A SCREENING LEVEL EVALUATION OF NONCANCER HAZARDS FOR OCCUPATIONAL EXPOSURES TO DECACHLOROBIPHENYL FROM INDOOR DUST

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Introduction

Polychlorinated biphenyls (PCBs), including decachlorobiphenyl (decaCB), can be inadvertently produced as byproducts in a wide variety of chemical processes in which both chlorine and hydrocarbons are present.[1] At a facility that produces magnesium using an anhydrous electrolytic process using concentrated brine , decaCB was detected in bulk dust that was sampled from inside the manufacturing facility. The source of the decaCB detected in the bulk dust is thought to be due to the de novo formation of decaCB during the melt process when a coal coke mixture is added to the magnesium chloride feedstock as an oxygen scavenger.[2]

The purpose of this analysis is to develop a method for assessing risks associated with worker exposure to decaPCB in dusts. Health risks from PCB exposure are typically evaluated based on the toxicity of the Aroclor mixtures or the dioxin-like PCBs; however, decaCB is not a component of any Aroclor mixture and it is not a dioxin-like PCB.[1,3] Therefore, in this assessment noncancer hazards are evaluated via a comparison of estimated worker decaPCB doses versus a decaPCB toxicity reference value derived from noncancer effects evaluated in animal studies.

Methods

The hazard index associated with noncancer health effects due to occupational exposures to decaCB in bulk dust was calculated using the following equation:

$$HI = \frac{ADD_{DI}}{RV_{oral}} + \frac{ADD_{DC}}{RV_{dermal}} + \frac{ADD_{PI}}{RV_{inh}}$$

Where HI is the hazard index, ADD_{DI} is the Average Daily Dose due to dust ingestion in mg decaCB/kg bw-day, ADD_{DC} is the Average Daily Dose for dermal contact with dust in mg decaCB/kg bw-day, and ADD_{PI} is the Average Daily Dose for particulate inhalation in mg decaCB/kg bw-day, RV_{oral} is the oral toxicity reference value in mg/kg-day, RV_{dermal} is the dermal toxicity reference value in mg/kg-day, and RV_{inh} is the inhalation toxicity reference value in mg/kg-day.

Toxicity Reference Value

A noncancer reference value of 5 mg/kg-day for decaCB was used for all three routes of exposure to estimate the hazard index. This value is based on a NOAEL of 500 mg/kg-day from a 15 day rat feeding study.[4] This NOAEL of 500 mg/kg-day was divided by an uncertainty factors of 10 for animal to human extrapolation and 10 for use of a subchronic study for a chronic exposure resulting in the noncancer reference value of 5 mg/kg-day.

Dust Ingestion

The ADD due to dust ingestion, ADD_{DI}, was calculated using the following equation:

$$ADD_{DI} = \frac{C_{dust} * CF * EF * ED * IRD * BIO}{BW * AT}$$

Where C_{dust} is the decaCB concentration in bulk dust (mg/kg), CF is a conversion factor (10^{-6} kg/mg), EF is the exposure frequency in days/year, ED is the exposure duration in years, IRD is the dust ingestion rate in mg/day, BIO is the oral bioavailability, BW is body weight in kg, and AT is the averaging time in days. Table 1 presents the values used for each of the parameters for this pathway.

The decaCB concentration of 250 mg/kg measured by NIOSH in a single bulk dust sample for the off-gas collection head was used to calculate the ADD for all three routes of exposure.[2] The USEPA default values for an industrial worker exposure scenario of 225 days/year for exposure frequency, 25 years for exposure duration, 70 kg for adult body weight, and 9,125 days for averaging time, which is the exposure duration in terms of days, were used.[5] The oral bioavailability of decaCB was conservatively assumed to be equal to 1. A dust ingestion rate of 9 mg/day was estimated assuming that dust ingestion in adults is due to hand-to-mouth contact by multiplying the site-specific dermal adherence rate of 0.06 mg/cm^2-day[6] by the surface area of the thumb and forefingers of both hands[7] of 72 cm^2 by an assumed 2 events per day.[8]

Dermal Contact
The dermal contact with dust ADD, ADD_{DC}, was calculated using the following equation:

$$ADD_{DC} = \frac{C_{dust} * CF * EF * ED * ESSA * SAF * ABS}{BW * AT}$$

Where ESSA is the exposed skin surface area in cm^2, the SAF is the soil-to-skin adherence factor (mg/cm^2-day), and ABS is the dermal bioavailability. Table 1 presents the values used for each of the parameters for this pathway. The exposed skin surface area was set equal to 3,300 cm^2 which is the USEPA default value for an industrial worker scenario[5], the soil-to-skin adherence factor was set equal to the site-specific value of 0.06 mg/cm^2-day,[6] and the ABS was set equal to the chemical-specific value of 0.14.[9]

Particulate Inhalation
The particulate inhalation ADD, ADD_{PI}, was calculated using the following equation:

$$ADD_{PI} = \frac{C_{dust} * EF * ED * IRA}{PEF * BW * AT}$$

Where IRA is the inhalation rate (m^3/day) and PEF is the particulate emission factor (m^3/kg). The default inhalation rate for a worker for an 8-hour work day of 10.4 m^3/day (1.3 m^3/hr*8 hr/day)[7] was used. Table 1 presents the values used for each of the parameters for this pathway.

There are no generally accepted methods for estimating the emissions of resuspended indoor dust from the walls and flat surfaces of an office or industrial space. A particulate emissions factor for resuspended dust was developed using a particulate emission model by Cowherd et al.[10] that estimates emissions due to the transfer of powder materials from one container to another and conservatively assuming that the all of the dust on the walls of a 20 ft x 10 ft x 10 ft office within the facility is emitted daily. Table 2 presents the key model parameters used to estimate the PEF. The Cowherd et al.[10] model relates the mg of particulate emitted per kg of dust disturbed as an empirical function of moisture content and particle size. The moisture content and particle size distribution associated with carbon black were used because no site-specific data were available and carbon black had the highest emission rate of any of the materials evaluated by Cowherd et al.[10] The mass emission rate was estimated by multiplying the mg particulate/kg dust disturbed by the area of the four walls of the office space and a unit dust loading and dividing by 28,800 sec (8 hrs). A mass balance box model was used to estimate the indoor dust concentration per mg/kg of decaCB in dust from the mass emission rate for the office space assuming a typical air exchange rate for an office of 4 air changes/hr.[11] The calculated PEF was 1.44 x 10^7 m^3/kg and is equivalent to an indoor particulate concentration of 69 μg/m^3. Table 2 presents the key model parameters used to estimate the PEF.

Results and Discussion

Table 3 presents the ADDs, hazard quotients, and percent contributions to the hazard index for each route of exposure. The hazard quotient is the ratio of the ADD to the toxicity reference value for a particular route of exposure. The predominant route of exposure is due to dermal contact, which produced the highest ADD of 6.1 x 10^{-5} and the highest hazard quotient of 1.2 x 10^{-5}, and had a percent contribution of 74% to the hazard index. The route of exposure that had the least impact on the hazard index was particulate inhalation, which only contributed 2% to the hazard index. This is fairly low considering that the indoor air particulate concentration due to the resuspension of indoor dust was conservatively estimated to be approximately 69 μg/m^3.

The hazard index (all exposure routes combined) was estimated to be 1.6 x 10^{-5}. This means that the indoor dust concentrations at the facility are orders of magnitude lower than those that would pose a noncancer hazard to facility workers. While site-specific dust ingestion and soil adherence rates were employed, the majority of the exposure assumptions used to calculate this hazard index are based on conservative assumptions. The dust concentration of decaCB used is based on a dust sample collected from a piece of equipment at the facility and likely represents a maximum concentration of decaCB, not the typical indoor dust concentrations of decaCB. In addition, the oral bioavailability of decaCB was conservatively assumed to be 100% and the dermal bioavailability of decaCB of 14% is based on the dermal bioavailability of Aroclor mixtures. Finally, the calculated indoor PEF, which is equivalent to an indoor particulate concentration of 69 μg/m^3, is conservative compared to the average $PM_{2.5}$ concentration for a typical office environment of 34.5 μg/m^3.[12]

References

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Table 1. Exposure parameters used to calculate the decaPCB ADDs for each of the routes of exposure.

Parameter	Value
Bulk dust concentration of decaCB (C_{dust}), mg/kg	250
Conversion factor (CF), kg/mg	10^{-6}
Exposure frequency (EF), days/year	225
Exposure duration (ED), years	25
Body weight (BW), kg	70
Averaging time (AT), days	9125
Dust ingestion rate (IRD), mg/day	9.0
Oral bioavailability (BIO), unitless	1.0
Exposed skin surface area (ESSA), cm^2	3,300
Soil-to-skin adherence factor (SAF), mg/cm^2-day	0.06
Dermal absorption (ABS), unitless	0.14
Inhalation rate (IRA), m^3/day	10.4
Particulate emission factor (PEF), m^3/kg	1.44×10^7

Table 2. Model parameters used to estimate the indoor particulate emission factor

Parameter	Value
Moisture content (M), %	3.4
Geometric standard deviation of particle size distribution (S_g), unitless	2.19
Mass median diameter of the particle size distribution (M_g), μm	78.5
Area of walls covered with dust that is disturbed (A_{wall}), m^2	55.7
Time period over which emissions occur (T), sec	28,800
Length of room (L), m	6.1
Width of room (W), m	3.0
Height of room (H), m	3.0
Air exchange rate (A_{ch}), hr^{-1}	4

Table 3. Estimated average decaPCB daily doses and hazard quotients due to occupational exposures to bulk dust at the facility.

Route of Exposure	Average Daily Dose (mg/kg-day)	Hazard Quotient	Percent Contribution to Hazard Index (%)
Dust Ingestion	2.0×10^{-5}	4.0×10^{-6}	24
Dermal Contact with Dust	6.1×10^{-5}	1.2×10^{-5}	74
Particulate Inhalation	1.6×10^{-6}	3.2×10^{-7}	2
Total	3.8×10^{-6}	1.6×10^{-5}	100