

Attachment G Risk Calculations

Arsenic—Morse Street Group of Properties

A. Noncancer risks, child aged 1–6 years

1. Ingestion Dose—Arsenic

This calculation estimates the average daily dose of arsenic to a child, age 1–6 years from incidental soil ingestion.

$$\text{ADD}_{\text{ingestion}} = \text{Irc} * [\text{Soil}] * \text{EF} * \text{ED} * \text{C1} * \text{C2} * 1/\text{BW}_c * 1/\text{AT}_{\text{nc}}$$

$$\text{ADD}_{\text{ingestion}} = 100 \text{ mg/day} * 54 \text{ mg/kg} * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/16 \text{ kg} * 1/6 \text{ years} = 2.5 \text{ E-4 mg/kg/day}$$

2. Dermal Dose—Arsenic

This calculation estimates the average daily dose of arsenic to a child, age 1-6 years from dermal contact.

$$\begin{aligned} \text{ADD}_{\text{dermal}} &= [\text{Soil}] * \text{AF} * \text{ABS}_d * \text{SA}_c * \text{EF} * \text{ED} * \text{F} * \text{C1} * \text{C2} * 1/\text{BW}_c * 1/\text{AT}_{\text{nc}} \\ &= 54 \text{ mg/kg} * 0.04 \text{ mg/cm}^2/\text{ev} * 0.03 * 3,307 \text{ cm}^2 * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1 \text{ ev/day} * 1/16 \text{ kg} * 1/6 \text{ year} \end{aligned}$$

$$\text{ADD}_{\text{dermal}} = 1\text{E-5 mg/kg/day}$$

3. Noncancer Hazard Index—Arsenic

$$\begin{aligned} \text{HI} &= \text{ADD}_{\text{ingestion}} + \text{ADD}_{\text{dermal}}/\text{RfD} \\ \text{HI} &= 2.5 \text{ E-4 mg/kg/day} + 1 \text{ E-5 mg/kg/day} = 2.6 \text{ E-4 mg/kg/day} \\ &2.6 \text{ E-4 mg/kg/day}/3.4 \text{ E-4 mg/kg/day} \end{aligned}$$

$$\text{HI} = 0.76$$

A hazard index (HI) of 1 means that the estimated dose is equal to the safe dose. A hazard index less than 1 indicates that the estimated dose is below the safe dose and noncancer health effects are unlikely. A hazard index greater than 1 indicates that the estimated dose exceeds the safe dose and noncancer health effects cannot be ruled out. In this case, the hazard index for arsenic is less than 1. This indicates that noncancer health effects from arsenic are unlikely.

4. Acute Ingestion dose for a child, aged 2 years

This calculation estimates the average daily dose of arsenic to a child, aged 2 years, from incidental ingestion of soil, assuming a large ingestion rate over a short period (7 days).

$$\begin{aligned} \text{ADD}_{\text{ac}} &= \text{IR}_{\text{ac}} * [\text{Soil}] * \text{EF} * \text{ED} * 1/\text{BW}_{\text{ac}} * 1/\text{AT}_{\text{ac}} \\ &= 400 \text{ mg/day} * 54 \text{ mg/kg} * 10^{-6} \text{ kg/mg} * 7 \text{ days/week} * 1 \text{ week} * 1/13 \text{ kg} * 1/7 \text{ days} \\ &= 0.0016 \text{ mg/kg/day} \end{aligned}$$

The acute ingestion dose for arsenic exposure for a child is 0.0016 mg/kg/day. ATSDR's acute oral maximum risk level for arsenic is 0.005 mg/kg/day, which is more than the acute ingestion dose. Therefore, these acute doses are within safe levels and do not pose a significant health threat.

B. Cancer Risks, Child/Adult Age 1–30 Years

1. Ingestion Dose—Arsenic

This calculation estimates the lifetime average daily dose of arsenic to a child/adult (age 1–30 years) from ingestion of soil.

$$\text{LADD}_{\text{child ingestion}} = \text{IR}_{\text{c}} * [\text{Soil}] * \text{EF} * \text{ED} * \text{C1} * \text{C2} * 1/\text{BW} * 1/\text{AT}_{\text{c}}$$

$$\text{LADD}_{\text{child ingestion}} = 100 \text{ mg/day} * 54 \text{ mg/kg} * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/16 \text{ kg} * 1/70 \text{ years} = 2.16 \text{ E-5 mg/kg/day}$$

$$\text{LADD}_{\text{adult ingestion}} = 50 \text{ mg/day} * 54 \text{ mg/kg} * 7 \text{ days/week} * 39 \text{ weeks/year} * 24 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/70 \text{ kg} * 1/70 \text{ years} = 9.89 \text{ E-6 mg/kg/day}$$

2. Dermal Dose—Arsenic

This calculation estimates the lifetime average daily dose of arsenic to a child/adult (age 1–30 years) from dermal contact.

$$\begin{aligned} \text{LADDD}_{\text{child dermal}} &= [\text{Soil}] * \text{AF} * \text{ABS}_{\text{d}} * \text{SA}_{\text{c}} * \text{EF} * \text{ED} * \text{F} * \text{C1} * \text{C2} * 1/\text{BW} * 1/\text{AT}_{\text{c}} = 54 \text{ mg/kg} * 0.04 \\ &\text{mg/cm}^2/\text{ev} * 0.03 * 3,307 \text{ cm}^2 * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 1 \text{ event/day} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} \\ &* 1/16 \text{ kg} * 1/70 \text{ years} = 8.5 \text{ E-7 mg/kg/day} \end{aligned}$$

$$\begin{aligned} \text{LADDD}_{\text{adult dermal}} &= [\text{Soil}] * \text{AF} * \text{ABS}_{\text{d}} * \text{SA}_{\text{c}} * \text{EF} * \text{ED} * \text{F} * \text{C1} * \text{C2} * 1/\text{BW} * 1/\text{AT}_{\text{c}} \\ &= 54 \text{ mg/kg} * 0.01 \text{ mg/cm}^2/\text{ev} * 0.03 * 5,672 \text{ cm}^2 * (7 \text{ days/week} * 39 \text{ weeks/year}) * 24 \text{ years} * 1 \text{ event/day} * 10^{-6} \\ &\text{kg/mg} * \text{year}/365 \text{ days} * 1/70 \text{ kg} * 1/70 \text{ years} = 3.36 \text{ E-7 mg/kg/day} \end{aligned}$$

3. Cancer Risk—Arsenic

$$\text{ELCR} = (\text{LADD}_{\text{child ingestion}} + \text{LADD}_{\text{adult ingestion}} + \text{LADDD}_{\text{child dermal}} + \text{LADDD}_{\text{adult dermal}}) * \text{CSF}$$

$$\text{ELCR} = (2.16 \text{ E-5} + 9.89 \text{ E-6} + 8.5 \text{ E-7} + 3.36 \text{ E-7}) * \text{CSF}$$

$$\text{ELCR} = 3.3 \text{ E-5 mg/kg/day} * 1.5 (\text{mg/kg/day})^{-1}$$

$$\text{ELCR} = 5 \text{ E-5}$$

The estimated lifetime cancer risk (ELCR) for arsenic is 5 E-5 (5 in 100,000). This means that if 100,000 people were exposed to arsenic in soil at the concentration, frequency and duration of exposure assumed in the calculation detailed above, there would be a theoretical increase of five cancers above the number of cancers that would normally be expected to occur in the population of 100,000. Background rates of cancer in the United States are one in two or three (National Cancer Institute, SEER Program 2001). This means that in a population of 100,000, background numbers of cancer cases would be approximately 33,000 to 50,000. Arsenic exposures could result in a theoretical increase of five cancer cases above the background number of 33,000 to 50,000 cancer cases. This represents a relatively low increased cancer risk.

Polycyclic Aromatic Hydrocarbons (PAHs)—Bryden Terrace Group of Properties

A. Noncancer risks, child aged 1–6 years

1. Ingestion Dose—PAHs

This calculation estimates the average daily dose of PAHs to a child, age 1-6 years from soil ingestion.

$$\text{ADD}_{\text{ingestion}} = 100 \text{ mg/day} * 30.2 \text{ mg/kg} * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/16 \text{ kg} * 1/6 \text{ years} = 1.4 \text{ E-4 mg/kg/day}$$

2. Dermal Dose—PAHs

This calculation estimates the average daily dose of PAHs to a child, age 1–6 years from dermal contact with soil.

$$\text{ADD}_{\text{dermal}} = 30.2 \text{ mg/kg} * 0.04 \text{ mg/cm}^2/\text{ev} * 0.13 * 3,307 \text{ cm}^2 * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 1 \text{ event/day} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/16 \text{ kg} * 1/6 \text{ years}$$
$$\text{ADD}_{\text{dermal}} = 2.4 \text{ E-5 mg/kg/day}$$

3. Noncancer Hazard Index—PAHs

$$\text{HI} = 1.4 \text{ E-4} + 2.4 \text{ E-5} / 0.02 \text{ mg/kg/day}$$

$$\text{HI} = 1.64 \text{ E-4} / 0.02 \text{ mg/kg/day}$$

$$\text{HI} = 0.008$$

A hazard index (HI) of 1 means that the estimated dose is equal to the safe dose. A hazard index less than 1 indicates that the estimated dose is less than the safe dose and noncancer health impacts are unlikely. A hazard index greater than 1 indicates that the estimated dose exceeds the safe dose and noncancer health effects cannot be ruled out. In this case, the hazard index for PAHs is well below 1. This indicates that noncancer health effects from PAHs are unlikely.

B. Cancer Risks, Child/Adult Age 1–30 Years

1. Ingestion Dose—PAHs

This calculation estimates the lifetime average daily dose of PAHs to a child/adult (age 1–30 years) from soil ingestion.

$$\text{LADD}_{\text{child ingestion}} = 100 \text{ mg/day} * 16.04 \text{ mg/kg} * 7 \text{ days/week} * 39 \text{ weeks/year} * 6 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/16 \text{ kg} * 1/70 \text{ years} = 6.4 \text{ E-6 mg/kg/day}$$

$$\text{LADD}_{\text{adult ingestion}} = 50 \text{ mg/day} * 16.04 \text{ mg/kg} * 7 \text{ days/week} * 39 \text{ weeks/year} * 24 \text{ years} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/70 \text{ kg} * 1/70 \text{ year} = 2.9 \text{ E-6 mg/kg/day}$$

2. Dermal Dose—PAHs

This calculation estimates the lifetime average daily dose of PAHs to a child/adult (age 1–30 years) from dermal contact with soil.

$$\text{LADDD}_{\text{child dermal}} = 16.04 \text{ mg/kg} * 0.04 \text{ mg/cm}^2/\text{ev} * 0.13 * 3,307 \text{ cm}^2 * (7 \text{ days/week} * 39 \text{ weeks/year}) * 6 \text{ years} * 1 \text{ event/day} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/16 \text{ kg} * 1/70 \text{ year} = 1.1 \text{ E-6 mg/kg/day}$$

$$\text{LADDD}_{\text{adult dermal}} = 16.04 \text{ mg/kg} * 0.01 \text{ mg/cm}^2/\text{ev} * 0.13 * 5,672 \text{ cm}^2 * (7 \text{ days/week} * 39 \text{ weeks/year}) * 24 \text{ years} * 1 \text{ event/day} * 10^{-6} \text{ kg/mg} * \text{year}/365 \text{ days} * 1/70 \text{ kg} * 1/70 \text{ year} = 4.3 \text{ E-7 mg/kg/day}$$

3. Cancer Risk—PAHs

$$\begin{aligned} \text{ELCR} &= \text{LADD}_{\text{child ingestion}} + \text{LADD}_{\text{adult ingestion}} + \text{LADDD}_{\text{child dermal}} + \text{LADDD}_{\text{adult dermal}} * \text{CSF} \\ \text{ELCR} &= 6.4 \text{ E-6} + 2.9 \text{ E-6} + 1.1 \text{ E-6} + 4.3 \text{ E-7} = 1.08 \text{ E-5 mg/kg/day} * 7.3 \text{ (mg/kg/day)}^{-1} \\ \text{ELCR} &= 8 \text{ E-5} \end{aligned}$$

The estimated lifetime cancer risk (ELCR) for PAHs is 8 E-5 (8 in 100,000). This means that if 100,000 people were exposed to PAHs in soil at the concentration, frequency and duration of exposure assumed in the calculation detailed above, there would be a theoretical increase of eight cancers above the number of cancers that would normally be expected to occur in the population of 100,000. Background rates of cancer in the United States are one in two or three (National Cancer Institute, SEER Program 2001). This means that in a population of 100,000, background numbers of cancer cases would be approximately 33,000 to 50,000. PAH exposures could result in a theoretical increase of 7 cancer cases above the background number of 33,000 to 50,000 cancer cases. This represents a small incremental increased cancer risk.

Definitions for terms used in risk equations:

ABS_d = Soil dermal absorption fraction

Arsenic: 0.03, PAHs: 0.13 (EPA 2001)

$\text{ADD}_{\text{ingestion}}$ = average daily dose from ingestion

$\text{ADD}_{\text{dermal}}$ = average daily dose from dermal contact

ADD_{ac} = average daily dose from acute ingestion

AF = skin-soil adherence factor for central tendency residential child; 0.04 mg/cm²/ev (EPA 2001)
skin-soil adherence factor for central tendency residential adult; 0.01 mg/cm²/ev (EPA 2001)

AT_{nc} = averaging time for noncancer risk; 6 years

AT_c = averaging time for cancer risk; 70 years

AT_{ac} = average time for acute noncancer risk; 7 days

BW = child 50th percentile body weight for age 1–6 years (EPA 1997); 16 kg

BW_a = adult 50th percentile body weight (EPA 1997); 70 kg

BW_{ac} = body weight, 2-year-old child (EPA 1997); 13 kg

C1 = conversion factor; 10⁻⁶ kg/mg

C2 = conversion factor; 1 year/365 days

CSF = cancer slope factor

Arsenic: 1.5 (mg/kg/day)⁻¹ (IRIS)

PAHs: benzo(a)pyrene; 7.3 (mg/kg/day)⁻¹ (IRIS)

ED = exposure duration; 6 years for child, 24 years for adult

EF = exposure frequency; 7 days/week, 39 weeks/year (non-winter weeks)

ELCR = estimated lifetime cancer risk

F = event frequency, 1 event/day

HI = hazard index

IR_c = soil ingestion rate for a child; 100 mg/day (EPA 1997)*

IR_a = soil ingestion rate for an adult; 50 mg/day (EPA 1997)*

I_{ac} = acute soil ingestion rate for a child (upper percentile) (EPA 1997)
 kg = kilograms
 $LADD_{child\ ingestion}$ = lifetime average daily dose from ingestion for child, aged 1–6 years
 $LADD_{adult\ ingestion}$ = lifetime average daily dose from ingestion for adult, aged 7–18 years
 $LADDD_{adult\ dermal}$ = lifetime average dermal daily dose for child, aged 1–6 years
 $LADDD_{child\ dermal}$ = lifetime average dermal daily dose for child, aged 7–30 years
 mg = milligrams
 RfD = EPA reference dose
 Arsenic; 3 E-4 mg/kg/day (IRIS)
 PAHs: naphthalene used as a surrogate for PAHs; 0.02 mg/kg/day (IRIS)
 SA_c = Skin surface area, 50th percentile legs, feet, hands, and arms, child aged 1–6 years; 3,307 cm² (EPA 1997)
 SA_d = skin surface area, 50th percentile legs, feet, hands, and arms, adult; 5,672 cm² (EPA 1997)
 [Soil] = soil concentration;
 Arsenic: 54 mg/kg (95% upper confidence limit of the arithmetic mean)[†]
 PAHs (noncancer calculation): 24.4 mg/kg (total of 95% UCLs for PAHs)
 PAHs (cancer calculation): 15.46 mg/kg (total TEF-adjusted 95% UCL for PAHs)

* EPA (1997) recommends using soil ingestion rates of 100 mg/day for child < 6 years and 50 mg/day a child/adult 6 years. EPA states that these values represent best estimates of average soil ingestion rates. EPA programs have used 200 mg/day and 100 mg/day as conservative estimates of average soil intake rates. CT DPH opted to use the best estimate average values of 100 mg/day and 50 mg/day rather than the more conservative estimates for the sake of consistency with other parameters describing the receptor which are also central estimates (for example, body weight, skin surface area and skin-soil adherence).

[†] ATSDR (2002) advises using the 95% upper confidence limit of the arithmetic mean. This was performed using Pro UCL (EPA 2001a). A 95% UCL accounts for the variability in the data and ensures that the mean is not underestimated.

Values used to calculate PAH concentrations for cancer and noncancer risk calculations

PAH	95% UCL (mg/kg)	Toxic Equivalency Factor (TEF)	TEF Adjusted Concentration (mg/kg)
Benzo(a)anthracene	5.2	0.1	0.52
Benzo(b)fluoranthene	5.7	0.1	0.57
Benzo(k)fluoranthene	5.8	0.1	0.58
Benzo(a)pyrene	6.3	1	6.3
Indeno(1,2,3-cd)pyrene	5.7	0.1	0.57
Dibenzo(ah)anthracene	1.5	5	7.5
Total of 95% UCLs	30.2	—	16.04