CFC SUBSTITUTES
GENERIC SCENARIO
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I. INTRODUCTION

This scenario applies to chemicals used as substitutes for CFCs in foam blowing, refrigeration, air-conditioning, sterilization, electronics and metal cleaning applications. This scenario is to be used for chemicals that are structurally similar to CFCs with similar properties. Physical and chemical properties for CFCs are given below in Table 1.

TABLE 1: PHYSICAL AND CHEMICAL PROPERTIES FOR CFCs

PROPERTY	CFC-11	CFC-12	CFC-113	CFC-114	CFC-115
Physical State	Liquid	Gas	Liquid	Gas	Gas
Molecular Formula	CCL_4F	CCL_2F_2	$C_2CL_3F_3$	$C_2CL_2F_4$	$CCLF_5$
Molecular Weight	137	121	187	171	155
Vapor Pressure, mmHg	790	4,887	400	2,280	6,981
Boiling Point, ^oC	23.9	-29.8	47.6	3.8	-38.7
Water Solubility Lb/100 Lb H_2O at 25^oC	0.110	0.028	0.017	0.013	0.006

This scenario provides the data and equations necessary to assess occupational exposure and environmental releases for these chemicals. Details on the processes as well as process flow diagrams can be found in PEI, 1990.

Occupational exposure estimates are given for the inhalation route only. The CFCs are highly volatile chemicals and evaporate almost instantaneously from the skin. The rapid evaporation suggest that skin absorption is negligible (Patty's, 87). Thus, dermal exposures are not quantified in this scenario.

Environmental release estimates are provided only for air. This is based on information in PEI, 90 which showed that releases to other media were insignificant in comparison to air releases.

II. POLYURETHANE (PUR) FOAM BLOWING

A. RIGID FOAM

1. Number of sites

$$NS = \frac{PV}{55.6 \text{ million kg}} \times 85$$

where:

NS = Number of sites that may use the PMN chemical to manufacture PUR foam

PV = production volume of the PMN chemical (kg/yr)

55.6 million kg = total CFC blowing agent used in 1985 for rigid PUR foam (OAR, 90).

85 = Number of major rigid foam producers (EPA, 87a; OAR, 87)

2. Days/site-yr = 250 (PEI, 90)

3. Number of workers/site = 2 to 10 (PEI, 90)

4. Inhalation Exposure Levels

8 HR-TWA = 500 ppm
15 minute peak = <5000 ppm

Basis: OSHA, NIOSH monitoring data (PEI, 90)

5. Environmental Release (Air)

Stack = 195 Kg/site-day
Fugitive = 20 Kg/site-day

Source: Macek, 1991

B. FLEXIBLE FOAM

1. Number of sites

$$NS = \frac{PV}{14.7 \text{ million kg}} \times 144$$

where:

14.7 million kg = total CFC blowing agent used in 1985 for flexible foam manufacture (PEI, 90)

144 = Number of major flexible foam producers (EPA, 87b)

2. Days/site-yr = 250 (PEI, 90)

3. Number of workers/site = 2 to 10 (PEI, 90)

4. Exposure Levels

   8 HR-TWA = 55 ppm
   15 minute peak = 550 ppm

   Basis: OSHA, NIOSH monitoring data (PEI, 90)

5. Environmental Releases (Air)

   Stack = 390 Kg/site-day
   Fugitive = 45 Kg/site-day

REFRIGERATION

A. MANUFACTURE

1. Retail Food Storage

a. Number of sites

$$NS = \frac{PV}{15 \text{ million kg}} \times 33{,}200$$

where:

NS = Number of retail food storage units that may use the PMN chemical

PV = production volume of PMN chemical (kg/yr)

15 million kg = amount of CFC refrigerant used in retail food storage (OAR, 89)

33,200 = Number of retail food storage units produced in 1985 (Radian, 87)

b. Days/yr = 250 (PEI, 90)

c. Number of workers

$$NW = NS \times 2 \frac{\text{worker-days}}{\text{site-yr}} \times \frac{1 \text{ yr}}{250 \text{ days}}$$

where:

NW = total number of workers exposed during manufacture

NS = Number of sites

d. Inhalation Exposure Levels

8 HR-TWA = 145 ppm
15 minute peak = 269 ppm

Basis: Mass balance model for exposure to HCFC-22 (PEI,90)

e. Environmental Releases (Air)

Fugitive = 20 kg/site-day for 1 day/yr
Source: Macek, 1991

2. Cold Storage Warehouses

a. Number of sites

$$NS = \frac{PV}{8.5 \text{ million Kg}} \times 1600$$

where:

8.5 million kg = amount of CFC refrigerant used in cold storage warehouses (OAR, 89)

1600 = Number of units produced in 1985 (PEI, 90)

b. Days/yr = 20 (PEI, 90)

c. Number of workers

$$NW = NS \times 2 \frac{\text{worker-days}}{\text{site}} \times \frac{1 \text{ yr}}{20 \text{ days}} = 160$$

d. Inhalation Exposure Levels

8-HR TWA = 481 ppm
15 minute peak = 3,280 ppm

Basis: Mass balance model for exposure to HCFC-22 (PEI, 90)

e. Environmental Releases (Air)

Fugitive = 273 kg/site-day for 1 day/yr

Source: Macek, 1991

3. Chillers

a. Number of sites

$$NS = \frac{PV}{11.6 \text{ million kg}} \times 4{,}260$$

where:

11.6 million kg = Amount of CFC refrigerant used in chillers (OAR, 89)

4,260 = Number of units produced in 1985 (OAR, 89)

b. Number of days/yr = 50 (PEI, 90)

c. Number of workers

$$NW = NS \times 2 \frac{\text{workers-days}}{\text{site-yr}} \times \frac{1 \text{ yr}}{250 \text{ days}}$$

d. Inhalation Exposure Levels

8-HR TWA = 100 ppm
15 minute peak = 1,326 ppm

Basis: Mass balance model for exposure to HCFC-123 during installation of centrifugal chillers.

e. Environmental Releases (Air)

Fugitive = 28 kg/site-day for 1 day/yr

Source: Macek, 1991

B. SERVICING

1. Retail Food Storage

a. Number of sites

$$NS = \frac{PV}{15 \text{ million kg}} \times 305{,}000$$

where:

305,000 = Number of retail food storage units in operation (OAR, 89)

b. Days/site-yr = 250 (PEI, 90)

c. Number of workers

D6 $\left(\frac{PV}{15 \text{ million kg}}\right)\left(\frac{305{,}000}{250}\right)(2)$

$$NW = \frac{PV}{15 \text{ million kg}} \times 2{,}440$$

where:

Estimate of the 2440 = total number of workers who service retail food storage units (Macek, 1991)

d. Inhalation Exposure Levels

8 HR-TWA = 71 ppm
15 minute peak = 497 ppm

Basis: Mass balance model for exposure to HCFC-22 (PEI, 90)

e. Environmental Releases (Air)

Fugitive = 8 Kg/site-day for 1 day/year

Source: Macek, 1991

2. Cold Storage Warehouses

a. Number of sites

$$NS = \frac{PV}{8.5 \text{ million kg}} \times 18{,}900$$

where: 18,900 = Number of CSWs that use CFCs

b. Days/site-yr = 250 (PEI, 90)

c. Number of Workers

$$NW = \frac{PV}{8.5 \text{ million kg}} \times 600$$

where:

600 = Estimate for the total number of workers who service cold storage warehouses (PEI, 90)

d. Inhalation Exposure Levels

8-HR TWA = 48 ppm
15 minute peak = 325 ppm

Basis: Mass balance exposure model for exposure to HCFC-22 (PEI, 90)

e. Environmental Releases (Air)

Fugitive = 76 Kg/site-day for 4 days/site-yr

Basis: Macek, 91

3. Chillers

a. Number of sites

$$NS = \frac{PV}{11.6 \text{ million kg}} \times 25{,}000$$

where:

25,000 = Number of chillers being serviced in any one year.

b. Days/site-yr = 250

c. Number of workers

$$NW = \frac{PV}{11.6 \text{ million kg}} \times 200$$

d. Inhalation Exposure Levels

8 HR-TWA = 171 ppm
15 minute peak = 1179 ppm

Basis: Mass balance model for exposure to HCFC-123 (PEI, 90)

e. Environmental Releases (Air)

Fugitive = 118 kg/site-day for 1 day/year

Source: Macek, 91

MOBILE AIR-CONDITIONING

A. MANUFACTURE

1. Number of sites

$$NS = \frac{PV}{44.3 \text{ million kg}} \times 64$$

where:

NS = number of sites that may use the PMN chemical as a refrigerant in automobile air-conditioners

PV = production volume of the PMN chemical (kg/yr)

44.3 million kg = total amount of CFCs used as a refrigerant in mobile air-conditioning (OAR, 89a)

64 = Number of vehicle manufacturing sites in the U.S. (MVMA, 88)

2. Days/site-yr = 250 (PEI, 90)

3. Number of workers/site = 20 (PEI, 90)

4. Exposure Levels (PEI, 90)

   8 HR-TWA = 105 ppm
   15 minute peak = 158 ppm

   Basis: Mass balance model for exposure to HFC-134a

5. Environmental Releases (Air) = 56 Kg/site-day (PEI, 90)

B. SERVICING

1. Number of sites

$$NS = \frac{PV}{44.3 \text{ million kg}} \times 329{,}000$$

where:

329,000 = Number of facilities in the U.S. that service MACs (MVMA, 86)

2. Days/site-yr: 11 to 170 (Macek, 1991)

3. Number of workers/site = 1 to 5 (PEI, 90)

4. Inhalation Exposure Levels

   8 HR-TWA = 21 ppm
   15 minute peak = 26 ppm

   Basis: Mass balance model for exposure to HFC-134a

5. Environmental Releases (Air)

   Fugitive = 0.3 to 4.3 kg/site-day

   Source: Macek, 1991

STERILIZATION

A. Number of sites

$$NS = \frac{PV}{22.1 \text{ million kg}} \times 6{,}000$$

where:

NS = Number of sites that may use the PMN chemical as a sterilant carrier

PV = production volume of PMN chemical (kg/yr)

22.1 million Kg = total amount CFCs used as a sterilant carrier (OAR, 89a)

6,000 = Number of hospitals in the U.S. that have sterilants (NIOSH, 77)

B. Days/site-yr = 365 (PEI, 90)

C. Number of workers/site = 5 (PEI, 90)

D. Inhalation Exposure Levels

8 HR-TWA = 3 ppm
15 minute peak exposure = 15 ppm

Basis: OSHA PEL for ethylene oxide (1 ppm) and the assumption that a 12 percent ethylene oxide/88 percent CFC substitute mixture is used.

E. Environmental Releases (Air)

Stack = 2 kg/site-day
Fugitive = 2 kg/site-day

Source: Macek, 1991

ELECTRONICS AND METAL CLEANING

A. PC BOARD

1. Number of sites

$$NS = \frac{PV}{23 \text{ million kg}} \times 705$$

where:

NS = Number of sites that may use the PMN chemical as a CFC substitute in PC board cleaning

PV = production volume of PMN chemical (kg/yr)

23 million kg = total amount of CFC-13 used in PC board cleaning (PEI, 90)

705 = Number of sites in U.S. that clean PC boards (PEI, 90)

2. Days/site-yr = 250 (PEI, 90)

3. Number of Workers/site = 25 (Based on 3 workers/unit, 8.5 units/site (PEI, 90))

4. Inhalation Exposure Levels (PEI, 90)

   8 HR-TWA = 1,000 ppm
   15 minute peak = <10,000 ppm

   These exposures are based on the PEL and STEL for CFC-113.

5. Environmental Releases (Air)

   Stack = 42 kg/site-day
   Fugitive = 98 kg/site-day

   Source: Macek, 91

B. OTHER ELECTRONIC/ELECTRICAL

1. Number of sites

$$NS = \frac{PV}{2.5 \text{ million kg}} \times 82$$

where:

2.5 million kg = total amount of CFC-113 used in the cleaning of other electrical equipment (PEI, 90)

82 = Number of sites in the U.S. that use CFC-113 to clean other electronic equipment. (PEI, 90)

2. Days/site-yr = 250 (PEI, 90)

3. Number of workers/site = 25 (Based on 3 workers/unit, 8.5 units/site (PEI, 90))

4. Inhalation Exposure Levels

Same as for PC Board

5. Environmental Releases (Air)

Stack = 36 Kg/site-day
Fugitive = 86 Kg/site-day

Source: Macek, 90)

C. METAL CLEANING

1. Number of sites

$$NS = \frac{PV}{43.5 \text{ million kg}} \times 1435$$

where:

43.5 million kg = total amount of CFC-113 used in the cleaning of metal parts (PEI, 90)

1435 = Number of sites in the U.S. that use CFC-113 to clean metal parts (PEI, 90)

2. Days/site-yr = 250

3. Number of workers/site = 25 (Based on 3 workers/unit, 8.5 units/site (PEI, 90))

4. Inhalation Exposure Levels

   Same as for PC Board Cleaning

5. Environmental Releases (Air)

   Stack = 36 kg/site-day
   Fugitive = 86 kg/site-day

   Source: Macek, 91

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CFC Substitutes

Refrigerant use

	Typical charge kg	Exposure (TWA) ppm	Recharge / Service Frequenc
Retail food storage	120	71 - 519	4 times/yr
Cold storage warehouse	11,400	48 - 386	4 times/yr
chillers	600	20 - 200	once every 4 yea

	Typical Servicing Releases kg/site-day	Typical operational Releases kg/site-day
Retail food storage	36.5	0.1
Cold storage warehouse	570	6.2
Chillers	118	0.12

assume exposure on daily basis for workers

Butadiene 910 mm Hg v.p.
24°F b.p.

Fire extinguisher fluid

See Al Hummel's detailed review report
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