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OF ARGONNE NATIONAL LABORATORY

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RISK ASSESSMENT OF SEEPS FROM THE 317 AREA OF ARGONNE NATIONAL LABORATORY

1 INTRODUCTION

Chlorinated hydrocarbon contaminants have recently been detected in groundwater seeps on forest preserve property south of the 317 Area at Argonne National Laboratory (ANL). The 317 Area is near ANL's southern boundary and is considered the source of the contamination (Figure 1). Five seeps are about 200 m (600 ft) south of the ANL property line and about the same distance from the nearest developed trails, in an area not frequently accessed by visitors to the forest preserve. Seep water reaches the ground surface in small amounts, forming a series of small puddles in the bottoms of several steep ravines. The flow disappears entirely within several hundred feet of the seeps as a result of evaporation and/or reabsorption into the soil.

Low levels of three volatile organic compounds (VOCs) — chloroform, carbon tetrachloride, and tetrachloroethylene — were recently detected in two seeps, at a combined concentration of less than 1 part per million (ppm). Exposures and related impacts are unlikely because water is only present on the surface in small, localized areas that are not typically accessed. Further, contaminant concentrations are low. However, potential health and ecological impacts have been quantitatively assessed to evaluate the safety of visitors and biota in the forest preserve. Potential health effects were assessed using standard methodology developed by the U.S. Environmental Protection Agency (EPA). Conservative assumptions that overestimate likely exposures were used for these analyses to bound possible impacts. Ecological effects were evaluated by comparing contaminant concentrations to EPA criteria and benchmark values for surface water, which were developed to be protective of wildlife. The health and ecological assessments are presented in Sections 2 and 3, respectively.

2 HUMAN HEALTH ASSESSMENT

2.1 Contaminant Information

Water from five seeps was sampled in the summer of 1996 and analyzed for the 51 VOCs on EPA's standard analyte list. No VOCs were detected in three seeps, and three VOCs were detected in the other two, with concentrations ranging from 3 to 340 $\mu\text{g/L}$ (parts per billion, or ppb). The sampling results are presented in Table 1. Seeps SP-01 and SP-04 are very close to one another and discharge to the same ravine. Figure 1 shows the locations of these seeps.

TABLE 1 Contaminant Data from the Seep Samples

Sample	Contaminant Concentration ($\mu\text{g/L}$) ^a		
	Carbon Tetrachloride	Chloroform	Tetrachloroethylene
SP-01	82	25	3
SP-02	-	-	-
SP-03	-	-	-
SP-04	340	24	6
SP-05	-	-	-

^a A dash indicates that the contaminant was not detected.

FIGURE 1 Seep Sampling Locations

2.2 Exposure Assessment

In order for the assessment to be conservative, an unlikely "maximum exposure" scenario was developed to estimate potential impacts for a hypothetical adult visitor to the forest preserve. This person was assumed to visit the seep area 20 times a year for the next 10 years. To represent a bounding exposure estimate, it was assumed that on each visit the individual drinks 400 mL (2 cups) of water from the seeps. It was also assumed that the water contains all three contaminants at their highest measured concentrations.

These assumptions are conservative (i.e., protective) for the following reasons. First, the seeps are a considerable distance from developed hiking trails and are not readily accessed, so 200 routine visits to that area over 10 years are unlikely. Second, the flow from the seep area is extremely low (less than 1 gal/min), and water is generally present as a thin layer on the ground surface but sometimes dries up completely. (More water tends to be present in the ravine during periods of heavy rain, but these conditions are associated with lower hiking activity, so the likelihood of frequent exposures under those conditions would be very low.) For someone to successfully collect and drink two cups of water during each visit would be highly unlikely, especially given that drinking water is provided nearby in the forest preserve. Because of its low volume, the seep water cannot possibly serve as a long-term drinking water source. Finally, contaminants are not expected to be at maximum levels throughout a 10-year period.

Nevertheless, the amount of each contaminant taken in by the hypothetical visitor to the forest preserve was calculated with these conservative assumptions, using the standard framework developed by EPA for health assessments (EPA 1989). In addition to the ingestion scenario, intakes from inhalation and dermal contact were also assessed to ensure that all possible (albeit unlikely) scenarios are considered in evaluating the safety of the seeps.

For the inhalation assessment, air concentrations of the three VOCs were estimated on the basis of seep emissions calculated with standard EPA methodology (EPA 1993). Again, the maximum measured concentrations of the three contaminants were used for this assessment. A conservative dispersion model (Screen3, EPA 1995) was then applied to estimate maximum air concentrations for hypothetical receptors. Additional conservative assumptions (including ground-level inhalation) were applied to estimate intakes. The hypothetical receptor was assumed to visit the area 20 times a year for 10 years and to breathe the air at the seeps for 1 hour during each visit. Standard EPA values were used for the basic intake parameters, such as the breathing rate (EPA 1989, 1991a).

To assess potential effects from dermal exposures, it was conservatively assumed that the visitor would walk barefoot in ankle-deep seep water for 1 hour during each of the 20 visits per year over a 10-year period. Maximum contaminant concentrations were also used for this analysis. Standard values for intake parameters were used, such as for the surface area of feet and the permeability of skin (EPA 1992).

For completeness, exposures were also evaluated for a hypothetical child who might visit the seep area. Standard EPA values were used for these analyses.

2.3 Toxicity Assessment

Two types of human health endpoints are addressed in evaluating chemical exposures: cancer and noncarcinogenic effects. The EPA has developed contaminant-specific toxicity values for

these endpoints in cases where scientific evidence indicates the potential for a health effect. These values are also specific to the route of exposure (e.g., ingestion versus inhalation).

The potential for a chemical to cause cancer in humans is based on laboratory studies (mammal) in combination with human epidemiological data, where they are available. From an evaluation of these data, the EPA assigns a weight-of-evidence classification to individual contaminants as follows: A — known human carcinogen; B1 — probable human carcinogen, for which limited human data are available; B2 — probable human carcinogen, as indicated by sufficient evidence in animals but inadequate or no evidence in humans; C — possible human carcinogen; D — not classifiable as to human carcinogenicity; and E — evidence of noncarcinogenicity in humans.

All three seep contaminants have been evaluated by EPA with regard to their potential human carcinogenicity. Carbon tetrachloride and chloroform are classified as group B2 carcinogens on the basis of an increased incidence of liver and kidney tumors in laboratory rats and mice. Tetrachloroethylene is not currently classified because its potential carcinogenicity is under review by EPA. The EPA has developed cancer slope factors for many chemicals that generally represent an upper-bound (conservative) estimate of the probability of a response (cancer) per unit intake over a lifetime. The slope factors for carbon tetrachloride and chloroform are shown in Table 2 (EPA 1996b). No slope factors are currently available for tetrachloroethylene, as previous values have been withdrawn per the ongoing review.

With regard to noncarcinogenic effects, all three contaminants have been shown to cause liver damage at relatively high concentrations in laboratory tests with mammals, as is typical of chlorinated hydrocarbons. However, little data exist for human exposures to environmental concentrations. Studies have shown that inhalation of higher concentrations of these compounds (more than a thousand ppm) can cause dizziness, and long-term exposures to lower levels (e.g., hundreds of ppm) have also been linked to liver and kidney damage. (Air concentrations associated with the seeps are less than one-millionth to one-billionth of study levels.) Ingestion of relatively high concentrations (orders of magnitude higher than in the seeps) over long periods also may affect the nervous system, liver, and kidney (ATSDR 1993a,b; 1994).

The relative noncarcinogenic potencies of the seep contaminants are reflected in their reference doses (RfDs). The RfD is an estimate of the average daily exposure that is likely to be without deleterious effects to humans during a lifetime. These toxicity values are derived primarily from animal studies, and to be protective they incorporate a number of order-of-magnitude "safety factors" to account for such adjustments as extrapolating from animals to humans and addressing sensitive subpopulations. The RfDs for the seep contaminants are shown in Table 2 (EPA 1996b).

2.4 Risk Characterization

The risk of developing cancer from exposure to a specific contaminant can be calculated by multiplying the intake estimated for a given receptor by the appropriate slope factor. The result represents the incremental risk (probability) of developing cancer from that exposure. The EPA has identified a target range of 10^{-4} to 10^{-6} — or 1 in 10,000 to 1 in 1 million — for the risk of excess (above background) cancer incidence associated with contaminated sites (40 *Code of Federal Regulations* Part 300). To put this target range in context, it is estimated that one in three Americans will develop cancer from all sources. Thus, EPA's target range for incremental risks from exposures to site contaminants represents a very small fraction of the overall cancer rate.

TABLE 2 Estimated Health Effects from Potential Exposures to Seep Contaminants^a

Seep Contaminant	Maximum Measured Concentration (µg/L)	Slope Factor ^b (mg/kg-day) ⁻¹		Estimated Cancer Risk ^c			Reference Dose ^d (mg/kg-day)		Estimated Hazard Quotient ^e		
		Ingestion	Inhalation	Ingestion	Inhalation	Dermal	Ingestion	Inhalation	Ingestion	Inhalation	Dermal
Carbon tetrachloride	340	0.13	0.053	2×10^{-6}	2×10^{-9}	3×10^{-7}	0.0007	0.00057	0.15	0.0004	0.02
Chloroform	25	0.0061	0.081	7×10^{-9}	3×10^{-9}	3×10^{-10}	0.01	0.01	0.005	0.00002	0.00004
Tetrachloroethylene	6	NA ^f	NA	NA	NA	NA	0.01	0.01	0.0002	0.000005	0.000007

^a Shown are results for a hypothetical adult visitor to the forest preserve; results for a hypothetical child are similar.

^b The EPA has not developed slope factors to quantify dermal exposures, so values have been extrapolated from those for ingestion, consistent with EPA guidance.

^c Using conservative assumptions, the total risk combined across all pathways is represented by that for ingestion of carbon tetrachloride, 2×10^{-6} . This is well below the level of potential concern above which action is generally indicated (10^{-4}).

^d The EPA has not developed reference doses to quantify dermal exposures, so values have been extrapolated from those for ingestion, consistent with EPA guidance. Similarly, route-to-route extrapolations were made for the inhalation reference doses for chloroform and tetrachloroethylene because those values are not available.

^e The sum of hazard quotients represents the hazard index. Using conservative assumptions, the hazard index summed across all contaminants and pathways is well below 1; hence, no noncarcinogenic effects are indicated.

^f NA = not available. The potential carcinogenicity of tetrachloroethylene is currently under review by EPA, so no slope factors are available to quantify risks. However, using previous EPA values results in risk estimates on the order of 10^{-8} (for ingestion) and lower.

In applying EPA's target range, no remedial action (such as access restrictions or containment) is indicated unless the estimated risk exceeds 10^{-4} , and in those cases further evaluation is typically warranted. For example, more realistic exposure assumptions are applied to assess the risks, and various control options are evaluated if reasonable estimates of risk exceed the 10^{-4} level. Once action is indicated (e.g., when reasonable estimates exceed 10^{-4}), EPA strives to manage incremental risk to within the target range. Risks below the range are generally not considered of concern (EPA 1991b).

The potential for noncarcinogenic health effects is calculated by dividing the estimated intake by the appropriate RfD to generate a hazard quotient for each contaminant. The hazard index represents the sum of the hazard quotients. If this sum exceeds 1, a potential for noncarcinogenic effects is indicated and further evaluation is often conducted. Conversely, a sum of less than or equal to 1 indicates that noncarcinogenic effects are not a concern.

The cancer risks and noncarcinogenic effects estimated for various exposures to seep contaminants are presented in Table 2. Using conservative assumptions, estimates exceed neither the target risk nor the noncarcinogenic threshold level developed by EPA to protect human health. The total risk combined across all pathways is 2×10^{-6} , and ingestion of carbon tetrachloride is the major contributor. The estimated risks for all other chemicals and pathways are much lower (below EPA's target range). Further, only if an individual were to regularly ingest carbon tetrachloride would the estimated risk be at the low end of EPA's range; applying more realistic exposure assumptions would result in an ingestion risk well below this range.

Risks from exposure to tetrachloroethylene were not quantified because of the current unavailability of slope factors. In such cases, the potential health effect is qualitatively evaluated. Given its low concentration and similar chemical structure, it is unlikely that exposure to tetrachloroethylene would pose a risk greater than carbon tetrachloride and chloroform. In fact, using toxicity values previously available from EPA, estimated risks are lower than those for carbon tetrachloride (i.e., 10^{-8} for ingestion, and lower for the other exposure routes).

2.5 Summary

Conservative assumptions were used to assess the possibility of adverse health effects associated with forest preserve seeps impacted by the 317 Area at ANL. The results of this health assessment indicate that neither cancer risks nor noncarcinogenic effects associated with exposures to seep contaminants are a concern. That is, the area is safe for all visitors.

3 ECOLOGICAL IMPACTS

An evaluation of carbon tetrachloride, chloroform, and tetrachloroethylene in the seeps indicates that the maximum reported concentrations pose no risks to aquatic biota that may be in extended contact with the water or to terrestrial wildlife (mammals) that may drink the water. The maximum measured concentrations of 340 $\mu\text{g/L}$ for carbon tetrachloride, 25 $\mu\text{g/L}$ for chloroform, and 6 $\mu\text{g/L}$ for tetrachloroethylene are well below available EPA benchmark values that were developed to protect wildlife. Further, these compounds are readily metabolized in animals, so biomagnification in the food chain is not expected to be important to the protection of wildlife or humans. For example, ingestion of deer that may be exposed would not pose a threat to human health.

The EPA ambient water quality criterion for chloroform is 1,240 µg/L for the protection of chronically exposed freshwater aquatic biota (EPA 1986). The highest concentration measured in the seeps is only about 2% of this level. Although no criteria have been developed for carbon tetrachloride or tetrachloroethylene, EPA has identified a "lowest observed adverse effect level" (LOAEL) of 35,200 µg/L for carbon tetrachloride (EPA 1986) and a surface water ecotox threshold value of 350 µg/L for tetrachloroethylene (EPA 1996a). The highest seep concentrations of these compounds are less than 1% and 2% of the respective EPA values.

In addition, the nature of the groundwater discharge further precludes the likelihood of adverse impacts to aquatic biota. The flow is very low, with most surface water disappearing within several hundred feet of the original discharge point either by loss to the subsurface or evaporation. Because of its limited presence, the water likely provides very little suitable habitat capable of supporting aquatic biota year-round, and biota that may exist likely are limited to invertebrates.

Terrestrial wildlife may use the water as a drinking water source, although it is unlikely that the stream provides a sole-source water supply for any area wildlife because of the nature of the flow. Scientists at Oak Ridge National Laboratory (Opresko et al. 1995) have developed guidelines for certain contaminants in surface water that represent safe concentrations in waters consumed by mammalian wildlife. Concentrations below these levels are considered to pose no risk to terrestrial wildlife that may drink the water. The lowest safe concentrations are 45,600 µg/L for carbon tetrachloride, 42,800 µg/L for chloroform, and 1,800 µg/L for tetrachloroethylene. Maximum concentrations in the seeps are much lower than these safe levels, which were based on exposures of white-tailed deer. These deer represent the most sensitive of the animal species for which benchmark values are available, and they are also a species of special concern in the ANL area.

In summary, the presence of the three contaminants in the seep water does not pose a risk to biota in the area. Thus, no adverse ecological impacts are associated with the seeps.

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