NIOSH Skin Notation Profiles

Acrylonitrile

SK

ID^{SK}

[~~SK~~]

SYS

SYS (FATAL

DIR

DIR (IRR)

DIR (COR)

SEN

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

NIOSH Skin Notation (SK) Profile

Acrylonitrile
[CAS No. 107–13–1]

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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Foreword

As the largest organ of the body, the skin performs multiple critical functions, such as serving as the primary barrier to the external environment. For this reason, the skin is often exposed to potentially hazardous agents, including chemicals, which may contribute to the onset of a spectrum of adverse health effects ranging from localized damage (e.g., irritant contact dermatitis and corrosion) to induction of immune-mediated responses (e.g., allergic contact dermatitis and pulmonary responses), or systemic toxicity (e.g., neurotoxicity and hepatoxicity). Understanding the hazards related to skin contact with chemicals is a critical component of modern occupational safety and health programs.

In 2009, the National Institute for Occupational Safety and Health (NIOSH) published *Current Intelligence Bulletin (CIB) 61: A Strategy for Assigning New NIOSH Skin Notations* [NIOSH 2009–147]. This document provides the scientific rationale and framework for the assignment of multiple hazard-specific skin notations (SK) that clearly distinguish between the systemic effects, direct (localized) effects, and immune-mediated responses caused by skin contact with chemicals. The key step within assignment of the hazard-specific SK is the determination of a substance's hazard potential, or its potential for causing adverse health effects as a result of skin exposure. This determination entails a health hazard identification process that involves use of the following:

- Scientific data on the physicochemical properties of a chemical
- Data on human exposures and health effects
- Empirical data from in vivo and in vitro laboratory testing
- Computational techniques, including predictive algorithms and mathematical models that describe a selected process (e.g., skin permeation) by means of analytical or numerical methods.

This *Skin Notation Profile* provides the SK assignment and supportive data for acrylonitrile (CAS No. 107-13-1). In particular, this document evaluates and summarizes the literature describing the substance's hazard potential and its assessment according to the scientific rationale and framework outlined in CIB 61. In meeting this objective, this Skin Notation Profile intends to inform the audience—mostly occupational health practitioners, researchers, policy- and decision-makers, employers, and workers in potentially hazardous workplaces—so that improved risk-management practices may be developed to better protect workers from the risks of skin contact with the chemical of interest.

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Contents

Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
CIB	Current Intelligence Bulletin
cm^2	square centimeter(s)
cm/hr	centimeter(s) per hour
DEREK™	Deductive Estimation of Risk from Existing Knowledge
DIR	skin notation indicating the potential for direct effects to the skin following contact with a chemical
EC	European Commission
GHS	Globally Harmonized System for Classification and Labeling of Chemicals
IARC	International Agency for Research on Cancer
(IRR)	subnotation of SK: DIR indicating the potential for a chemical to be a skin irritant following exposure to the skin
K_{aq}	coefficient in the watery epidermal layer
K_p	skin permeation coefficient
K_{pol}	coefficient in the protein fraction of the stratum corneum
K_{psc}	permeation coefficient in the lipid fraction of the stratum corneum
LD_{50}	dose resulting in 50% mortality in the exposed population
LD_{Lo}	dermal lethal dose
LOAEL	lowest-observed-adverse-effect level
log K_{OW}	base-10 logarithm of a substance's octanol–water partition
m^3	cubic meter(s)
mg	milligram(s)
$mg/cm^2/hr$	milligram(s) per square centimeter per hour
mg/kg	milligram(s) per kilogram body weight
mg/m^3	milligram(s) per cubic meter
mL/kg	milliliter(s) per kilogram body weight
MW	molecular weight
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no-observed-adverse-effect level
NTP	National Toxicology Program
OEL	occupational exposure limit
OSHA	Occupational Safety and Health Administration
REL	recommended exposure limit
RF	retention factor

SEN	skin notation indicating the potential for immune-mediated reactions following exposure of the skin
SI ratio	ratio of skin dose to inhalation dose
SK	skin notation
S_W	solubility
SYS	skin notation indicating the potential for systemic toxicity following exposure of the skin
USEPA	United States Environmental Protection Agency
µL	microliter(s)
µmol	micromole(s)

Glossary

Absorption—The transport of a chemical from the outer surface of the skin into both the skin and systemic circulation (including penetration, permeation, and resorption).

Acute exposure—Contact with a chemical that occurs once or for only a short period of time.

Cancer—Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Contaminant—A chemical that is (1) unintentionally present within a neat substance or mixture at a concentration less than 1.0% or (2) recognized as a potential carcinogen and present within a neat substance or mixture at a concentration less than 0.1%.

Cutaneous (or percutaneous)—Referring to the skin (or through the skin).

Dermal—Referring to the skin.

Dermal contact—Contact with (touching) the skin.

Direct effects—Localized, non-immune-mediated adverse health effects on the skin, including corrosion, primary irritation, changes in skin pigmentation, and reduction/disruption of the skin barrier integrity, occurring at or near the point of contact with chemicals.

Immune-mediated responses—Responses mediated by the immune system, including allergic responses.

Sensitization—A specific immune-mediated response that develops following exposure to a chemical, which, upon re-exposure, can lead to allergic contact dermatitis (ACD) or other immune-mediated diseases such as asthma, depending on the site and route of re-exposure.

Substance—A chemical.

Systemic effects—Systemic toxicity associated with skin absorption of chemicals after exposure of the skin.

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1 Introduction

1.1 General Substance Information

Chemical Acrylonitrile

CAS No: 107-13-1

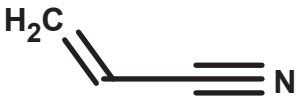
Molecular weight (MW): 53.06

Molecular formula: CH_2CHCN

Synonyms:

2-Propenenitrile; Acrylonitrile monomer; Vinyl cyanide; VCN

Structural formula:



Uses:

Acrylonitrile is a high-volume chemical primarily used in the manufacturing of synthetic fibers, resins, plastics, elastomers, and rubber for a variety of consumer goods [Cohrssen 2001]. It is also applied as a fumigant. In 1990, acrylonitrile was ranked 38th among the top 50 chemicals produced in the United States; an estimated 3.03 billion pounds (~1.4 billion kilograms) is manufactured annually [Cohrssen 2001].

1.2 Purpose

This Skin Notation Profile presents (1) a brief summary of technical data associated with skin contact with acrylonitrile and (2) the rationale behind the hazard-specific skin notation (SK) assignment for acrylonitrile. The SK assignment is based on the scientific rationale and logic outlined in the *Current Intelligence Bulletin (CIB) 61: A Strategy for Assigning New NIOSH Skin Notations* [NIOSH 2009]. The summarized information and health hazard assessment are limited to an evaluation of the potential health effects of dermal exposure to acrylonitrile. A literature search was conducted through July 2010 to identify information on acrylonitrile, including but not limited to data relating to its toxicokinetics, acute toxicity, repeated-dose systemic toxicity, carcinogenicity, biological system/function–specific effects (including reproductive and developmental effects and immunotoxicity), irritation, and sensitization. Information was considered from studies of humans, animals, or appropriate modeling systems that are relevant to assessing the effects of dermal exposure to acrylonitrile.

1.3 Overview of SK Assignment

Acrylonitrile is potentially capable of causing numerous adverse health effects following skin contact. A critical review of available data has resulted in the following SK assignment for acrylonitrile: **SK: SYS (FATAL)-DIR (IRR)-SEN**. Table 1 provides an overview of the critical effects and data used to develop the SK assignment for acrylonitrile.

Table 1. Summary of the SK assignment for acrylonitrile

Skin notation	Critical effect(s)	Available data
SK: SYS (FATAL)	Neurotoxicity, vascular congestion, hemorrhages	Limited human data; sufficient animal data
SK: DIR (IRR)	Skin irritation	Sufficient human and animal data
SK: SEN	Skin allergy	Sufficient human data

2 Systemic Toxicity from Skin Exposure (SK: SYS)

There is limited information on the toxicokinetics of acrylonitrile following dermal exposure. The potential for dermal absorption was demonstrated in the report of one case, in which a worker was inadvertently sprayed with acrylonitrile, resulting in recurring signs of cyanide poisoning over a 3-day period [Vogel and Kirkendall 1984]. Some evidence of dermal absorption of acrylonitrile in animals was provided by studies of acute dermal toxicity that resulted in death [Roudabush et al. 1965; Dow Chemical USA 1977; Vernon et al. 1990].

The potential of acrylonitrile to pose a skin absorption hazard was also evaluated, with a predictive algorithm for estimating and evaluating the health hazards of dermal exposure to substances [NIOSH 2009]. This evaluation method compares an estimated dose accumulated in the body from skin absorption and an estimated dose from respiratory absorption associated with a reference occupational exposure limit. On the basis of this algorithm, a ratio of the skin dose to the inhalation dose (SI ratio) of 44 was calculated for acrylonitrile. An SI ratio of ≥0.1 indicates that a chemical is capable of producing systemic toxicity from skin exposure [NIOSH 2009]. Additional information on the SI ratio and the variables used in its calculation are included in the appendix.

No dermal lethal dose (LD_{Lo}) has been identified for humans. However, a 10-year-old girl was reported dead following dermal exposure to an unspecified concentration of acrylonitrile during lice treatment [Lorz 1950], indicating that dermal exposure can result in systemic toxicity. A dermal LD_{50} (the dose resulting in 50% mortality in the exposed population) of 63 milligrams per kilogram body weight (mg/kg) was reported for the rabbit [Dow Chemical USA 1977], and that of 0.28 milliliter per kilogram body weight (mL/kg) (corresponding to 224 mg/kg) was reported for abraded skin [Roudabush et al. 1965]. Vernon et al. [1990] reported the dermal LD_{50} to be less than 200 mg/kg for rabbits. In guinea pigs, the dermal LD_{50} was reported to be 0.46 mL/kg (corresponding to 368 mg/kg) with intact abdomen skin and 0.84 mL/kg (corresponding to 672 mg/kg) with abraded back skin [Roudabush et al. 1965]. An LD_{50} of 148 to 282 mg/kg was noted for rats when liquid acrylonitrile was applied to the skin of their tails [Zotova 1976]. Because the reported acute dermal LD_{50} values for animals are all lower than the critical dermal LD_{50} value of 2000 mg/kg body weight that identifies substances with the potential for acute dermal toxicity [NIOSH 2009],

acrylonitrile is considered systemically toxic by the acute dermal route. In addition, numerous studies reported LD_{50} values for various animal species at or lower than 200 mg/kg body weight, indicating acrylonitrile is extremely toxic following skin contact and potentially lethal.

In humans, the limited data show that acrylonitrile can elicit neurotoxic effects. For example, Vogel and Kirkendall [1984] reported signs of cyanide poisoning—dizziness, redness, nausea, vomiting, and hallucinations that persisted for 3 days—in a man accidentally sprayed with an unspecified concentration of acrylonitrile, which covered his face, eyes, and body. In animals, guinea pigs receiving topical applications of unspecified amounts of acrylonitrile twice daily for three weeks (15 treatment days) experienced an increased average weekly pulse rate (265 to 316). The pulse rate decreased from 316 to 281 within 3 weeks after treatment was discontinued [E.I. DuPont de Nemours and Company 1942].

No standard toxicity studies evaluating biological system-specific or function-specific effects (including reproductive or developmental effects, or immunotoxicity) following dermal exposure to acrylonitrile were identified.

Evaluations of dermally-induced carcinogenicity were limited to a single study. In this study, Banerjee and Segal [1986] found no evidence of tumors when rats were exposed to 300 micromoles (µmol) of acrylonitrile in 100 microliters (µL) acetone, three times per week, for 450 days. Insufficient data were identified to accurately evaluate the carcinogenic potential of acrylonitrile following dermal exposure. Table 2 provides a summary of carcinogenic designations for acrylonitrile from multiple governmental and nongovernmental organizations.

Table 2. Summary of the carcinogenic designations* for acrylonitrile by numerous governmental and nongovernmental organizations

Organization	Carcinogenic designation
NIOSH [2005]	Potential occupational carcinogen
NTP [2009]	Reasonably anticipated to be a human carcinogen
USEPA [2009]	Group B1: Probable human carcinogen (based on limited evidence of carcinogenicity in humans)
IARC [1999]	Group 2B: Possibly carcinogenic to humans
EC [2010]	R45: May cause cancer
ACGIH [2005]	Group A3: Confirmed animal carcinogen with unknown relevance to humans

Abbreviations: ACGIH = American Conference of Governmental Industrial Hygienists; EC = European Commission, Joint Research, Institute for Health and Consumer Protection; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health; NTP = National Toxicology Program; USEPA = United States Environmental Protection Agency.

*Note: The listed cancer designations were based on data from nondermal (such as oral or inhalation) exposure rather than dermal exposure.

The limited toxicokinetic data on humans **[Lorz 1950; Vogel and Kirkendall 1984*]** indicate that acrylonitrile can be absorbed through the human skin. Sufficient data were identified from acute **[Roudabush et al. 1965; Dow Chemical USA 1977; Vernon et al. 1990]** and repeat-dose **[E.I. DuPont de Nemours and Company 1942]** dermal toxicity studies in animals to demonstrate that acrylonitrile is extremely toxic, causing systemic toxicity (including vascular congestion and hemorrhages, and neurotoxicity) and may be life-threatening following skin contact. Therefore, on the basis of the data for this assessment, acrylonitrile is assigned the SK: SYS (FATAL) notation.

3 Direct Effects on Skin (SK: DIR)

A literature search revealed no data from in vitro tests for corrosivity of acrylonitrile in human or animal skin models or from in vitro tests of integrity with cadaver skin. Occupational exposure studies indicated that direct contact with liquid acrylonitrile can cause skin irritation, erythema, blistering, peeling, and slow healing, but these studies provided no evidence of corrosivity [Wilson et al. 1948; Bakker et al. 1991; Muto et al. 1992]. The potential for acrylonitrile to be a skin irritant was also supported by the results of studies involving animals. For example, following use of a Draize protocol, Vernon et al. [1990] reported a Primary Draize Irritation Score of 7.6/8.0 and indicated that there was no significant difference in the severity of irritation observed when the acrylonitrile solution was applied to intact or abraded rabbit skin. Topical application of acrylonitrile to the shaved abdomen of rabbit skin resulted in slight local vasodilation (1 mL/kg) or slight erythema (2 to 3 mL/kg) [McOmie 1949]. The structure-activity relationship model, Deductive Estimation of Risk from Existing Knowledge (DEREK) for Windows, predicted acrylonitrile to be negative for skin irritation. On the basis of results from occupational exposure studies **[Wilson et al. 1948; Bakker et al. 1991; Muto et al. 1992]** and studies in animals **[McOmie 1949]**, there is sufficient information to conclude that acrylonitrile is a severe skin irritant, but there is insufficient evidence of corrosivity. Therefore, on the basis of the data for this assessment, acrylonitrile is assigned the SK: DIR (IRR) notation.

4 Immune-mediated Responses (SK: SEN)

The potential of acrylonitrile to cause skin sensitization following repeated or prolonged exposure has been demonstrated in several case reports and animal studies. One case report described 10 workers who were examined for skin irritation complaints; it was concluded that five of them had irritant dermatitis and the remaining five experienced relapses of dermatitis [Bakker et al. 1991]. However, patch testing for 0.1% acrylonitrile was positive for the five who had the relapses. Positive patch test findings were also reported for other individuals [Bakker et al. 1991; Chu and Sun 2001]. No readily available predictive tests in experimental animals—including guinea pig maximization tests, Buehler tests, murine local lymph node assays, or mouse ear swelling tests—were identified that evaluated the potential of acrylonitrile to be a skin

*References in **bold** text indicate studies that serve as the basis of the SK assignments

sensitizer. However, DEREK predicted acrylonitrile to be a probable skin sensitizer. The case report and a number of human patch tests **[Bakker et al. 1991; Chu and Sun 2001]** identified are sufficient to demonstrate that acrylonitrile is a potential skin sensitizer. Therefore, on the basis of the data for this assessment, acrylonitrile is assigned the SK: SEN notation.

5 Summary

Information from a limited number of human toxicokinetic studies **[Lorz 1950; Vogel and Kirkendall 1984],** supported by predictions from mathematical algorithms, indicates that acrylonitrile can be absorbed through the skin following dermal exposure. Acute **[Roudabush et al. 1965; Dow Chemical USA 1977; Vernon et al. 1990]** and repeat-dose **[Zotova 1976]** dermal toxicity studies in animals provide sufficient evidence that acrylonitrile is extremely toxic, causing systemic toxicity (including vascular congestion and hemorrhages, and neurotoxicity) and may be life-threatening following skin contact. Occupational exposure studies **[Muto et al. 1992; Bakker et al. 1991; Wilson et al. 1948]** and animal studies **[McOmie 1949]** also provide sufficient information to conclude that acrylonitrile is a severe skin irritant in humans and animals, but there is insufficient evidence of corrosivity. There is sufficient information from a case report and a number of human patch tests **[Bakker et al. 1991; Chu and Sun 2001]** to demonstrate that acrylonitrile is a potential skin sensitizer. Therefore, on the basis of these assessments, acrylonitrile is assigned a composite skin notation of **SK: SYS (FATAL)-DIR (IRR)-SEN**.

Table 3 summarizes the skin hazard designations for acrylonitrile previously issued by NIOSH and other organizations. The equivalent dermal designations for acrylamide, according to the Global Harmonized System (GHS) of Classification and Labeling of Chemicals, are Acute Toxicity Category 3 (Hazard statement: Toxic in contact with the skin), Skin Irritation Category 2 (Hazard statement: Causes skin irritation), and Skin Sensitization Category 1 (Hazard statement: May cause an allergic skin reaction) [European Parliament 2008]. Acrylonitrile has been identified as a Category 1B Carcinogen (Hazard statement: May cause cancer) European Parliament 2008].

Table 3. Summary of the previously issued skin hazard designations for acrylonitrile

Organization	Skin hazard designation
NIOSH [2005]	[skin]: Potential for dermal absorption; Prevent skin contact
OSHA [2007]	[skin]: Based on systemic toxicity, expressed as vascular congestion and hemorrhages, in rats from dermal absorption of acrylonitrile
ACGIH [2005]	[skin]: Based on potential contribution to the overall exposure by the cutaneous route, including the mucous membranes and the eyes, either by the airborne route or, more particularly, by direct contact with the substance
EC [2009]	R24: Toxic in contact with skin R38: Irritating to skin R43: May cause sensitization by skin contact

Abbrevieations: ACGIH = American Conference of Governmental Industrial Hygienists; EC = European Commission, Joint Research, Institute for Health and Consumer Protection; NIOSH = National Institute for Occupational Safety and Health; OSHA = Occupational Safety and Health Administration.

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Note: Asterisks (*) denote sources cited in text; daggers (†) denote additional resources.

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Appendix: Calculation of the SI Ratio for Acrylonitrile

The appendix presents an overview of the SI ratio and a summary of the calculation of the SI ratio for acrylonitrile. Although the SI ratio is included within the determination of a substance's hazard potential following skin contact, it is intended only to serve as supportive data during the assignment of the NIOSH SK. An in-depth discussion on the rationale and calculation of the SI ratio can be located in Appendix B of the *Current Intelligence Bulletin (CIB) 61: A Strategy for Assigning New NIOSH Skin Notations* [NIOSH 2009].

Overview

The SI ratio is a predictive algorithm for estimating and evaluating the health hazards of skin exposure to substances. The algorithm is designed to evaluate the potential for a substance to penetrate the skin and induce systemic toxicity [NIOSH 2009]. The goals for incorporating this algorithm into the proposed strategy for assigning SYS notation are as follows:

1. Provide an alternative method to evaluate substances for which no clinical reports or animal toxicity studies exist or for which empirical data are insufficient to determine systemic effects.
2. Use the algorithm evaluation results to determine whether a substance poses a skin absorption hazard and should be labeled with the SYS notation.

The algorithm evaluation includes three steps: (1) determining a skin permeation coefficient (K_p) for the substance of interest, (2) estimating substance uptake by the skin and respiratory absorption routes, and (3) evaluating whether the substance poses a skin exposure hazard.

The algorithm is flexible in the data requirement and can operate entirely on the basis of the physicochemical properties of a substance and the relevant exposure parameters. Thus, the algorithm is independent of the need for biologic data. Alternatively, it can function with both the physicochemical properties and the experimentally determined permeation coefficient when such data are available and appropriate for use.

The first step in the evaluation is to determine the Kp for the substance to describe the transdermal penetration rate of the substance [NIOSH 2009]. The K_p, which represents the overall diffusion of the substance through the stratum corneum and into the blood capillaries of the dermis, is estimated from the compound's molecular weight (MW) and base-10 logarithm of its octanol–water partition coefficient (log K_{OW}). In this example, K_p is determined for a substance with use of Equation 1. A self-consistent set of units must be used, such as centimeters per hour (cm/hr), outlined in Table A1. Other model-based estimates of K_p may also be used [NIOSH 2009].

Equation 1: Calculation of Skin Permeation Coefficient (K_p)

$$K_p + \frac{1}{\frac{1}{K_{psc} + K_{pol}} + \frac{1}{K_{aq}}}$$

where K_{psc} is the permeation coefficient in the lipid fraction of the stratum corneum, K_{pol} is the coefficient in the protein fraction of the stratum corneum, and K_{aq} is

the coefficient in the watery epidermal layer. These components are individually estimated by

$$\log_{kpsc} = -1.326 + 0.6097 \times \log K_{OW} - 0.1786 \times MW^{0.5}$$

$$K_{pol} = 0.0001519 \times MW^{-0.5}$$

$$K_{aq} = 2.5 \times MW^{-0.5}$$

The second step is to calculate the biologic mass uptake of the substance from skin absorption (skin dose) and inhalation (inhalation dose) during the same period of exposure. The skin dose is calculated as a mathematical product of the K_p, the water solubility (SW) of the substance, the exposed skin surface area, and the duration of exposure. Its units are milligrams (mg). Assume that the skin exposure continues for 8 hours to unprotected skin on the palms of both hands (a surface area of 360 cm^2).

Equation 2: Determination of Skin Dose

$$\text{Skin dose} = K_p \times S_W \times \text{Exposed skin surface area} \times \text{Exposure time}$$

$$= K_p(\text{cm/hr}) \times S_W\ (\text{mg/cm}^3) \times 360\ \text{cm}^2 \times 8\ \text{hours}$$

The inhalation dose (in mg) is derived on the basis of the occupational exposure limit (OEL) of the substance—if the OEL is developed to prevent the occurrence of systemic effects rather than sensory/irritant effects or direct effects on the respiratory tract. Assume a continuous exposure of 8 hours, an inhalation volume of 10 cubic meters (m^3) inhaled air in 8 hours, and a factor of 75% for retention of the airborne substance in the lungs during respiration (retention factor, or RF).

Equation 3: Determination of Inhalation Dose

$$\text{Inhalation dose} = \text{OEL} \times \text{Inhalation volume} \times \text{RF}$$

$$= \text{OEL}\ (\text{mg/m}^3) \times 10\ \text{m}^3 \times 0.75$$

The final step is to compare the calculated skin and inhalation doses and to present the result as a ratio of skin dose to inhalation dose (the SI ratio). This ratio quantitatively indicates (1) the significance of dermal absorption as a route of occupational exposure to the substance and (2) the contribution of dermal uptake to systemic toxicity. If a substance has an SI ratio greater than or equal to 0.1, it is considered a skin absorption hazard.

Calculation

Table A1 summaries the data applied in the previously described equations to determine the SI ratio for acrylonitrile. The calculated SI ratio was 44.05. On the basis of these results, acrylonitrile is predicted to represent a skin absorption hazard.

Table A1. Summary of data used to calculate the SI ratio for acrylonitrile

Variables used in calculation	Units	Value
Skin permeation coefficient		
Permeation coefficient of stratum corneum lipid path(K_{psc})	cm/hr	0.00335
Permeation coefficient of the protein fraction of the stratum corneum (K_{pol})	cm/hr	2.08533×10^{-5}
Permeation coefficient of the watery epidermal layer (K_{aq})	cm/hr	0.34321
Molecular weight (MW)*	amu	53.06
Base-10 logarithm of its octanol–water partition coefficient (Log K_{OW})*	None	0.25
Calculated skin permeation coefficient (K_p)	cm/hr	0.00334
Skin dose		
Water solubility (S_W)*	mg/cm^3	74.5
Calculated skin permeation coefficient (K_p)	cm/hr	0.00334
Estimated skin surface area (palms of hand)	cm^2	360
Exposure time	hr	8
Calculated skin dose	mg	716.89
Inhalation dose		
Occupational exposure limit (OEL)†	mg/m^3	2.17
Inhalation volume	m^3	10
Retention factor (RF)	None	0.75
Inhalation dose	mg	16.28
Skin dose–to–inhalation dose (SI) ratio	None	44.05

*Variables identified from SRC [2009].
†The OEL used in calculation of the SI ratio was the NIOSH recommended exposure limit (REL) of 1 part per million (5 mg/m^3) [NIOSH 2005].

Appendix References

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