

Synthetic Turf Wars: A Crumb Rubber Human Health Risk Assessment

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Abstract

Background: Crumb rubber (CR) is a recycled product generated from automotive and truck scrap tires and produced with a granulated consistency, often treated with several chemicals before being spread into the environment. It is often found on athletic artificial/synthetic turf fields and children's playgrounds. Current studies have established that there is no correlation between CR exposure and non-carcinogenic and carcinogenic health effects. However, other research has found hazardous substances within CR. No matter the case, concerns among the general public continue to grow about the health risks of CR, most notably regarding soccer player, specifically goalkeeper, populations.

Objective: The purpose of this study was to investigate the level of health risk CR poses to exposed human populations, particularly individuals 6-21 years old.

Methods: A human health risk assessment (HHRA) was conducted in four phases with an initial planning phase: 1) hazard identification, 2) dose-response assessment, 3) exposure assessment, and 4) risk characterization.

Results: This study examined 115 chemicals of potential concern (COPCs). Intake dose (ID), lifetime average daily dose (LADD), reference dose (RfD), reference concentration (RfC), oral slope factor (OSF), inhalation unit risk (IUR), hazard quotient (HQ), excess lifetime cancer risk (ELCR), hazard index (HI), and total cancer risk (TCR) were analyzed.

Discussion: Average combined HQ and ELCR was not statistically significant. Therefore, health effects may not be observed in individuals 6-21 years old when chronically exposed to CR.

There is uncertainty if COPCs pose a health risk when concentrations are increased.

Keywords: crumb rubber, human health risk assessment, synthetic turf

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Since the 1990s, the United States Environmental Protection Agency (EPA) has been searching for new ways to dispose of old, used, and worn tires. These new methods of removal were to be used as alternatives to disposing scrap tires in landfills. In recent years, states have passed legislation regarding landfill disposal of scrap tires. Almost all states have enacted laws for the management of scrap tires, and eleven states have banned all tires from landfills. These scrap tires, also called end-of-life tires, may present a potential fire hazard as well as being a breeding ground for insects and rodents. Because of this, the EPA discovered a solution to this issue which was to make a product out of this waste that could be sold commercially. The end-of-life tires were to be shredded into smaller pieces that could then have many uses. These shredded pieces of tire would go on to be known as crumb rubber (CR).

One of the most common and popular uses of CR is infill for synthetic playing areas. It is estimated that there are over 12,000 synthetic turf sports fields in the United States, with around 1,200-1,500 new turf fields being installed each year (United States Environmental Protection Agency [EPA], Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry [CDC/ATSDR], & United States Consumer Product Safety Commission [CPSC]/Directorate for Health Sciences, 2016). Amy Griffin, who was an associate head and goalkeeper coach for the University of Washington's women's soccer team for 24 years, compiled a list of athletes from all sports who have been exposed to CR and have been diagnosed with some form of cancer. Coach Griffin's list of athletes comes from Environment & Human Health, Inc. (EHHI) which is a nonprofit organization based in North Haven, Connecticut. As of January 2019, Coach Griffin's list was at 260 total athletes diagnosed with cancer (122 females and 138 males). 203 of the 260 total athletes are soccer players, and 119 of

the 203 soccer players are goalkeepers (EHHI, 2019). Although this list may exhibit bias or confounding variables because the athletes communicated their situation to Coach Griffin, it is worth exploring the possibility that CR may have had an influence on these cancer cases.

In a memorandum to the EPA Headquarters, the EPA Region 08 (2008) office in Denver, Colorado stated that "...children's chronic repeated exposure to tire crumb could present health hazards" and identified four possible CR health hazards to children. In the memo, they support the use of tire crumb when it does not disproportionately present human health hazards. The Denver office ultimately urged EPA Headquarters to investigate this further in order to establish the safety of CR using evidence-based practices. Although the EPA was promoting this product, there had not yet been a risk assessment performed by the agency. At the time, there was very little data to indicate if CR posed a health risk.

Since the 2008 memorandum, many CR studies have been conducted. For the purpose of this study, current literature has been sorted into three categories: 1) CR and cancer incidence, 2) molecular analysis of CR, and 3) previously performed human health risk assessments (HHRAs).

Crumb Rubber and Cancer Incidence

Bleyer and Keegan (2018) investigated synthetic turf fields in California and the incidence of malignant lymphoma among soccer players. This study investigated if rates of lymphoma among 7,214 individuals between 14 and 30 years old were higher or increasing in regions with more synthetic turf fields. The authors measured lymphoma incidence, synthetic turf field density, race/ethnicity, and income in California's 58 counties to perform a statistical analysis of the data. It was found that there was no association between individual synthetic turf exposure and cancer incidence and there is no need to avoid synthetic turf fields for fear of increased cancer risk (Bleyer & Keegan, 2018).

In agreement with Bleyer and Keegan (2018), Peterson, Lemay, Shubin, and Prueitt (2018) determined that CR in synthetic turf fields poses insignificant risks to human health. This comprehensive multi-pathway study collected all North American data from previous research in order to perform their study. Peterson et al. (2018) investigated ingestion, dermal contact, and inhalation routes in children, adolescent, and adult populations, and found that all evaluated cancerous and non-cancerous scenarios were within EPA guidelines.

Particularly in response to Coach Griffin's list of athletes with cancer, the Washington State Department of Health (WSDOH) conducted a related investigation in 2017. The objectives of this report were to "1) compare the number of cancers among soccer players on the coach's list to the number that would be expected if rates of cancer among soccer players were the same as rates among all Washington residents of the same ages and 2) describe individuals reported by the coach in terms of their demographics, factors related to cancer, and history of playing soccer and other sports" (WSDOH, 2017). The department stated that their report was not designed to investigate if CR exposures increased the overall risk of cancer in soccer players. The WSDOH report supports the findings of Bleyer and Keegan (2018) and Peterson et al. (2018) that CR does not present significant human health risks.

Molecular Analysis of Crumb Rubber

A study was performed to evaluate the presence of 40 organic compounds in CR, including adipates, antioxidants, polycyclic aromatic hydrocarbons (PAHs), phthalates, and vulcanization additives, as well as to determine the release of these organic compounds from the CR to the water and air (Celeiro, Dagnac, & Llompart, 2018). Crumb rubber samples were collected from 15 synthetic turf fields in Santiago de Compostela, Spain. The authors also collected runoff water samples from the fields. Ultrasound assisted extraction (UAE) was used to

extract the target compounds from the collected CR samples and gas chromatography-mass spectrometry (GC-MS) was used to analyze the target compounds. Solid phase microextraction (SPME) was used to analyze the runoff water samples and the air above the synthetic turf surfaces. Celeiro et al. (2018) revealed that 24 of the 40 target compounds, including 14 of the 16 PAHs listed by the EPA, and high concentrations of various heavy metals were detected in the analyzed CR. It was also revealed that target compounds were found in the water and air samples (Celeiro et al., 2018). Because of these findings, the authors recommend that regulations to the use of these fields should be accepted moving forward.

Li, Berger, Musante, and Mattina (2010) also characterized compounds found within CR samples. The researchers developed methods to identify organic compounds in the vapor phase and leachate from the CR by using GC-MS and SPME. Ten volatile compounds were identified in the vapor phase with benzothiazole (BTZ) as the highest detected volatile compound in all tested samples. This study was intended to characterize molecular compounds discovered in CR. In contrast to Celeiro et al. (2018), Li et al. (2010) does not address any human health risks associated with CR.

Previously Performed Human Health Risk Assessments

Ginsburg et al. (2011) performed a HHRA of five synthetic turf fields in Connecticut. The authors found 27 chemicals of potential concern (COPCs) in their samples from both indoor and outdoor fields. This study found that there were no elevated health risks with exposure to CR. Furthermore, Ginsburg et al. (2011) recommend that building operators of indoor fields provide adequate ventilation in order to prevent a buildup of CR related volatile organic chemicals (VOCs) and semi-volatile organic chemicals (SVOCs).

Kim et al. (2012) performed a health risk assessment focusing on lead ingestion exposure and its relationship with the individual particle sizes of CR on synthetic turf with the consideration of bioavailability. This study used particle sizes more and less than 250 μm to evaluate ingestion exposure. The CR samples and bioavailability were analyzed by using the body ingestion exposure estimate method. In contrast to much of the literature described, Kim et al. (2012) showed that as the particle size of CR gets smaller, lead ingestion exposure and risk level increases. Furthermore, it was calculated that some of the study's populations exceeded the maximum hazard index (HI). More studies should be conducted to support or reject these results.

Many items that individuals use in everyday life, such as cell phones and laptops, contain some sort of chemical that may present health risks. The question that remains is if the chemicals found in CR are at high enough concentrations to impose various human health effects. The purpose of this study was to investigate the level of health risk CR poses to exposed human populations, particularly individuals 6-21 years old.

Methods

The current study conducted a HHRA with procedures provided by the EPA (2017a). This risk assessment was conducted in four phases with an initial planning phase: 1) hazard identification, 2) dose-response assessment, 3) exposure assessment, and 4) risk characterization.

Planning

The initial phase of this HHRA was to organize preliminary information about CR. This information included the environmental hazard of concern, the populations who may be affected, various routes of exposure, how the body reacts (i.e. absorption, distribution, excretion, or metabolism) to the hazard, the influence of demographics, the duration of exposure in which the hazard causes a toxic effect (i.e. acute – within 24 hours, subchronic – weeks to months totaling

less than 10% of the human lifespan, chronic – at least seven years, or intermittent), and the overall health effects of the hazard.

The current study investigated a population consisting of individuals between 6 and 21 years old who are chronically exposed to the material. It is observed that there are insignificant health effects when this population is acutely, subchronically, or intermittently exposed to CR which allows for the exclusion of these timeframes. Ingestion and inhalation of the material were the routes of exposure for non-carcinogenic and carcinogenic assessment.

Hazard Identification

The first phase of this HHRA was to identify the types of health effects that CR may cause or influence. Furthermore, the weight of evidence (WOE) for the identifications were categorized into five classes:

- Class A: carcinogenic to humans
- Class B: probable carcinogen
 - B1 – indicates some human evidence
 - B2 – indicates evidence in animals and limited or no evidence in humans
- Class C: suggestive evidence of carcinogenic potential
- Class D: not classifiable
- Class E: evidence of non-carcinogenicity

This phase of the HHRA determined if CR exposure increases the incidence of health effects. Because this study examined COPCs within CR, the available scientific data on these compounds were collected and the WOE of each COPC was categorized to establish a potential correlation between the chemicals and the health effects they may cause. This is important

because exposure to a chemical may cause more than one health effect. Figure 1 depicts the Hazard Identification phase.

Dose-Response Assessment

The second phase of this HHRA was to describe the relationship between a dose and its health effect. A dose-response relationship measures the likelihood and severity of health effects (the responses) in relation to the amount and condition of exposure to CR (the dose). Another name for this relationship is concentration-response, which focuses on the concentration of a chemical. An exposure-response relationship is the general term for the two previously mentioned, in which it is a relationship between the duration, frequency, and intensity of an exposure and the duration, frequency, and intensity of the biological response to that exposure.

In general, there is a positive correlation between a dose and its response, denoting that as the dose increases, the measured response also increases. However, there may not be detectable responses at low doses. Responses begin to be detected in a portion of the investigated population at a certain dose level. Moreover, the dose at which a response appears and the rate at which the response increases may vary between exposure routes, individuals, pollutants, etc. The shape of the relationship depends on the CR sample, the responses it may trigger, and the experimental subject (i.e. humans) being investigated.

Intake dose (ID) for the three life stages (6 to <11 years old, 11 to <16 years old, and 16 to <21 years old as recommended by the EPA) via ingestion and inhalation routes was calculated as: $ID (mg) = COPC \text{ Average Concentration } (\mu g/g) \times Intake \text{ Rate } (mg/day \text{ or } m^3/day) \times Exposure \text{ Duration } (days)$. ID was used to calculate lifetime average daily dose (LADD), also called chronic daily intake (CDI), and was calculated as: $LADD (mg/kg -$

$$day) = \frac{ID (mg)}{Body \text{ Weight } (kg) \times Lifetime (days)}.$$

Non-linear dose-response assessment.

Non-linear dose-response assessment is used for non-carcinogenic scenarios and states that exposures from zero to some value may be tolerated with no possibility of response expression. Moreover, the dose threshold is where the responses or their precursors start to show. Dose-response assessment is termed non-linear if mode of action (MOA, a sequence of processes that explains an agent's interaction with a cell) suggests that the dose has a threshold. A non-linear assessment uses a dose-response relationship whose slope is zero (no response) at a dose of zero or possibly above zero.

Reference dose (RfD), expressed in mg/kg-day, estimates oral or dermal exposure of a dose likely to be without a significant risk of health effects to the human population. Reference concentration (RfC), expressed in mg/m³, estimates inhalation exposure of a dose likely to be without a significant risk of health effects to the human population. Hazard quotient (HQ) is the probability that an individual will develop non-carcinogenic health effects in their lifetime due to a dose. HQ is calculated as: $HQ = \frac{LADD}{RfD \text{ or } RfC}$. HQ greater than one is considered statistically significant.

Linear dose-response assessment.

Linear dose-response assessment is used for carcinogenic scenarios and states that there is at least a small probability of producing a carcinogenic response for any level of exposure to a carcinogenic dose. Dose-response assessment is termed linear if the MOA suggests that the dose does not have a threshold. Furthermore, linear extrapolation is used if the MOA data is lacking. A linear assessment uses a dose-response relationship whose slope is the straight line from the origin (zero dose and zero response) to the benchmark dose lower-confidence limit (BMDL) for the observed data. The slope of this straight line is called the oral slope factor (OSF) and is used

to estimate risks at exposure levels that fall along the line (EPA, 2005). Inhalation unit risk (IUR) is a similar term and is used to assess carcinogenic inhalation risks.

Excess lifetime cancer risk (ELCR) is the probability that an individual will develop cancer in their lifetime due to exposure to a carcinogenic dose. ELCR is obtained from exposure and OSF or IUR and is calculated as: $ELCR = LADD (mg/kg - day) \times OSF \text{ or } IUR (kg - day/mg \text{ or } m^3/\mu g)$. ELCR outside of $1 \times 10^{-6} < x < 1 \times 10^{-4}$ is considered statistically significant. Figure 2 depicts the Dose-Response Assessment phase.

Exposure Assessment

The third phase of this HHRA was to calculate a numerical estimate of exposure or dose. Exposure assessment is the process estimating the duration, frequency, and magnitude of human exposure to CR in the environment (EPA, 2019). Furthermore, this phase estimates future exposures that have not been published. An exposure assessment includes a discussion of the nature, size, and types of exposed human populations.

This phase considers both the pathway (the course CR takes from its source to the affected population) and the route (how CR enters the body). Moreover, the type of dose that was examined was the potential dose as it is the amount of CR or chemical that is ingested or inhaled. The approach used for quantifying exposure was scenario evaluation (indirect measurement), which is exposure estimated by separately measuring exposure concentration and time of contact, then combining them in calculation. HI was calculated by summing the average combined (ingestion and inhalation) HQs and total cancer risk (TCR) was calculated by summing the average combined ELCRs. Range of exposure is another consideration of the exposure assessment. Some individuals may have a higher degree of contact while others may have a lower degree of contact to CR. Figure 3 depicts the Exposure Assessment phase.

Risk Characterization

The fourth and final phase of this HHRA was to integrate and summarize the data from the previous phases in order to achieve an overall conclusion about the risk of CR (EPA, 2000).

Risk characterization is a concise recommendation including:

1. Type and presence/absence of risks as well as how the evaluation was conducted
2. If assumptions and uncertainties still exist
3. The potential policy choices or changes that need to be made

Transparency, clarity, consistency, and reasonableness (TCCR) should be applied to achieve proper risk characterization. A thorough characterization upholds these four principles:

- Transparency: research contains full and explicit statement of assumptions, extrapolations, logic, methods, rationale, strength, and uncertainties
- Clarity: text, tables, and figures are easily understood by readers and concise, professional language is used
- Consistency: research presented in a manner consistent with EPA policy and other published works
- Reasonableness: research based on reliable judgment, using evidence-based practices to accomplish a study that is balanced, complete, and informative

Subsequently, conclusions and inferences were made to characterize the risk to human health from CR exposures. The Discussion section was reserved for this phase of the HHRA.

Figure 4 depicts the Risk Characterization phase.

Results

Hazard Identification

There are various health effects that CR may cause or influence. It was identified that COPCs target specific organs or organ systems via ingestion and inhalation routes, including dermal, developmental, endocrine, hematological, hepatic, immunological, neurological, reproductive, respiratory, systemic, urinary, and other systems. Identifying the biological systems potentially affected by CR was sufficient for the purposes of this study. Therefore, isolating certain health effects was unnecessary to fulfill the goals set forth.

The EPA, CDC/ATSDR, and CPSC/Directorate for Health Sciences (2019) compiled 355 total chemical constituents from multiple published research studies that could be potentially found in CR. The current study examined 86 of the 355 COPCs. Furthermore, this study investigated 29 additional COPCs that were compiled from individual research articles exploring similar health effects, totaling 115 COPCs deemed to be of primary concern. There were 36 VOCs, 55 SVOCs (including all 16 EPA PAHs), and 24 elements analyzed.

All 115 COPCs were categorized into the five WOE classes based on published data by the EPA and others. There were eight in Class A, four in Class B1, 11 in Class B2, 15 in Class C, 77 in Class D, and zero in Class E. Each COPC was sorted by alphabetical order and assigned a classification number 1-115. Classification numbers, COPCs, their abbreviations, and average concentrations in CR are depicted in Table 2.

Dose-Response Assessment

Calculations for ingestion and inhalation ID and LADD required life stage data provided by the EPA. Life stage data are depicted in Table 1. Ingestion and inhalation ID (mean \pm one standard deviation) for the three life stages were calculated. Ingestion ID was $1.38 \times 10^5 \pm$

3.30×10^5 mg for each life stage. Inhalation ID was $1.51 \times 10^4 \pm 3.60 \times 10^4$ mg, $1.91 \times 10^4 \pm 4.56 \times 10^4$ mg, and $2.05 \times 10^4 \pm 4.89 \times 10^4$ mg, respectively. Ingestion and inhalation LADD (mean \pm one standard deviation) for the three life stages were then calculated. Ingestion LADD was $1.53 \times 10^{-1} \pm 3.64 \times 10^{-1}$ mg/kg-day, $8.55 \times 10^{-2} \pm 2.04 \times 10^{-1}$ mg/kg-day, and $6.78 \times 10^{-2} \pm 1.62 \times 10^{-1}$ mg/kg-day, respectively. Inhalation LADD was $1.67 \times 10^{-2} \pm 3.97 \times 10^{-2}$ mg/kg-day, $1.18 \times 10^{-2} \pm 2.82 \times 10^{-2}$ mg/kg-day, and $1.00 \times 10^{-2} \pm 2.40 \times 10^{-2}$ mg/kg-day, respectively. Data for each COPC and the sums, means, and standard deviations of this preliminary dose-response assessment are depicted in Table 3.

Ingestion and inhalation HQ (mean \pm one standard deviation) for the three life stages were calculated. Ingestion HQ was $3.30 \times 10^{-1} \pm 5.66 \times 10^{-1}$, $1.85 \times 10^{-1} \pm 3.17 \times 10^{-1}$, and $1.46 \times 10^{-1} \pm 2.51 \times 10^{-1}$, respectively. Inhalation HQ was $7.94 \times 10^{-2} \pm 2.31 \times 10^{-1}$, $5.63 \times 10^{-2} \pm 1.64 \times 10^{-1}$, and $4.79 \times 10^{-2} \pm 1.39 \times 10^{-1}$, respectively. Data for each COPC, RfD and RfC values (collected from multiple sources), and the sums, means, and standard deviations of the non-linear dose-response assessment are depicted in Table 4. If a given COPC RfD or RfC was not provided, it was assigned $0.00 \times 10^{+0}$.

Ingestion and inhalation ELCR (mean \pm one standard deviation) for the three life stages were calculated. Ingestion ELCR was $9.15 \times 10^{-4} \pm 3.77 \times 10^{-3}$, $5.12 \times 10^{-4} \pm 2.11 \times 10^{-3}$, and $4.07 \times 10^{-4} \pm 1.67 \times 10^{-3}$, respectively. Inhalation ELCR was $4.80 \times 10^{-4} \pm 4.01 \times 10^{-3}$, $3.40 \times 10^{-4} \pm 2.85 \times 10^{-3}$, and $2.90 \times 10^{-4} \pm 2.42 \times 10^{-3}$, respectively. Data for each COPC, OSF and IUR values (collected from multiple sources), and the sums, means, and standard deviations of the linear dose-response assessment are depicted in Table 5. If a given COPC OSF or IUR was not provided, it was assigned $0.00 \times 10^{+0}$.

Exposure Assessment

By utilizing RfD, RfC, OSF, and IUR, this study focused on the ingestion and inhalation routes of exposure. Other routes of exposure given by the EPA (2019) include dermal, the eyes, and injections. This study examined ingestion and inhalation because ingestion often occurs accidentally or unknowingly, and inhalation tends to be the easiest and fastest route of exposure.

The exposure pathway was observed in three parts: 1) the source of contamination (synthetic turf fields, children's playgrounds, and other locations where individuals 6-21 years old may be exposed to CR), 2) the mode of travel (surface soil, surface water, and air), and 3) the point of exposure (an individual's mouth and nose).

HI was calculated by summing the average combined HQ of each COPC and was found to be $1.62 \times 10^{+1}$. TCR was calculated by summing the average combined ELCR of each COPC and was found to be 5.64×10^{-2} .

Although this study focused on individuals 6-21 years old, the population group who may be exposed are those who engage in activity on surfaces that contain CR, such as synthetic turf fields. Those who live near or in areas where synthetic turf fields are concentrated may also be in this population group. Furthermore, those who live near CR manufacturing and production plants may be exposed.

Discussion

The primary objective of this study was to explore the potential health risks of CR when individuals 6-21 years old are exposed to CR. Most of the COPCs examined were not classifiable to human carcinogenicity, meaning that there was inadequate data to support or reject human carcinogenicity. There was at least a small amount of each COPC examined in CR. The average concentrations were collected from multiple research studies which sampled CR at different

locations across the United States of America (USA). Moreover, COPCs may have different concentrations because of the manufacturing, production, and treatment of the material.

It is important to note that for COPCs that have RfD, RfC, OSF, and IUR assigned $0.00 \times 10^{+0}$, these values had not yet been assessed by the EPA or others. Thus, this study could not accurately assess these COPCs because key data was unavailable. These COPCs may not have a calculated HQ or ELCR and may not contribute to HI or TCR.

Average combined HQ and ELCR of each COPC was less than one and $1 \times 10^{-6} < x < 1 \times 10^{-4}$, respectively. Consequently, there were no statistically significant values to establish a correlation between a COPC and a potential non-carcinogenic or carcinogenic response. Furthermore, HI and TCR were not statistically significant. Based on the findings of this study, health effects may not be observed in individuals 6-21 years old when chronically exposed to CR. When ingestion and inhalation HQ and ELCR values are analyzed separately, there may be potential health risks as a given COPC may prefer to attack via one route of exposure over another. However, average combined HQ and ELCR are sufficient to fulfill the goals of this study. There is still uncertainty if the COPCs examined pose a health risk when their concentrations are increased. Furthermore, it is uncertain how the COPCs interact with the body when they are ingested or inhaled in combination with other COPCs.

Limitations of this study include the inability to complete chemical analyses of CR samples due to insufficient time and funding. The total duration for the completion of this study was approximately one year. Research that has been and is currently being conducted by the EPA and other organizations is in process for at least two years. Furthermore, the EPA and others have continuous funding provided by the United States Federal Government and additional financial contributors. The author of this study did not receive any financial contributions to complete the

HHRA. An additional limitation is the lack of reference data for COPCs provided by the EPA and other organizations. Because key data was unavailable prior to the completion of this study, HQ and ELCR for some COPCs were not calculated.

Further research should investigate CR samples in southeastern Michigan to address local health concerns. Other locations, such as where several synthetic turf fields are concentrated in one geographical area, should be of interest. Factors not considered in the current study, including but not limited to outdoor vs. indoor synthetic turf fields, air temperature, sunray UV exposure directly on CR, weather events, etc., and the influences of each should be explored to determine potential correlations to negative health effects. Future studies should target specific COPCs deemed to be of biological and environmental concern. Lastly, future studies should fill the research gaps as designated by the EPA, CDC/ATSDR, and CPSC/Directorate for Health Sciences (2019; 2016) and other organizations.

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Tables

Table 1

EPA Life Stage Data

Factors	6 to <11 years old	11 to <16 years old	16 to <21 years old
Ingestion Rate (mg/day)	110	110	110
Inhalation Rate (m ³ /day)	12	15.2	16.3
Exposure Duration (days)	1825	1825	1825
Weight (kg)	31.8	56.8	71.6
Lifetime (days)	28470	28470	28470

Note: All values were taken directly from the EPA (2019; 2011).

Table 2

Hazard Identification Data

Classification Number	COPC Name	Key	Average Concentration (µg/g)
1	1,1,1-Trichloroethane*	1,1,1-TCE	1.00E-05
2	1,1-Dichloroethane*	1,1-DCA	1.00E-05
3	1,1-Dichloroethylene*	1,1-DCE	1.00E-02
4	1,2-Dichlorobenzene*	1,2-DCB	1.00E-05
5	1,2-Dichloroethane*	1,2-DCA	1.00E-05
6	1,2-Dichloroethylene*	1,2-DCE	1.10E-03
7	1,2-Dichloropropane*	1,2-DCP	1.00E-05
8	1,3,5-Trimethylbenzene*	1,3,5-TMB	1.00E-01
9	1,3-Butadiene*	1,3-BD	1.00E-05
10	1,3-Dichlorobenzene*	1,3-DCB	1.90E-03
11	1,4-Dichlorobenzene*	1,4-DCB	1.90E-03
12	1-Methylnaphthalene%	1-MN	5.00E-02
13	1-Methylphenanthrene%	1-MP	1.60E+00
14	2-(Bromomethyl)naphthalene%	2-BMN	1.00E-05
15	2-Mercaptobenzothiazole%	2-MBT	1.80E-04
16	2-Methylnaphthalene%	2-MN	8.30E-03
17	2-Methylphenanthrene%	2-MP	3.00E+00
18	3-Methylphenanthrene%	3-MP	2.30E+00
19	4-Ethyltoluene*	4-ET	2.60E-01
20	4-tert-butylphenol%	4-TBP	8.20E-01
21	4-tert-octylphenol%	4-TOP	9.80E+00
22	Acenaphthene%#	ACE	8.90E-02
23	Acenaphthylene%#	ACY	4.60E-02
24	Acetone*	ACT	2.90E-01
25	Aluminum^	Al	1.30E-01
26	Aniline%	ANI	2.00E-03
27	Anthracene%#	ANC	5.20E-01
28	Antimony^	Sb	9.50E-04
29	Arsenic^	As	3.80E-03

Classification Number	COPC Name	Key	Average Concentration (µg/g)
30	Barium [^]	Ba	8.30E-03
31	Benz[a]anthracene ^{%#}	B[a]A	2.20E+00
32	Benzene [*]	BEN	2.10E-04
33	Benzo[a]pyrene ^{%#}	B[a]P	1.00E-05
34	Benzo[b]fluoranthene ^{%#}	B[b]F	1.30E+00
35	Benzo[e]pyrene [%]	B[e]P	1.90E+00
36	Benzo[ghi]perylene ^{%#}	B[ghi]P	1.30E+00
37	Benzo[k]fluoranthene ^{%#}	B[k]F	4.50E-01
38	Benzothiazole [%]	BTZ	1.10E+01
39	Benzyl butyl phthalate [%]	BBP	1.20E+00
40	Beryllium [^]	Be	8.00E-04
41	Bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate [%]	BTPS	7.80E-01
42	Bisphenol A [%]	BPA	4.00E-01
43	Butylated hydroxyanisole [%]	BHA	2.00E-03
44	Butylated hydroxytoluene [%]	BHT	1.30E+00
45	Butylbenzene [%]	BBEN	1.40E-01
46	Cadmium [^]	Cd	9.50E-05
47	Carbon disulfide [*]	CDS	2.40E-01
48	Carbon tetrachloride [*]	CTC	1.00E-05
49	Chlorobenzene [*]	CBEN	2.80E-03
50	Chloromethane [*]	CM	1.00E-03
51	Chromium [^]	Cr	1.60E+00
52	Chrysene ^{%#}	CHY	2.50E+00
53	Cis-2-Butene [*]	C2B	2.00E-01
54	Cobalt [^]	Co	1.40E-04
55	Copper [^]	Cu	2.60E-02
56	Coronene [%]	COR	5.40E-03
57	Cyclohexane [*]	CHX	1.30E+00
58	Cyclohexyl isothiocyanate [%]	CITC	2.50E-01
59	Di(2-ethylhexyl) adipate [%]	DEHA	4.70E+00
60	Di(2-ethylhexyl) phthalate [%]	DEHP	1.00E-01
61	Di(methoxyethyl) phthalate [%]	DMEP	1.00E-05

Classification Number	COPC Name	Key	Average Concentration (µg/g)
62	Dibenz[a,h]anthracene ^{%#}	D[ah]A	9.60E-02
63	Dibenzothiophene [%]	DBT	3.10E-02
64	Dibutyl phthalate [%]	DBP	1.50E-01
65	Dichlorodifluoromethane [*]	DCFM	4.10E-02
66	Dichloromethane [*]	DCM	5.00E-03
67	Dicyclohexyl phthalate [%]	DCHP	1.00E-05
68	Diethyl adipate [%]	DEA	1.00E-05
69	Diethyl phthalate [%]	DEP	5.20E-01
70	Diisobutyl phthalate [%]	DIBP	1.20E+00
71	Diisodecyl phthalate [%]	DIDP	1.00E-05
72	Diisoheptyl phthalate [%]	DIHP	1.00E-05
73	Diisononyl phthalate [%]	DINP	1.00E-05
74	Diisopentyl phthalate [%]	DIPP	1.00E-05
75	Dimethyl adipate [%]	DMA	1.00E-05
76	Dimethyl phthalate [%]	DMP	2.70E-02
77	Dioctyl phthalate [%]	DOP	2.50E-02
78	Dipentyl phthalate [%]	DPP	1.00E-05
79	Diphenyl phthalate [%]	DPhP	1.00E-05
80	Ethylbenzene [*]	EBEN	5.50E-01
81	Fluoranthene ^{%#}	FLA	4.50E-03
82	Fluorene ^{%#}	FLU	1.80E-01
83	Formaldehyde [*]	FOR	1.60E-01
84	Heptane [*]	HP	1.00E-03
85	Hexadecane [%]	HXD	9.40E-01
86	Hexane [*]	HX	2.00E-01
87	Indeno[1,2,3-cd]pyrene ^{%#}	IND	2.00E-02
88	Iron [^]	Fe	6.10E+00
89	Lead [^]	Pb	2.40E-04
90	Magnesium [^]	Mg	3.30E+00
91	Manganese [^]	Mn	7.70E-04
92	Mercury [^]	Hg	3.30E-04
93	Methyl ethyl ketone [*]	MEK	1.20E-01

Classification Number	COPC Name	Key	Average Concentration (µg/g)
94	Methyl isobuetyl ketone*	MIBK	2.40E-01
95	Molybdenum^	Mo	1.60E-02
96	Naphthalene%#	NAP	3.40E-02
97	Nickel^	Ni	2.70E-03
98	Phenanthrene%#	PHN	2.30E+00
99	Pyrene%#	PYR	1.20E-01
100	Rubidium^	Rb	1.90E+00
101	Selenium^	Se	1.00E-05
102	Silver^	Ag	6.00E-03
103	Strontium^	Sr	3.40E+00
104	Styrene*	STY	1.10E+00
105	Tetrachloroethylene*	TECE	1.40E-03
106	Thallium^	Tl	1.00E-04
107	Tin^	Sn	1.60E+00
108	Toluene*	TOL	1.10E-01
109	Trans-2-Butene*	T2B	2.20E-01
110	Trichloroethylene*	TCE	1.00E-05
111	Trichlorofluoromethane*	TCFM	2.30E-01
112	Trichlorotrifluoroethane*	TCFE	1.00E-05
113	Vanadium^	V	1.90E-03
114	Xylenes*	XYL	8.00E-01
115	Zinc^	Zn	1.50E+00
198	SUM	-	7.92E+01
199	MEAN	-	6.89E-01
200	STANDARD DEVIATION	-	1.64E+00

Note: * = volatile organic compound (VOC), % = semi-volatile organic compound (SVOC),

^ = element, # = EPA polycyclic aromatic hydrocarbon (PAH).

Table 3

Preliminary Dose-Response Assessment Data

Classification Number	Ingestion ID 6 to <11 years old (mg)	Ingestion ID 11 to <16 years old (mg)	Ingestion ID 16 to <21 years old (mg)	Inhalation ID 6 to <11 years old (mg)	Inhalation ID 11 to <16 years old (mg)	Inhalation ID 16 to <21 years old (mg)	Ingestion LADD 6 to <11 years old (mg/kg- day)	Ingestion LADD 11 to <16 years old (mg/kg- day)	Ingestion LADD 16 to <21 years old (mg/kg- day)	Inhalation LADD 6 to <11 years old (mg/kg- day)	Inhalation LADD 11 to <16 years old (mg/kg- day)	Inhalation LADD 16 to <21 years old (mg/kg- day)
1	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
2	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
3	2.01E+03	2.01E+03	2.01E+03	2.19E+02	2.77E+02	2.97E+02	2.22E-03	1.24E-03	9.85E-04	2.42E-04	1.72E-04	1.46E-04
4	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
5	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
6	2.21E+02	2.21E+02	2.21E+02	2.41E+01	3.05E+01	3.27E+01	2.44E-04	1.37E-04	1.08E-04	2.66E-05	1.89E-05	1.61E-05
7	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
8	2.01E+04	2.01E+04	2.01E+04	2.19E+03	2.77E+03	2.97E+03	2.22E-02	1.24E-02	9.85E-03	2.42E-03	1.72E-03	1.46E-03
9	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
10	3.81E+02	3.81E+02	3.81E+02	4.16E+01	5.27E+01	5.65E+01	4.21E-04	2.36E-04	1.87E-04	4.60E-05	3.26E-05	2.77E-05
11	3.81E+02	3.81E+02	3.81E+02	4.16E+01	5.27E+01	5.65E+01	4.21E-04	2.36E-04	1.87E-04	4.60E-05	3.26E-05	2.77E-05
12	1.00E+04	1.00E+04	1.00E+04	1.10E+03	1.39E+03	1.49E+03	1.11E-02	6.21E-03	4.92E-03	1.21E-03	8.58E-04	7.30E-04
13	3.21E+05	3.21E+05	3.21E+05	3.50E+04	4.44E+04	4.76E+04	3.55E-01	1.99E-01	1.58E-01	3.87E-02	2.74E-02	2.33E-02
14	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
15	3.61E+01	3.61E+01	3.61E+01	3.94E+00	4.99E+00	5.35E+00	3.99E-05	2.23E-05	1.77E-05	4.35E-06	3.09E-06	2.63E-06
16	1.67E+03	1.67E+03	1.67E+03	1.82E+02	2.30E+02	2.47E+02	1.84E-03	1.03E-03	8.17E-04	2.01E-04	1.42E-04	1.21E-04
17	6.02E+05	6.02E+05	6.02E+05	6.57E+04	8.32E+04	8.92E+04	6.65E-01	3.72E-01	2.95E-01	7.26E-02	5.15E-02	4.38E-02
18	4.62E+05	4.62E+05	4.62E+05	5.04E+04	6.38E+04	6.84E+04	5.10E-01	2.86E-01	2.27E-01	5.56E-02	3.95E-02	3.36E-02

Classification Number	Ingestion ID 6 to <11 years old (mg)	Ingestion ID 11 to <16 years old (mg)	Ingestion ID 16 to <21 years old (mg)	Inhalation ID 6 to <11 years old (mg)	Inhalation ID 11 to <16 years old (mg)	Inhalation ID 16 to <21 years old (mg)	Ingestion LADD 6 to <11 years old (mg/kg- day)	Ingestion LADD 11 to <16 years old (mg/kg- day)	Ingestion LADD 16 to <21 years old (mg/kg- day)	Inhalation LADD 6 to <11 years old (mg/kg- day)	Inhalation LADD 11 to <16 years old (mg/kg- day)	Inhalation LADD 16 to <21 years old (mg/kg- day)
19	5.22E+04	5.22E+04	5.22E+04	5.69E+03	7.21E+03	7.73E+03	5.77E-02	3.23E-02	2.56E-02	6.29E-03	4.46E-03	3.79E-03
20	1.65E+05	1.65E+05	1.65E+05	1.80E+04	2.27E+04	2.44E+04	1.82E-01	1.02E-01	8.08E-02	1.98E-02	1.41E-02	1.20E-02
21	1.97E+06	1.97E+06	1.97E+06	2.15E+05	2.72E+05	2.92E+05	2.17E+00	1.22E+00	9.65E-01	2.37E-01	1.68E-01	1.43E-01
22	1.79E+04	1.79E+04	1.79E+04	1.95E+03	2.47E+03	2.65E+03	1.97E-02	1.10E-02	8.76E-03	2.15E-03	1.53E-03	1.30E-03
23	9.23E+03	9.23E+03	9.23E+03	1.01E+03	1.28E+03	1.37E+03	1.02E-02	5.71E-03	4.53E-03	1.11E-03	7.89E-04	6.71E-04
24	5.82E+04	5.82E+04	5.82E+04	6.35E+03	8.04E+03	8.63E+03	6.43E-02	3.60E-02	2.86E-02	7.01E-03	4.97E-03	4.23E-03
25	2.61E+04	2.61E+04	2.61E+04	2.85E+03	3.61E+03	3.87E+03	2.88E-02	1.61E-02	1.28E-02	3.14E-03	2.23E-03	1.90E-03
26	4.02E+02	4.02E+02	4.02E+02	4.38E+01	5.55E+01	5.95E+01	4.43E-04	2.48E-04	1.97E-04	4.84E-05	3.43E-05	2.92E-05
27	1.04E+05	1.04E+05	1.04E+05	1.14E+04	1.44E+04	1.55E+04	1.15E-01	6.46E-02	5.12E-02	1.26E-02	8.92E-03	7.59E-03
28	1.91E+02	1.91E+02	1.91E+02	2.08E+01	2.64E+01	2.83E+01	2.11E-04	1.18E-04	9.36E-05	2.30E-05	1.63E-05	1.39E-05
29	7.63E+02	7.63E+02	7.63E+02	8.32E+01	1.05E+02	1.13E+02	8.43E-04	4.72E-04	3.74E-04	9.19E-05	6.52E-05	5.55E-05
30	1.67E+03	1.67E+03	1.67E+03	1.82E+02	2.30E+02	2.47E+02	1.84E-03	1.03E-03	8.17E-04	2.01E-04	1.42E-04	1.21E-04
31	4.42E+05	4.42E+05	4.42E+05	4.82E+04	6.10E+04	6.54E+04	4.88E-01	2.73E-01	2.17E-01	5.32E-02	3.77E-02	3.21E-02
32	4.22E+01	4.22E+01	4.22E+01	4.60E+00	5.83E+00	6.25E+00	4.66E-05	2.61E-05	2.07E-05	5.08E-06	3.60E-06	3.06E-06
33	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
34	2.61E+05	2.61E+05	2.61E+05	2.85E+04	3.61E+04	3.87E+04	2.88E-01	1.61E-01	1.28E-01	3.14E-02	2.23E-02	1.90E-02
35	3.81E+05	3.81E+05	3.81E+05	4.16E+04	5.27E+04	5.65E+04	4.21E-01	2.36E-01	1.87E-01	4.60E-02	3.26E-02	2.77E-02
36	2.61E+05	2.61E+05	2.61E+05	2.85E+04	3.61E+04	3.87E+04	2.88E-01	1.61E-01	1.28E-01	3.14E-02	2.23E-02	1.90E-02
37	9.03E+04	9.03E+04	9.03E+04	9.86E+03	1.25E+04	1.34E+04	9.98E-02	5.59E-02	4.43E-02	1.09E-02	7.72E-03	6.57E-03
38	2.21E+06	2.21E+06	2.21E+06	2.41E+05	3.05E+05	3.27E+05	2.44E+00	1.37E+00	1.08E+00	2.66E-01	1.89E-01	1.61E-01
39	2.41E+05	2.41E+05	2.41E+05	2.63E+04	3.33E+04	3.57E+04	2.66E-01	1.49E-01	1.18E-01	2.90E-02	2.06E-02	1.75E-02
40	1.61E+02	1.61E+02	1.61E+02	1.75E+01	2.22E+01	2.38E+01	1.77E-04	9.93E-05	7.88E-05	1.94E-05	1.37E-05	1.17E-05

Classification Number	Ingestion ID 6 to <11 years old (mg)	Ingestion ID 11 to <16 years old (mg)	Ingestion ID 16 to <21 years old (mg)	Inhalation ID 6 to <11 years old (mg)	Inhalation ID 11 to <16 years old (mg)	Inhalation ID 16 to <21 years old (mg)	Ingestion LADD 6 to <11 years old (mg/kg- day)	Ingestion LADD 11 to <16 years old (mg/kg- day)	Ingestion LADD 16 to <21 years old (mg/kg- day)	Inhalation LADD 6 to <11 years old (mg/kg- day)	Inhalation LADD 11 to <16 years old (mg/kg- day)	Inhalation LADD 16 to <21 years old (mg/kg- day)
41	1.57E+05	1.57E+05	1.57E+05	1.71E+04	2.16E+04	2.32E+04	1.73E-01	9.68E-02	7.68E-02	1.89E-02	1.34E-02	1.14E-02
42	8.03E+04	8.03E+04	8.03E+04	8.76E+03	1.11E+04	1.19E+04	8.87E-02	4.97E-02	3.94E-02	9.68E-03	6.86E-03	5.84E-03
43	4.02E+02	4.02E+02	4.02E+02	4.38E+01	5.55E+01	5.95E+01	4.43E-04	2.48E-04	1.97E-04	4.84E-05	3.43E-05	2.92E-05
44	2.61E+05	2.61E+05	2.61E+05	2.85E+04	3.61E+04	3.87E+04	2.88E-01	1.61E-01	1.28E-01	3.14E-02	2.23E-02	1.90E-02
45	2.81E+04	2.81E+04	2.81E+04	3.07E+03	3.88E+03	4.16E+03	3.10E-02	1.74E-02	1.38E-02	3.39E-03	2.40E-03	2.04E-03
46	1.91E+01	1.91E+01	1.91E+01	2.08E+00	2.64E+00	2.83E+00	2.11E-05	1.18E-05	9.36E-06	2.30E-06	1.63E-06	1.39E-06
47	4.82E+04	4.82E+04	4.82E+04	5.26E+03	6.66E+03	7.14E+03	5.32E-02	2.98E-02	2.36E-02	5.81E-03	4.12E-03	3.50E-03
48	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
49	5.62E+02	5.62E+02	5.62E+02	6.13E+01	7.77E+01	8.33E+01	6.21E-04	3.48E-04	2.76E-04	6.77E-05	4.80E-05	4.09E-05
50	2.01E+02	2.01E+02	2.01E+02	2.19E+01	2.77E+01	2.97E+01	2.22E-04	1.24E-04	9.85E-05	2.42E-05	1.72E-05	1.46E-05
51	3.21E+05	3.21E+05	3.21E+05	3.50E+04	4.44E+04	4.76E+04	3.55E-01	1.99E-01	1.58E-01	3.87E-02	2.74E-02	2.33E-02
52	5.02E+05	5.02E+05	5.02E+05	5.48E+04	6.94E+04	7.44E+04	5.54E-01	3.10E-01	2.46E-01	6.05E-02	4.29E-02	3.65E-02
53	4.02E+04	4.02E+04	4.02E+04	4.38E+03	5.55E+03	5.95E+03	4.43E-02	2.48E-02	1.97E-02	4.84E-03	3.43E-03	2.92E-03
54	2.81E+01	2.81E+01	2.81E+01	3.07E+00	3.88E+00	4.16E+00	3.10E-05	1.74E-05	1.38E-05	3.39E-06	2.40E-06	2.04E-06
55	5.22E+03	5.22E+03	5.22E+03	5.69E+02	7.21E+02	7.73E+02	5.77E-03	3.23E-03	2.56E-03	6.29E-04	4.46E-04	3.79E-04
56	1.08E+03	1.08E+03	1.08E+03	1.18E+02	1.50E+02	1.61E+02	1.20E-03	6.70E-04	5.32E-04	1.31E-04	9.26E-05	7.88E-05
57	2.61E+05	2.61E+05	2.61E+05	2.85E+04	3.61E+04	3.87E+04	2.88E-01	1.61E-01	1.28E-01	3.14E-02	2.23E-02	1.90E-02
58	5.02E+04	5.02E+04	5.02E+04	5.48E+03	6.94E+03	7.44E+03	5.54E-02	3.10E-02	2.46E-02	6.05E-03	4.29E-03	3.65E-03
59	9.44E+05	9.44E+05	9.44E+05	1.03E+05	1.30E+05	1.40E+05	1.04E+00	5.83E-01	4.63E-01	1.14E-01	8.06E-02	6.86E-02
60	2.01E+04	2.01E+04	2.01E+04	2.19E+03	2.77E+03	2.97E+03	2.22E-02	1.24E-02	9.85E-03	2.42E-03	1.72E-03	1.46E-03
61	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
62	1.93E+04	1.93E+04	1.93E+04	2.10E+03	2.66E+03	2.86E+03	2.13E-02	1.19E-02	9.45E-03	2.32E-03	1.65E-03	1.40E-03

Classification Number	Ingestion ID 6 to <11 years old (mg)	Ingestion ID 11 to <16 years old (mg)	Ingestion ID 16 to <21 years old (mg)	Inhalation ID 6 to <11 years old (mg)	Inhalation ID 11 to <16 years old (mg)	Inhalation ID 16 to <21 years old (mg)	Ingestion LADD 6 to <11 years old (mg/kg- day)	Ingestion LADD 11 to <16 years old (mg/kg- day)	Ingestion LADD 16 to <21 years old (mg/kg- day)	Inhalation LADD 6 to <11 years old (mg/kg- day)	Inhalation LADD 11 to <16 years old (mg/kg- day)	Inhalation LADD 16 to <21 years old (mg/kg- day)
63	6.22E+03	6.22E+03	6.22E+03	6.79E+02	8.60E+02	9.22E+02	6.87E-03	3.85E-03	3.05E-03	7.50E-04	5.32E-04	4.52E-04
64	3.01E+04	3.01E+04	3.01E+04	3.29E+03	4.16E+03	4.46E+03	3.33E-02	1.86E-02	1.48E-02	3.63E-03	2.57E-03	2.19E-03
65	8.23E+03	8.23E+03	8.23E+03	8.98E+02	1.14E+03	1.22E+03	9.09E-03	5.09E-03	4.04E-03	9.92E-04	7.03E-04	5.98E-04
66	1.00E+03	1.00E+03	1.00E+03	1.10E+02	1.39E+02	1.49E+02	1.11E-03	6.21E-04	4.92E-04	1.21E-04	8.58E-05	7.30E-05
67	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
68	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
69	1.04E+05	1.04E+05	1.04E+05	1.14E+04	1.44E+04	1.55E+04	1.15E-01	6.46E-02	5.12E-02	1.26E-02	8.92E-03	7.59E-03
70	2.41E+05	2.41E+05	2.41E+05	2.63E+04	3.33E+04	3.57E+04	2.66E-01	1.49E-01	1.18E-01	2.90E-02	2.06E-02	1.75E-02
71	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
72	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
73	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
74	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
75	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
76	5.42E+03	5.42E+03	5.42E+03	5.91E+02	7.49E+02	8.03E+02	5.99E-03	3.35E-03	2.66E-03	6.53E-04	4.63E-04	3.94E-04
77	5.02E+03	5.02E+03	5.02E+03	5.48E+02	6.94E+02	7.44E+02	5.54E-03	3.10E-03	2.46E-03	6.05E-04	4.29E-04	3.65E-04
78	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
79	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
80	1.10E+05	1.10E+05	1.10E+05	1.20E+04	1.53E+04	1.64E+04	1.22E-01	6.83E-02	5.42E-02	1.33E-02	9.43E-03	8.03E-03
81	9.03E+02	9.03E+02	9.03E+02	9.86E+01	1.25E+02	1.34E+02	9.98E-04	5.59E-04	4.43E-04	1.09E-04	7.72E-05	6.57E-05
82	3.61E+04	3.61E+04	3.61E+04	3.94E+03	4.99E+03	5.35E+03	3.99E-02	2.23E-02	1.77E-02	4.35E-03	3.09E-03	2.63E-03
83	3.21E+04	3.21E+04	3.21E+04	3.50E+03	4.44E+03	4.76E+03	3.55E-02	1.99E-02	1.58E-02	3.87E-03	2.74E-03	2.33E-03
84	2.01E+02	2.01E+02	2.01E+02	2.19E+01	2.77E+01	2.97E+01	2.22E-04	1.24E-04	9.85E-05	2.42E-05	1.72E-05	1.46E-05

Classification Number	Ingestion ID 6 to <11 years old (mg)	Ingestion ID 11 to <16 years old (mg)	Ingestion ID 16 to <21 years old (mg)	Inhalation ID 6 to <11 years old (mg)	Inhalation ID 11 to <16 years old (mg)	Inhalation ID 16 to <21 years old (mg)	Ingestion LADD 6 to <11 years old (mg/kg-day)	Ingestion LADD 11 to <16 years old (mg/kg-day)	Ingestion LADD 16 to <21 years old (mg/kg-day)	Inhalation LADD 6 to <11 years old (mg/kg-day)	Inhalation LADD 11 to <16 years old (mg/kg-day)	Inhalation LADD 16 to <21 years old (mg/kg-day)
85	1.89E+05	1.89E+05	1.89E+05	2.06E+04	2.61E+04	2.80E+04	2.08E-01	1.17E-01	9.26E-02	2.27E-02	1.61E-02	1.37E-02
86	4.02E+04	4.02E+04	4.02E+04	4.38E+03	5.55E+03	5.95E+03	4.43E-02	2.48E-02	1.97E-02	4.84E-03	3.43E-03	2.92E-03
87	4.02E+03	4.02E+03	4.02E+03	4.38E+02	5.55E+02	5.95E+02	4.43E-03	2.48E-03	1.97E-03	4.84E-04	3.43E-04	2.92E-04
88	1.22E+06	1.22E+06	1.22E+06	1.34E+05	1.69E+05	1.81E+05	1.35E+00	7.57E-01	6.01E-01	1.48E-01	1.05E-01	8.90E-02
89	4.82E+01	4.82E+01	4.82E+01	5.26E+00	6.66E+00	7.14E+00	5.32E-05	2.98E-05	2.36E-05	5.81E-06	4.12E-06	3.50E-06
90	6.62E+05	6.62E+05	6.62E+05	7.23E+04	9.15E+04	9.82E+04	7.32E-01	4.10E-01	3.25E-01	7.98E-02	5.66E-02	4.82E-02
91	1.55E+02	1.55E+02	1.55E+02	1.69E+01	2.14E+01	2.29E+01	1.71E-04	9.56E-05	7.58E-05	1.86E-05	1.32E-05	1.12E-05
92	6.62E+01	6.62E+01	6.62E+01	7.23E+00	9.15E+00	9.82E+00	7.32E-05	4.10E-05	3.25E-05	7.98E-06	5.66E-06	4.82E-06
93	2.41E+04	2.41E+04	2.41E+04	2.63E+03	3.33E+03	3.57E+03	2.66E-02	1.49E-02	1.18E-02	2.90E-03	2.06E-03	1.75E-03
94	4.82E+04	4.82E+04	4.82E+04	5.26E+03	6.66E+03	7.14E+03	5.32E-02	2.98E-02	2.36E-02	5.81E-03	4.12E-03	3.50E-03
95	3.21E+03	3.21E+03	3.21E+03	3.50E+02	4.44E+02	4.76E+02	3.55E-03	1.99E-03	1.58E-03	3.87E-04	2.74E-04	2.33E-04
96	6.83E+03	6.83E+03	6.83E+03	7.45E+02	9.43E+02	1.01E+03	7.54E-03	4.22E-03	3.35E-03	8.22E-04	5.83E-04	4.96E-04
97	5.42E+02	5.42E+02	5.42E+02	5.91E+01	7.49E+01	8.03E+01	5.99E-04	3.35E-04	2.66E-04	6.53E-05	4.63E-05	3.94E-05
98	4.62E+05	4.62E+05	4.62E+05	5.04E+04	6.38E+04	6.84E+04	5.10E-01	2.86E-01	2.27E-01	5.56E-02	3.95E-02	3.36E-02
99	2.41E+04	2.41E+04	2.41E+04	2.63E+03	3.33E+03	3.57E+03	2.66E-02	1.49E-02	1.18E-02	2.90E-03	2.06E-03	1.75E-03
100	3.81E+05	3.81E+05	3.81E+05	4.16E+04	5.27E+04	5.65E+04	4.21E-01	2.36E-01	1.87E-01	4.60E-02	3.26E-02	2.77E-02
101	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
102	1.20E+03	1.20E+03	1.20E+03	1.31E+02	1.66E+02	1.78E+02	1.33E-03	7.45E-04	5.91E-04	1.45E-04	1.03E-04	8.76E-05
103	6.83E+05	6.83E+05	6.83E+05	7.45E+04	9.43E+04	1.01E+05	7.54E-01	4.22E-01	3.35E-01	8.22E-02	5.83E-02	4.96E-02
104	2.21E+05	2.21E+05	2.21E+05	2.41E+04	3.05E+04	3.27E+04	2.44E-01	1.37E-01	1.08E-01	2.66E-02	1.89E-02	1.61E-02
105	2.81E+02	2.81E+02	2.81E+02	3.07E+01	3.88E+01	4.16E+01	3.10E-04	1.74E-04	1.38E-04	3.39E-05	2.40E-05	2.04E-05
106	2.01E+01	2.01E+01	2.01E+01	2.19E+00	2.77E+00	2.97E+00	2.22E-05	1.24E-05	9.85E-06	2.42E-06	1.72E-06	1.46E-06

Classification Number	Ingestion ID 6 to <11 years old (mg)	Ingestion ID 11 to <16 years old (mg)	Ingestion ID 16 to <21 years old (mg)	Inhalation ID 6 to <11 years old (mg)	Inhalation ID 11 to <16 years old (mg)	Inhalation ID 16 to <21 years old (mg)	Ingestion LADD 6 to <11 years old (mg/kg- day)	Ingestion LADD 11 to <16 years old (mg/kg- day)	Ingestion LADD 16 to <21 years old (mg/kg- day)	Inhalation LADD 6 to <11 years old (mg/kg- day)	Inhalation LADD 11 to <16 years old (mg/kg- day)	Inhalation LADD 16 to <21 years old (mg/kg- day)
107	3.21E+05	3.21E+05	3.21E+05	3.50E+04	4.44E+04	4.76E+04	3.55E-01	1.99E-01	1.58E-01	3.87E-02	2.74E-02	2.33E-02
108	2.21E+04	2.21E+04	2.21E+04	2.41E+03	3.05E+03	3.27E+03	2.44E-02	1.37E-02	1.08E-02	2.66E-03	1.89E-03	1.61E-03
109	4.42E+04	4.42E+04	4.42E+04	4.82E+03	6.10E+03	6.54E+03	4.88E-02	2.73E-02	2.17E-02	5.32E-03	3.77E-03	3.21E-03
110	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
111	4.62E+04	4.62E+04	4.62E+04	5.04E+03	6.38E+03	6.84E+03	5.10E-02	2.86E-02	2.27E-02	5.56E-03	3.95E-03	3.36E-03
112	2.01E+00	2.01E+00	2.01E+00	2.19E-01	2.77E-01	2.97E-01	2.22E-06	1.24E-06	9.85E-07	2.42E-07	1.72E-07	1.46E-07
113	3.81E+02	3.81E+02	3.81E+02	4.16E+01	5.27E+01	5.65E+01	4.21E-04	2.36E-04	1.87E-04	4.60E-05	3.26E-05	2.77E-05
114	1.61E+05	1.61E+05	1.61E+05	1.75E+04	2.22E+04	2.38E+04	1.77E-01	9.93E-02	7.88E-02	1.94E-02	1.37E-02	1.17E-02
115	3.01E+05	3.01E+05	3.01E+05	3.29E+04	4.16E+04	4.46E+04	3.33E-01	1.86E-01	1.48E-01	3.63E-02	2.57E-02	2.19E-02
198	1.59E+07	1.59E+07	1.59E+07	1.73E+06	2.20E+06	2.36E+06	1.76E+01	9.83E+00	7.80E+00	1.92E+00	1.36E+00	1.16E+00
199	1.38E+05	1.38E+05	1.38E+05	1.51E+04	1.91E+04	2.05E+04	1.53E-01	8.55E-02	6.78E-02	1.67E-02	1.18E-02	1.00E-02
200	3.30E+05	3.30E+05	3.30E+05	3.60E+04	4.56E+04	4.89E+04	3.64E-01	2.04E-01	1.62E-01	3.97E-02	2.82E-02	2.40E-02

Classification Number	RfD (mg/kg-day)	Ingestion HQ 6 to <11 years old	Ingestion HQ 11 to <16 years old	Ingestion HQ 16 to <21 years old	Average Ingestion HQ	RfC (mg/m ³)	Inhalation HQ 6 to <11 years old	Inhalation HQ 11 to <16 years old	Inhalation HQ 16 to <21 years old	Average Inhalation HQ	Average Combined HQ
108	8.00E-02	3.05E-01	1.71E-01	1.35E-01	2.04E-01	5.00E+00	5.32E-04	3.77E-04	3.21E-04	4.10E-04	1.02E-01
109	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
110	5.00E-04	4.43E-03	2.48E-03	1.97E-03	2.96E-03	2.00E-03	1.21E-04	8.58E-05	7.30E-05	9.32E-05	1.53E-03
111	3.00E-01	1.70E-01	9.52E-02	7.55E-02	1.14E-01	4.00E-01	1.39E-02	9.86E-03	8.39E-03	1.07E-02	6.21E-02
112	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
113	5.00E-03	8.43E-02	4.72E-02	3.74E-02	5.63E-02	1.00E-04	4.60E-01	3.26E-01	2.77E-01	3.54E-01	2.05E-01
114	2.00E-01	8.87E-01	4.97E-01	3.94E-01	5.92E-01	1.00E-01	1.94E-01	1.37E-01	1.17E-01	1.49E-01	3.71E-01
115	3.00E-01	1.11E+00	6.21E-01	4.92E-01	7.41E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.70E-01
198	2.51E+01	3.79E+01	2.12E+01	1.68E+01	2.53E+01	7.37E+01	9.13E+00	6.48E+00	5.51E+00	7.04E+00	1.62E+01
199	2.18E-01	3.30E-01	1.85E-01	1.46E-01	2.20E-01	6.41E-01	7.94E-02	5.63E-02	4.79E-02	6.12E-02	1.41E-01
200	1.06E+00	5.66E-01	3.17E-01	2.51E-01	3.78E-01	3.08E+00	2.31E-01	1.64E-01	1.39E-01	1.78E-01	2.08E-01

Note: The value in red is the hazard index (HI) for exposure assessment.

Classification Number	WOE Class	OSF (kg-day/mg)	Ingestion ELCR 6 to <11 years old	Ingestion ELCR 11 to <16 years old	Ingestion ELCR 16 to <21 years old	Average Ingestion ELCR	IUR (m ³ /μg)	Inhalation ELCR 6 to <11 years old	Inhalation ELCR 11 to <16 years old	Inhalation ELCR 16 to <21 years old	Average Inhalation ELCR	Average Combined ELCR
108	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
109	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
110	A	4.60E-02	1.02E-07	5.71E-08	4.53E-08	6.81E-08	4.10E-06	9.92E-13	7.03E-13	5.98E-13	7.64E-13	3.41E-08
111	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
112	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
113	C	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
114	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
115	D	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
198	-	1.52E+01	1.05E-01	5.89E-02	4.67E-02	7.03E-02	5.62E+01	5.52E-02	3.92E-02	3.33E-02	4.26E-02	5.64E-02
199	-	1.32E-01	9.15E-04	5.12E-04	4.07E-04	6.11E-04	4.88E-01	4.80E-04	3.40E-04	2.90E-04	3.70E-04	4.91E-04
200	-	8.08E-01	3.77E-03	2.11E-03	1.67E-03	2.52E-03	4.69E+00	4.01E-03	2.85E-03	2.42E-03	3.09E-03	2.14E-03

Note: The value in red is the total cancer risk (TCR) for exposure assessment.

Figures

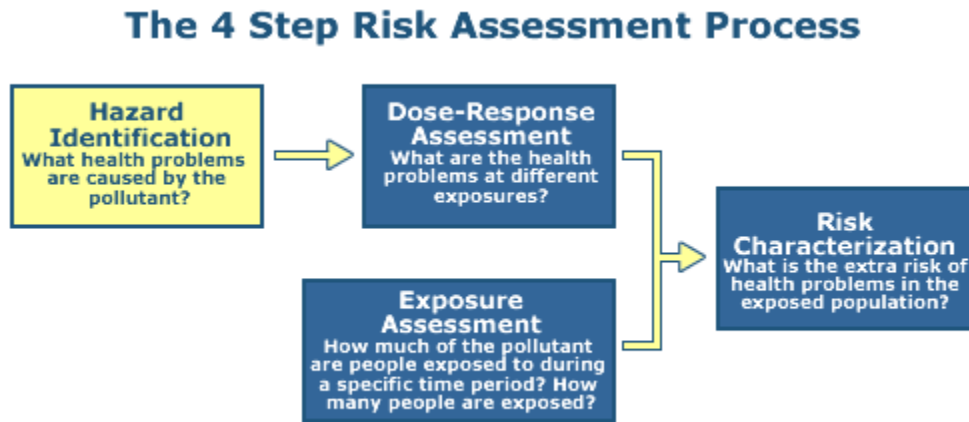


Figure 1. The first phase of a HHRA is Hazard Identification (EPA, 2017a).

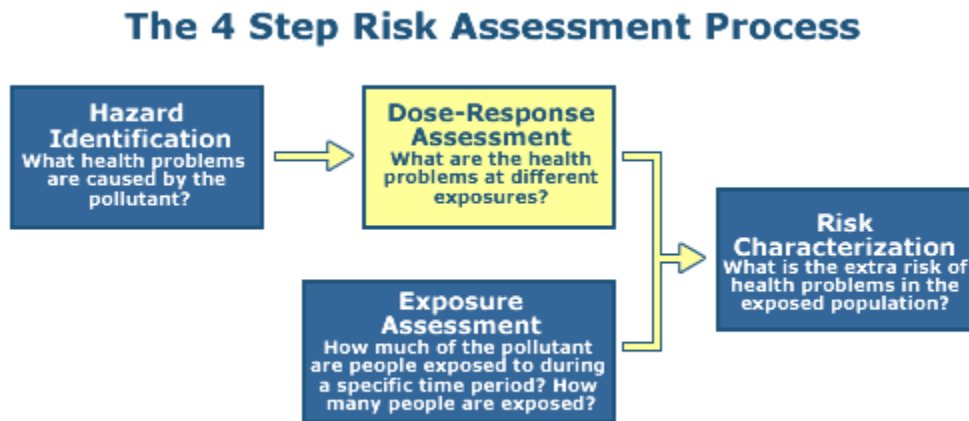


Figure 2. The second phase of a HHRA is Dose-Response Assessment (EPA, 2017a).

The 4 Step Risk Assessment Process

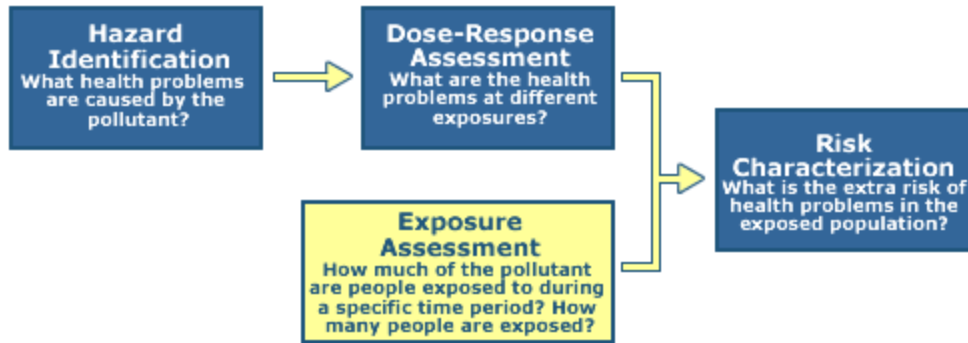


Figure 3. The third phase of a HHRA is Exposure Assessment (EPA, 2017a).

The 4 Step Risk Assessment Process

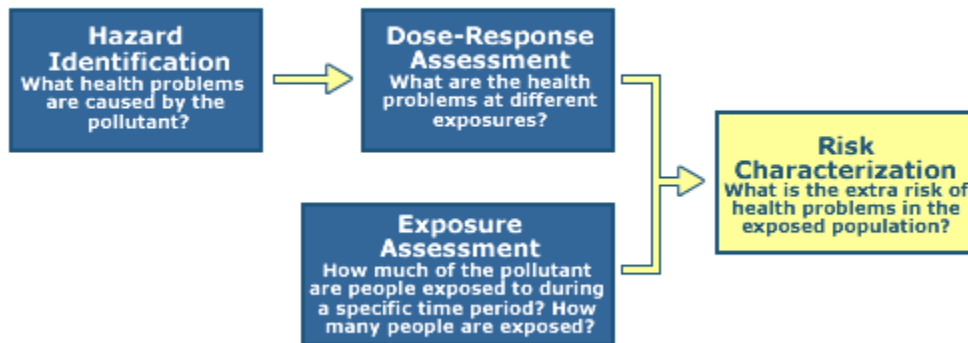


Figure 4. The fourth phase of a HHRA is Risk Characterization (EPA, 2017a).