	Developmental; Liver; Immune

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				system; Male reproductive system
		Cancer	NA	--
Vinyl chloride	0.4	Acute	ND	--
		Short-term	20	Liver
		Subchronic	20	Liver
		Chronic	10	Liver
		Cancer	0.2	Cancer

NA = Not Available

ND = Not Derived (due to insufficient toxicity information)

There are no common health endpoints for the acute duration. For the short-term duration, the immune system is a common health endpoint for benzene and chloroform. The short-term hazard index for immune effects is:

$$\text{Noncancer Immune HRI}_{\text{short-term}} = \frac{2.8}{10} + \frac{1.5}{30} = 0.3 + 0.05 = 0.35$$

For the subchronic duration, the immune system is a common health endpoint for benzene and chloroform and the liver system is a common health endpoint for chloroform and vinyl chloride. The subchronic hazard index for immune effects is:

$$\text{Noncancer Immune HRI}_{\text{subchronic}} = \frac{2.8}{3} + \frac{1.5}{30} = 0.9 + 0.05 = 0.95$$

The subchronic hazard index for liver effects is:

$$\text{Noncancer Liver HRI}_{\text{subchronic}} = \frac{1.5}{30} + \frac{0.4}{20} = 0.05 + 0.02 = 0.07$$

For the chronic duration, the immune and liver systems are common health endpoints for the same pairings of chemicals as in the subchronic case. The chronic hazard index for immune effects is:

$$\text{Noncancer Immune HRI}_{\text{chronic}} = \frac{2.8}{3} + \frac{1.5}{30} = 0.9 + 0.05 = 0.95$$

The chronic hazard index for liver effects is:

$$\text{Noncancer Liver HRI}_{\text{chronic}} = \frac{1.5}{30} + \frac{0.4}{10} = 0.05 + 0.04 = 0.09$$

Cancer is a common health endpoint for benzene and vinyl chloride. The cancer hazard index is:

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$$\text{Cancer HRI} = \frac{2.8}{2} + \frac{0.4}{0.2} = 1.4 + 2 = 3.4$$

None of the noncancer health risk indices exceeded 1. However, the health risk index for cancer does exceed one, indicating a cancer health concern for the combined exposure to benzene and vinyl chloride.

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Updated Thursday, August 28, 2014 at 10:21AM