

# **Evaluating Potential Human Health Risks Associated with the Development of Utility-Scale Solar Energy Facilities on Contaminated Sites**

---

**Environmental Science Division**

### **About Argonne National Laboratory**

Argonne is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC under contract DE-AC02-06CH11357. The Laboratory's main facility is outside Chicago, at 9700 South Cass Avenue, Argonne, Illinois 60439. For information about Argonne and its pioneering science and technology programs, see [www.anl.gov](http://www.anl.gov).

### **DOCUMENT AVAILABILITY**

**Online Access:** U.S. Department of Energy (DOE) reports produced after 1991 and a growing number of pre-1991 documents are available free via DOE's SciTech Connect (<http://www.osti.gov/scitech/>)

### **Reports not in digital format may be purchased by the public from the National Technical Information Service (NTIS):**

U.S. Department of Commerce  
National Technical Information Service  
5301 Shawnee Rd  
Alexandria, VA 22312  
**[www.ntis.gov](http://www.ntis.gov)**  
Phone: (800) 553-NTIS (6847) or (703) 605-6000  
Fax: (703) 605-6900  
Email: **[orders@ntis.gov](mailto:orders@ntis.gov)**

### **Reports not in digital format are available to DOE and DOE contractors from the Office of Scientific and Technical Information (OSTI):**

U.S. Department of Energy  
Office of Scientific and Technical Information  
P.O. Box 62  
Oak Ridge, TN 37831-0062  
**[www.osti.gov](http://www.osti.gov)**  
Phone: (865) 576-8401  
Fax: (865) 576-5728  
Email: **[reports@osti.gov](mailto:reports@osti.gov)**

### **Disclaimer**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor UChicago Argonne, LLC, nor any of their employees or officers, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of document authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, Argonne National Laboratory, or UChicago Argonne, LLC.

# **Evaluating Potential Human Health Risks Associated with the Development of Utility-Scale Solar Energy Facilities on Contaminated Sites**

---

by

J.-J. Cheng<sup>1</sup>, Y.-S. Chang<sup>1</sup>, H. Hartmann<sup>1</sup>, K. Wescott<sup>1</sup>, and C. Krygeris<sup>2</sup>

<sup>1</sup>Environmental Science Division, Argonne National Laboratory

<sup>2</sup>Indiana University of Pennsylvania

September 2013



## **ACKNOWLEDGMENTS**

The authors would like to thank Gail Mosey of the National Renewable Energy Laboratory for providing direction for accessing available resources associated with the U.S. Environmental Protection Agency's (EPA) RE-Powering America's Lands Initiative and for providing connection to EPA for the review of this report; Adam Klinger of EPA for arranging the review of this report by EPA's risk assessment team; and Katie Brown and Marc Thomas of EPA's risk assessment team for reviewing the report and providing valuable comments. The authors appreciate the comments and suggestions of Molly Finster and Karen Smith of Argonne National Laboratory on the presentation and content of this report. Work conducted for this study was funded by the U.S. Department of Energy, Solar Energy Technologies Program.



# CONTENTS

ACKNOWLEDGMENTS .....		iii
NOTATION.....		xv
1 INTRODUCTION .....		1
2 CONTAMINATED SITES WITH UTILITY-SCALE SOLAR ENERGY POTENTIAL .....		5
2.1 Preliminary Screening Criteria for Utility-Scale Solar Energy Potential .....		5
2.2 Contaminated Sites Passing EPA and NREL Screening .....		6
3 CONTAMINANTS OF CONCERN AND POTENTIAL HUMAN EXPOSURE PATHWAYS.....		9
3.1 Contaminants of Concern .....		9
3.2 Environmental Transport of Contaminants and Potential Human Exposure Pathways .....		10
3.2.1 Soil Contamination .....		10
3.2.2 Surface-Water and Groundwater Contamination.....		11
4 DEVELOPMENT OF A GENERAL METHODOLOGY FOR ASSESSING HUMAN HEALTH RISKS ASSOCIATED WITH SOLAR ENERGY FACILITIES .....		13
4.1 Establishment of Calculation Framework.....		13
4.1.1 Conceptual Model and the Daily Risk Approach .....		13
4.1.2 Basic Assumptions.....		15
4.1.3 Estimating Daily Risks with Solar Facility Soil Concentration Limits .....		16
4.1.4 Calculation of Total Risk .....		18
4.2 Development of SFSCs for Exposures of Facility Workers Based on Carcinogenic Risks .....		20
4.2.1 Soil Ingestion Pathway .....		21
4.2.1.1 SSL Equation and Parameter Values Used to Derive RSLs .....		21
4.2.1.2 Modification of RSLs to Obtain SFSCs .....		21
4.2.2 Inhalation of Volatiles Pathway.....		26
4.2.2.1 SSL Equations and Parameter Values Used to Derive RSLs .....		26
4.2.2.2 Modification of RSLs to Obtain SFSCs .....		27
4.2.3 Inhalation of Particulate Pathway .....		32
4.2.3.1 SSL Equations and Parameter Values Used to Derive RSLs .....		32
4.2.3.2 Modification of RSLs to Obtain SFSCs .....		33

**CONTENTS (Cont.)**

4.2.4	Dermal Absorption Pathway.....	38
4.2.4.1	SSL Equation and Parameter Values Used to Derive RSLs.....	38
4.2.4.2	Modification of RSLs to Obtain SFSCls.....	39
4.3	Development of SFSCls for Exposures of Facility Workers Based on Non-Carcinogenic Risks .....	43
4.3.1	Soil Ingestion Pathway .....	43
4.3.1.1	SSL Equation and Parameter Values Used to Derive RSLs.....	43
4.3.1.2	Modification of RSLs to Obtain SFSCls.....	43
4.3.2	Inhalation of Volatiles Pathway.....	46
4.3.2.1	SSL Equations and Parameter Values Used to Derive RSLs .....	46
4.3.2.2	Modification of RSLs to Obtain SFSCls.....	48
4.3.3	Inhalation of Particulate Pathway.....	51
4.3.3.1	SSL Equations and Parameter Values Used to Derive RSLs .....	51
4.3.3.2	Modification of RSLs to Obtain SFSCls.....	52
4.3.4	Dermal Absorption Pathway.....	56
4.3.4.1	SSL Equation and Parameter Values Used to Derive RSLs.....	56
4.3.4.2	Modification of RSLs to Obtain SFSCls.....	57
4.4	Development of SFSCls for Exposures of Offsite Residents Based on Carcinogenic Risks .....	58
4.4.1	Inhalation of Volatiles Pathway.....	60
4.4.1.1	SSL Equations and Parameter Values Used to Derive RSLs .....	60
4.4.1.2	Modification of RSLs to Obtain SFSCls.....	61
4.4.2	Inhalation of Particulate Pathway .....	65
4.4.2.1	SSL Equations and Parameter Values Used to Derive RSLs .....	65
4.4.2.2	Modification of RSLs to Obtain SFSCls.....	66
4.5	Development of SFSCls for Offsite Residents based on Non-carcinogenic Risks.....	66
4.5.1	Inhalation of Volatiles Pathway.....	70
4.5.1.1	SSL Equations and Parameter Values Used to Derive RSLs .....	70
4.5.1.2	Modification of RSLs to Obtain SFSCls.....	71
4.5.2	Inhalation of Particulate Pathway.....	74
4.5.2.1	SSL Equation and Parameter Values Used to Derive RSLs.....	74
4.5.2.2	Modification of RSLs to Obtain SFSCls.....	75
4.6	Values of the Activity Level Modification Factor, MF <sub>a</sub> .....	78
4.6.1	MF <sub>a</sub> for Release of Volatiles.....	79
4.6.1.1	Release by Construction .....	79
4.6.1.2	Release by Wind .....	84
4.6.1.3	Values of MF <sub>a</sub> .....	85
4.6.2	MF <sub>a</sub> for Release of Particulates .....	91
4.6.2.1	Release by Construction .....	91
4.6.2.2	Release by Wind .....	94
4.6.2.3	Values of MF <sub>a</sub> .....	95

## CONTENTS (Cont.)

4.7	Values for the Distance Modification Factor, MF <sub>d</sub> .....	95
	4.7.1 MF <sub>d</sub> for Workers in the Non-contaminated Area .....	96
	4.7.2 MF <sub>d</sub> for Offsite Resident Exposures.....	97
5	UNCERTAINTIES, APPLICATIONS, AND MITIGATION MEASURES .....	101
	5.1 Uncertainties and Use of Site-specific Data .....	101
	5.2 Applications of the Methodology. ....	103
	5.3 Mitigation Measures. ....	104
6	Conclusions.....	105
7	References.....	107
APPENDIX A Demonstration of Application of the General Methodology .....		A-1
APPENDIX B Potential Contaminants of Concern.....		B-1

## FIGURE

4-1	Conceptual Model for Human Exposures to Contamination in a Solar Energy Facility. ....	14
-----	--	----

## TABLES

2-1	Distribution of Contaminated Sites with Utility-Scale CSP Energy Generation Potential—Stirling Engine Systems.....	7
2-2	Distribution of Contaminated Sites with Utility-Scale CSP Energy Generation Potential—Parabolic Trough and Power Tower Systems.....	8
2-3	Distribution of Contaminated Sites with Utility-Scale PV Solar Energy Generation Potential.....	8
4-1	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Contaminated Area.....	22

## TABLES (Cont.)

4-2	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Non-contaminated Area .....	23
4-3	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Contaminated Area .....	24
4-4	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Non-contaminated Area .....	25
4-5	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area .....	28
4-6	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area .....	30
4-7	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Operation in the Contaminated Area .....	31
4-8	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Operation in the Non-contaminated Area.....	32
4-9	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area .....	34
4-10	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area .....	36
4-11	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Contaminated Area .....	37
4-12	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Non-contaminated Area.....	38

**TABLES (Cont.)**

4-13	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Contaminated Area .....	40
4-14	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Non-contaminated Area.....	41
4-15	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Contaminated Area.....	42
4-16	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Non-contaminated Area.....	42
4-17	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Contaminated Area .....	44
4-18	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Non-contaminated Area.....	45
4-19	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Contaminated Area.....	45
4-20	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Non-contaminated Area.....	46
4-21	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area .....	48
4-22	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area .....	49
4-23	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatile Pathway during Operation in the Contaminated Area .....	50

**TABLES (Cont.)**

4-24	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Operation in the Non-contaminated Area.....	51
4-25	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area .....	53
4-26	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area .....	54
4-27	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Contaminated Area .....	55
4-28	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Non-contaminated Area.....	56
4-29	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Contaminated Area .....	58
4-30	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Non-contaminated Area .....	59
4-31	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Contaminated Area .....	59
4-32	Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Non-contaminated Area.....	60
4-33	Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area .....	62

**TABLES (Cont.)**

4-34 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area ..... 64

4-35 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during the Operation Phase ..... 65

4-36 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area ..... 67

4-37 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area ..... 68

4-38 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during the Operation Phase ..... 69

4-39 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area ..... 72

4-40 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area ..... 73

4-41 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during the Operation Phase ..... 74

4-42 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area ..... 76

4-43 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area ..... 77

4-44 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during the Operation Phase ..... 78

**TABLES (Cont.)**

4-45	Calculation of the Emission Rates for Volatile Organic Compounds and the Value of MF <sub>a</sub> ' .....	86
4-46	Metal Concentration and Enrichment Data.....	93
4-47	Values of Coefficients a, b, and c for Different Contaminated Areas .....	98
A-1	Volatility and Toxicity Values of COCs.....	A-5
A-2	RCLs Corresponding to a Target Cancer Risk of $1 \times 10^{-6}$ .....	A-5
A-3	RCLs Corresponding to a Target Hazard Quotient of 1 .....	A-6
A-4	Modification Factor for Activity Level and Modification Factor for Exposure Distance .....	A-7
A-5	Modification Factors for Use to Adjust RCLs to Obtain SFSCSLs Concerning Carcinogenic Risks Incurred by Workers .....	A-8
A-6	Modification Factors for Use to Adjust RCLs to Obtain SFSCSLs Concerning Non-carcinogenic Risks Incurred by Workers.....	A-9
A-7	Modification Factors for Use to Adjust RCLs to Obtain SFSCSLs Concerning Carcinogenic Risks Incurred by Offsite Residents .....	A-10
A-8	Modification Factors for Use to Adjust RCLs to Obtain SFSCSLs Concerning Non-carcinogenic Risks Incurred by Offsite Residents.....	A-11
A-9	SFSCSLs Based on Carcinogenic Risks Incurred by Workers.....	A-12
A-10	SFSCSLs Based on Non-carcinogenic Risks Incurred by Workers.....	A-13
A-11	SFSCSLs Based on Carcinogenic Risks Incurred by Offsite Residents .....	A-14
A-12	SFSCSLs Based on Non-carcinogenic Risks Incurred by Offsite Residents.....	A-14
A-13	Carcinogenic Risks from One-day Exposure—Workers.....	A-15
A-14	Hazard Quotients from One-day Exposure—Workers .....	A-16
A-15	Carcinogenic Risks from One-day Exposure—Residents .....	A-16

**TABLES (Cont.)**

A-16 Hazard Quotients from One-day Exposure—Residents ..... A-17

A-17 Exposure Durations for Different Activities and Receptors ..... A-18

A-18 Carcinogenic Risks over the Entire Duration of Activities—Exposures  
of Workers ..... A-19

A-19 Hazard Quotients over the Entire Duration of Activities—Exposures  
of Workers ..... A-20

A-20 Carcinogenic Risks over the Entire Duration of Activities—Exposures  
of Residents..... A-20

A-21 Hazard Quotients over the Entire Duration of Activities—Exposures  
of Residents..... A-21

A-22 Total Cancer Risk to Each Receptor ..... A-22

A-23 Total Hazard Index to Each Receptor ..... A-22

B-1 List of Contaminants of Concern..... B-3



## NOTATION

The following is a list of acronyms, abbreviations, and units of measure used in this document. Some acronyms used only in tables may be defined only in those tables.

### GENERAL ACRONYMS AND ABBREVIATIONS

AF	soil adherence factor
AT	averaging period
COC	contaminant of concern
CSF	cancer slope factor
CSP	concentrating solar power
EPA	U.S. Environmental Protection Agency
HHMSSL	human health medium-specific screening limit
HI	hazard index
HQ	hazard quotient
IRA	inhalation rate
IRS	soil ingestion rate
MF <sub>a</sub>	activity level modification factor
MF <sub>d</sub>	distance modification factor
MF <sub>e</sub>	exposure pattern modification factor
NREL	National Renewable Energy Laboratory
PAH	polycyclic aromatic hydrocarbon
PPE	personal protective equipment
PRG	preliminary remediation goal
PV	photovoltaic
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RSL	regional screening level
SA	skin surface area
SF	slope factor
SFSCCL	solar facility soil concentration limit
SSL	soil screening limit

URF	unit risk factor
VOC	volatile organic compound

## UNITS OF MEASURE

acre	acre
atm	atmospheric pressure
°C	degree(s) Celsius
cm	centimeter(s)
cm <sup>2</sup>	square centimeter(s)
cm <sup>3</sup>	cubic centimeter(s)
day	day
ft	foot (feet)
ft <sup>2</sup>	square foot (feet)
g	gram(s)
hr	hour(s)
°K	degree(s) Kelvin
kg	kilogram(s)
kW	kilowatt(s)
kWh	kilowatt-hour(s)
m	meter(s)
mg	milligram(s)
m <sup>2</sup>	square meter(s)
m <sup>3</sup>	cubic meter(s)
mi	mile(s)
mm	millimeter(s)
mm Hg	millimeter(s) of mercury
mol	mole(s)
m/s	meter(s) per second
s	second(s)
W	watt(s)
yr	year
µm	micrometer(s) (microns)

## 1 INTRODUCTION

Utility-scale solar energy facilities occupy large tracts of land, generally from about 40 acres up to several thousand acres (BLM and DOE 2012). Siting such facilities on formerly used, environmentally contaminated sites may provide a suitable alternative to siting on large parcels of pristine, natural habitat, provided the associated human health risks are acceptably low. In addition to avoiding the environmental impacts of siting on pristine lands, developing on formerly used sites with existing infrastructure, including access to transmission lines and substations and to transportation corridors, could also reduce development costs and other associated impacts. Prior to reuse, the potential human health risks associated with exposure to contaminants present at the site during solar facility construction and operation need to be assessed; if the assessment indicates that the potential risks associated with existing contamination would exceed the acceptable levels, additional remediation of the site prior to solar energy development may be needed to ensure the protection of workers and the general public during the reuse. Conversely, if the assessment indicates that the potential risks associated with existing contamination would not exceed the acceptable levels, siting of a solar facility may occur without the need for extensive remediation. However, if remediation activities are required, they may be integrated with the design and construction of the solar facility to reduce the overall exposures of workers and the general public to the contaminants (EPA 2013a).

Although potential human health risks associated with operating a utility-scale solar energy facility constructed on a contaminated site do exist, these risks are expected to be no greater than those associated with industrial use and lower than those associated with residential use of the same contaminated site. The risk would not be greater or would be lower because solar energy facilities are generally secured sites. The operation of a solar energy facility is not labor intensive, does not require many workers spending long hours at the facility, and typically, does not involve vigorous land-disturbing activities that could contribute to the release of contaminants from soils or other media and increase the potential risk for subsequent contaminant exposures. During the construction and decommissioning (post-operation) of a solar energy facility when grading, foundation installation, or other land-disturbing activities may be occurring, the potential exposures to contaminants would be higher than during the operation phase; however, these exposures likely would be similar to those associated with the remediation or construction of houses or industrial buildings on the contaminated site. With advance planning and implementation of best management practices (e.g., soil erosion control, use of personal protective equipment [PPE]), potential human health risks associated with the construction and decommissioning of a utility-scale solar energy facility on a contaminated site can be greatly reduced.

This report presents a general methodology for obtaining preliminary estimates of the potential human health risks associated with developing a utility-scale solar energy facility on a contaminated site, based on potential exposures to contaminants in soils (including transport of

those contaminants into the air).<sup>1</sup> A clear understanding of the potential risks is needed to evaluate the feasibility of developing a particular contaminated site, the need for further remediation, and/or use of protective measures, and the associated economic impacts on a project. To facilitate risk assessment in the initial evaluation of a site, the methodology requires only a limited number of site-specific parameters critical to the determination of potential human health risk and adopts conservative values for less critical parameters. Therefore, the methodology can be applied to evaluate a contaminated site regardless of its remediation status. However, as remediation proceeds, more site-specific data can be obtained and used to replace the conservative values of less critical parameters to improve the precision of the risk estimates. Although this methodology was initially developed on the basis of information available for and conditions present at contaminated sites in six southwestern states (Arizona, California, Colorado, Nevada, New Mexico, and Utah), due to the general approach and conservative assumptions used, it is anticipated that the methodology can also be adapted to evaluate contaminated sites in other regions of the country.<sup>2</sup>

The methodology follows the U.S. Environmental Protection Agency (EPA) guidance on human health risk assessment (EPA 1989) and is based on the equations developed by EPA for deriving soil screening limits (SSLs) for contaminated sites (EPA 1996a,b). Briefly, the methodology modifies the existing generic SSLs for individual contaminants that were derived for standard resident and industrial worker scenarios to develop soil concentration limits for specific activities associated with construction and operation of utility-scale solar facilities. It then scales the concentration limits with measured or estimated soil concentrations which are expected to be present at the time of solar facility construction and operation to obtain preliminary estimates of potential risks associated with solar energy development. Because the modifications of the generic SSLs take into account the nature of the specific activities associated with solar energy development, which differ somewhat from the default activity assumptions used to derive the generic SSLs, as well as the size of soil contamination, the land area of the solar facility, and the distance to the off-site general public, the methodology provides a more refined estimate of potential risks to workers and the general public specific to solar energy development on the contaminated site evaluated.

Facility workers and the general public living near a solar energy facility built on an unremediated contaminated site have the potential to be chronically exposed to contaminants which are present in soils within the facility. However, the exposures would vary over time depending on the type, location, and duration of activities conducted within the facility. To streamline the risk assessment approach, the methodology assesses the risk to each type of receptor (i.e., facility workers and offsite resident receptors) associated with the individual

---

<sup>1</sup> Transport of contaminants from soil to surface water or groundwater could occur; however, at contaminated sites with high potential for utility-scale solar energy development, such transport would be much less significant than the transport from soil into the air because of the low precipitation and high evapotranspiration at locations in the arid Southwestern U.S. Therefore, only the potential exposures related to the transport of contaminants from soil into air are considered in this report.

<sup>2</sup> Site-specific factors applicable to various parts of the U.S., such as geology and meteorological conditions, can be taken into account to improve the precision of initial conservative risk estimates.

activities that would be conducted for solar energy development. For each activity, the potential risk is calculated on the basis of daily exposure, which is referred to as “daily risk” in this report. The potential daily risks incurred by a receptor can be multiplied by the number of days required for each activity, which is dependent on the size of the facility, and the products can then be summed over the different activities to yield an estimate of the total risk to that receptor.

The calculation of potential daily risks entails the use of the SSL equations to derive soil concentration limits specific to the daily exposures associated with development and operation of a solar facility. In this report, these limits are called solar facility soil concentration limits (SFSCs) to differentiate them from other SSLs derived with the same SSL equations. These SFSCs are derived on the basis of a target risk limit of  $1 \times 10^{-6}$  for carcinogenic effects, or a target hazard quotient limit of 1 for noncarcinogenic effects. Potential daily risks from exposure to a chemical associated with each activity can be estimated by scaling the measured or estimated soil concentration of that chemical with its SFSC, specifically, by multiplying the cancer risk or hazard quotient limit by the ratio of the measured or estimated soil concentration of that chemical to its SFSC. To obtain SFSCs, the input parameters used in the SSL equations need to be selected carefully to reflect the exposure conditions of each receptor under consideration.

Although the SFSCs can be developed by using the SSL equations directly, the methodology developed in this report employs an alternative, simpler approach to accomplish the same objective. It calculates the SFSCs by modifying the existing regional screening levels (RSLs) developed by EPA (EPA 2013b,c). The RSLs were also developed using the SSL equations to evaluate the potential chronic exposures of a standard industrial worker and resident to chemical contamination in soils. Because they use the same SSL equations, RSLs can be adjusted with appropriate modification factors to obtain SFSCs. In this way, the SFSCs can be obtained without performing full-scale calculations with the SSL equations. These modification factors should be determined by comparing the input parameter values used to derive the RSLs with those that should be used for deriving the SFSCs. This report describes the determination of the modification factors, taking into account the area of the solar energy facility, the size of the contaminated area within the facility, the distance to nearby residents, and the increase in airborne emissions of chemicals caused by construction and decommissioning activities.

Under EPA’s RE-Powering America’s Lands Initiative: Siting Renewable Energy on Potentially Contaminated Lands, Landfills, and Mine Sites, EPA, in partnership with various state agencies and in cooperation with the Department of Energy’s National Renewable Energy Laboratory (NREL), has conducted preliminary screening of more than 66,000 sites in the U.S. and developed a database of contaminated sites with renewable energy development potential (EPA 2013d,e). Chapter 2 of this report provides a summary of the work performed by EPA and NREL, focusing on contaminated sites with utility-scale solar energy development potential. The contaminated sites that passed the preliminary screening for utility-scale solar energy development in the EPA/NREL study are ideal candidates for further evaluation of the potential human health risks associated with solar energy development at the sites. According to the EPA and NREL study, a total of 1,580 sites evaluated meet the qualification requirements for photovoltaic (PV) solar energy systems; 438 of them also meet the qualification requirements for concentrating solar power (CSP) technology with Stirling engine systems, and 268 of them also

meet the qualification requirements for CSP technology with parabolic trough or power tower systems (EPA 2013f). These sites include six different categories – abandoned mine lands, brownfields, federal Superfund sites, non-federal Superfund sites, landfills, and Resource Conservation and Recovery Act (RCRA) sites (EPA 2013a), and the sites are at different stages of investigation and/or remediation.

Chapter 3 of this report discusses the potential contaminants of concern, contaminated media, and human exposure pathways associated with contaminated sites with utility-scale solar energy potential. Although the information supporting the discussions was obtained from contaminated sites located in the southwestern United States (the region with the highest potential for utility-scale solar energy development), given the comprehensiveness of the list of chemical contaminants compiled, it is anticipated that the reviews of contaminants of concern, contaminated media, and human exposure pathways compiled on the basis of the contamination information for sites in the southwestern U.S. would be applicable to comparable sites in other regions of the country.

Detailed discussions on the methodology for evaluating potential human health risks associated with the development of a utility-scale solar energy facility on contaminated sites are provided in Chapter 4. The overall approach and basic assumptions are first discussed in Section 4.1. Sections 4.2–4.7 provide detailed discussions of the SSL equations; comparisons of the parameter values that derive the RSLs and those that should be used to derive the SFSCSLs; and the development and calculation of the modification factors that can be used to obtain the SFSCSLs from the RSLs. The discussions in Sections 4.2–4.7 are intended for individuals tasked with assessing the risk associated with developing a specific contaminated site for solar development. It is assumed these risk assessors are familiar with EPA guidance on human health risk assessments for chemical exposures and have a working knowledge of how to apply the SSL equations. Therefore, the discussions do not elaborate on the use of each input parameter and the assumptions associated with the development of the SSL equations (the users are referred to the original EPA documents [EPA 1989, 1996a, b] to obtain background information). If a reader is not required to perform human health risk assessments to evaluate a contaminated site, he or she can read Section 4.1 for an overview of the proposed methodology, skip the detailed technical discussions presented in Sections 4.2–4.7, and proceed to Chapter 5.

In Chapter 5, discussions about the uncertainty associated with the general methodology, use of site-specific data to improve the precision of risk estimation, and applications of the general methodology are provided. In addition, mitigation measures that can be applied during the construction and/or decommissioning of a solar energy facility to reduce potential human exposures are presented for consideration. Conclusions are presented in Chapter 6. Appendix A demonstrates the implementation of the general methodology using a sample site. Appendix B lists the potential contaminants of concern compiled with data from more than 80 contaminated sites in the southwest region of this country.

## **2 CONTAMINATED SITES WITH UTILITY-SCALE SOLAR ENERGY POTENTIAL**

Under the RE-Powering America's Lands Initiative: Siting Renewable Energy on Potentially Contaminated Lands, Landfills, and Mine Sites, EPA, in partnership with various state agencies and in cooperation with NREL, has conducted preliminary screening of more than 66,000 sites across the U.S. and developed a database of existing contaminated sites with renewable energy development potential. Based on the screening criteria developed by EPA and NREL, existing contaminated sites were screened for the potential of solar, wind, biomass, and geothermal potential at various levels of development (EPA 2013d,e). Since the inception of the RE-Powering America's Lands Initiative, more than 70 renewable energy projects have been installed on contaminated lands or landfills. These early projects represent just over 200 MW of installed capacity, which could power approximately 30,000 homes, and provide a foundation for future development as demonstrations of the latest technologies in both renewable energy and remediation design (EPA 2013g).

This chapter summarizes the criteria developed by EPA and NREL for screening contaminated sites for utility-scale solar energy development potential and the various types of contaminated sites that passed the preliminary evaluation.

### **2.1 PRELIMINARY SCREENING CRITERIA FOR UTILITY-SCALE SOLAR ENERGY POTENTIAL**

Two sets of screening criteria were developed by EPA and NREL for evaluating contaminated sites for utility-scale solar energy potential (EPA 2013d). The first set considers solar energy development using concentrating solar power (CSP) technology, including Stirling engine systems, parabolic trough, and power tower technologies. The second set considers solar energy development with photovoltaic (PV) technology.

Among the criteria for CSP technology, specific requirements for available land area are different for different power systems. The following are screening criteria for CSP technologies:

1. Estimated energy project capacity range is  $> 5$  MW for Stirling engine systems and  $> 30$  MW for trough and power tower systems,
2. Direct normal solar resource availability is  $\geq 6$  kWh/m<sup>2</sup>/day,
3. Distance to electric transmission lines<sup>3</sup> is  $\leq 10$  mi,

---

<sup>3</sup> A short distance to existing transmission lines may facilitate development by decreasing the cost of connecting the facility with the grid; however, it is unlikely that sufficient transmission capacity is available on existing lines to accommodate larger solar facilities

4. Property size is  $\geq 40$  acres for Stirling engine system and  $\geq 250$  acres for trough and power tower systems, and
5. Distance to graded roads is  $\leq 10$  mi.

For PV technology, the screening criteria are as follows:

1. Estimated energy project capacity range is  $> 6.5$  MW,
2. Direct normal solar resource availability is  $\geq 5$  kWh/m<sup>2</sup>/day,
3. Distance to electric transmission lines<sup>4</sup> is  $\leq 10$  mi,
4. Property size is  $\geq 40$  acres, and
5. Distance to graded roads is  $\leq 10$  mi.

For most contaminated sites, it is likely that there will not be sufficient transmission capacity with existing lines to accommodate large utility-scale solar energy systems. However, the available right of way and potential reuse of transmission towers may reduce the economic burden of a utility-scale solar energy development project.

## **2.2 CONTAMINATED SITES PASSING EPA AND NREL SCREENING**

Through the RE-Powering America's Land Initiative, EPA has screened more than 66,000 EPA- and state-tracked contaminated sites (comprising over 35 million acres of contaminated land) for potential for renewable energy development (EPA 2013f). Through the screening, 1,580 sites were found to have the potential for utility-scale solar energy development. While all 1,580 sites meet the qualification requirements for PV solar energy systems, only 438 of them meet the qualification requirements for CSP technology with Stirling engine systems, and 268 of them meet the qualification requirements for CSP technology with parabolic trough or power tower systems (EPA 2013f).

These potentially contaminated sites can be divided into six different categories: abandoned mine lands, brownfields, federal Superfund sites, non-federal Superfund sites, landfills, and Resource Conservation and Recovery Act (RCRA) sites (EPA 2013a). With the use of the RE-Powering Screening Dataset compiled by EPA (2013e), the distributions of contaminated sites with the potential for utility-scale solar energy development among different states were determined. Table 2-1 shows the distributions of contaminated sites suitable for development with Stirling engine systems, Table 2-2 shows distributions of contaminated sites suitable for development with parabolic trough and power tower systems, and Table 2-3 shows

---

<sup>4</sup> See footnote 3

distributions of contaminated sites suitable for development with PV systems. The states listed in each table include the six states that are generally considered to have high overall potential for utility-scale solar development over the next 20 years (BLM and DOE 2012) – Arizona, California, Colorado, Nevada, New Mexico, and Utah.

The potentially contaminated sites that passed EPA and NREL screening are ideal candidates for further evaluation. The methodology developed in this report can be applied for individual sites to provide preliminary estimates of the potential human health risks associated with solar energy development at these sites and to determine whether cleanup is required; the level of cleanup needed, if any, before the site can be utilized safely for solar energy development; and/or the need for other protective measures (e.g., the use of PPE during certain construction activities).

**TABLE 2-1 Distribution of Contaminated Sites with Utility-Scale CSP Energy Generation Potential—Stirling Engine Systems<sup>a</sup>**

State	Abandoned Mine Land	Brownfield	RCRA	Federal Superfund	Non-federal Superfund	Landfill	Total
Arizona		27		3	7	15	52
California	1	6	1	6	3	44	61
Colorado	6	8	6		5	6	31
Hawaii		1				1	2
New Mexico		13	17	1	3	6	40
Nevada	1	14	8		1	5	29
Texas			12	1	1	6	20
Utah	2		1	1	2	1	7
Total	10	69	45	12	22	84	242

Source: EPA 2013e

<sup>a</sup> Excluding those under the California Department of Toxic Substances Control (DTSC) cleanup program and Hawaii Hazard Evaluation and Emergency Response Office (HEERO) program.

**TABLE 2-2 Distribution of Contaminated Sites with Utility-Scale CSP Energy Generation Potential—Parabolic Trough and Power Tower Systems<sup>a</sup>**

State	Abandoned Mine Land	Brownfield	RCRA	Federal Superfund	Non-federal Superfund	Landfill	Total
Arizona		5	9	3	6	6	29
California	1	1	9	4	2	4	21
Colorado	5	1	6		4	3	19
New Mexico		4	15		1	2	22
Nevada		3	6		1	3	13
Texas			9	1		4	14
Utah	2		1	1	2		6
Total	8	14	55	9	16	22	124

Source: EPA 2013e

<sup>a</sup> Excluding those under the California DTSC cleanup program and Hawaii HEERO program.

**TABLE 2-3 Distribution of Contaminated Sites with Utility-Scale PV Solar Energy Generation Potential<sup>a</sup>**

State	Abandoned Mine Land	Brownfield	RCRA	Federal Superfund	Non-federal Superfund	Landfill	Total
Arizona		27	17	3	7	15	69
California	2	35	64	20	19	147	287
Colorado	10	21	21	3	15	19	89
Florida		1					1
Hawaii		3	4	1		6	14
Idaho	2	15	2	2	3	10	34
Kansas		7	3			5	15
Montana	1	1	2		3		7
Nebraska		1	3			2	6
New Mexico		13	17	1	3	6	40
Nevada	1	14	8		1	5	29
Oklahoma		22	8		1	5	36
Oregon	1	12	1	1		6	21
Puerto Rico		1	12		2	4	19
South Dakota	2	2		1	2	1	8
Texas		1	25	1	1	12	40
Utah	10	4	15	4	1	7	41
Washington			2			2	4
Wyoming		6	9	1	1	1	18
Total	29	186	213	38	59	253	778

Source: EPA 2013e

<sup>a</sup> Excluding those under the California DTSC cleanup program, Hawaii HEERO, and Oregon Department of Environmental Quality cleanup program.

### 3 CONTAMINANTS OF CONCERN AND POTENTIAL HUMAN EXPOSURE PATHWAYS

The existing contaminated sites identified through EPA's RE-Powering America's Land Initiative with utility-scale solar energy development potential include abandoned mine lands, brownfields, federal Superfund sites, non-federal Superfund sites, landfills, and RCRA sites. Depending on past activities conducted at these sites, different contaminants of concern could be present and have the potential to result in adverse impacts on human health associated with solar energy development. To help focus the general methodology to assess the potential human health risks associated with exposure, a list of typical contaminants of concern (COCs) present at these types of sites was compiled. This list of COCs was obtained using the Google Earth interactive mapping tool developed by EPA (2010), in which contamination profiles were accessed and reviewed by following the links for each mapped contaminated site<sup>5</sup>. The following sections provide general discussions on the COCs, contaminated media, fate and transport of contaminants from those media, and potential exposure pathways through which human receptors could be exposed to COCs and experience adverse health effects.

#### 3.1 CONTAMINANTS OF CONCERN

When accessing and reviewing contamination profiles for contaminated sites, it was found that profiles were available for 330 contaminated sites located in the six southwest states that had utility-scale solar energy development potential.<sup>6</sup> These profiles were searched to retrieve information on contaminants present at the sites. Depending on the status of investigation or remediation actions, information on contaminants at each site was not always available or up to date. In the end, a list of COCs was compiled for about 80 contaminated sites, the majority of which were federal or non-federal Superfund sites, with a few abandoned mine lands. Although details on the contaminants at RCRA sites, brownfields, and landfills were largely not available for the compilation, it is likely that the majority of the COCs for these sites are included in the approximately 250 contaminants in the list assembled for the Superfund sites and abandoned mine lands and presented in Appendix B.

As shown in the compiled list, the COCs include metals, volatile and semi-volatile organic compounds (VOCs and semi-VOCs), other chemicals (e.g., pesticides and polycyclic aromatic hydrocarbons [PAHs]), and some radionuclides. In general, chemical contaminants are far more prevalent than radioactive contaminants. Therefore, in this report, the scope of

---

<sup>5</sup> The review was conducted in the summer of 2012 using 2010 data, since then many more contaminated sites have been screened by EPA, and the database and mapping tool of contaminated sites with renewable energy development potential have been updated (EPA 2013e, h).

<sup>6</sup> COCs were compiled on the basis of a review of contamination profiles for sites with potential for utility-scale solar development in Arizona, California, Colorado, Nevada, New Mexico, and Utah. It is anticipated that this list is representative of COCs that would be present at comparable sites (i.e., abandoned mine lands, brownfields, federal Superfund sites, non-federal Superfund sites, landfills, and RCRA sites) in other states.

evaluation of potential human health risks is limited to those related to the spectrum of identified chemical contaminants.

Potential adverse health effects caused by chemical contaminants are typically characterized as carcinogenic and non-carcinogenic; many chemicals can have both effects. The potential risks associated with carcinogenic effects are quantified using slope factors (SFs) for ingestion exposure and unit risk factors (URFs) for inhalation exposures. A slope factor is the estimated probability of developing a cancer associated with a unit intake of that chemical [ $1/(\text{mg}/\text{kg}\text{-day})$ , the inverse of a milligram of chemical per unit bodyweight per day]. A URF is the estimated probability of developing a cancer associated with immersion in air with a unit air concentration of that chemical [ $1/(\text{mg}/\text{m}^3)$ , the inverse of a milligram per cubic meter]. Carcinogenic risk associated with exposure to a chemical is then estimated as the product of either the daily intake rate and its SF or air concentration and its URF. The target cancer risk limit used to protect human health is generally set between  $10^{-6}$  and  $10^{-4}$ , which corresponds to a probability of 1 in 1,000,000 to 1 in 10,000 of developing an excess cancer during one's lifetime.

Non-carcinogenic effects are quantified using reference doses (RfDs) for ingestion exposures and reference concentrations (RfCs) for inhalation exposures. An RfD is defined as the threshold daily intake rate in terms of  $\text{mg}/\text{kg}\text{-day}$  of a particular chemical. An RfC is defined as the threshold air concentration in terms of  $\text{mg}/\text{m}^3$ . The ratio of estimated daily intake rate (the average over exposure duration) to RfD or estimated air concentration (the average over exposure duration) to RfC is used to gauge whether an adverse effect could result from a given exposure. This ratio is called a hazard quotient; the sum of hazard quotients across different exposure pathways or over different chemicals of concern is called a hazard index. When setting contamination limits for environmental media to protect human health, a hazard index of 1 is usually selected as the target risk level.

### **3.2 ENVIRONMENTAL TRANSPORT OF CONTAMINANTS AND POTENTIAL HUMAN EXPOSURE PATHWAYS**

#### **3.2.1 Soil Contamination**

According to the contamination profiles reviewed, soil is the predominant contaminated medium, existing at almost every site assessed. Therefore, it is expected that workers and the general public at and near solar facilities are most likely to be exposed to contaminants from this source. As a result, soil contamination is the primary focus for addressing potential human health risks associated with developing solar energy facilities at contaminated sites.

Ingestion and dermal absorption are the two direct-contact exposure routes for contaminated soil quantified for solar facility workers. For the general public who live in the vicinity of the contaminated site, direct contact with contaminated soil would not generally occur because it is assumed that access to the contaminated site would be restricted to workers involved in the solar energy development activities.

Contaminants in soil can be transported into other environmental media and lead to further human exposures. These media include both water (i.e., surface water bodies or groundwater aquifers) and air (i.e., atmosphere). In order to move to a nearby surface water body or groundwater aquifer, contaminants generally need to be carried by water. In general, in an area where precipitation is low and evapotranspiration dominates the loss of precipitation, the potential for contaminants in the soil to be transported via water to a surface water body or groundwater aquifer is greatly reduced. This is the case in many of the contaminated sites located in the southwest region. During rain events, contaminants can run off from the soil. However, the runoff can be controlled by adopting best management practices during construction and by proper design of the solar facility. For this report, these best management practices are assumed to be in place, and exposures through runoff would be minimized. As such, consideration of the potential transport of contaminants to the surrounding media is limited to the transport from soil to air.

Contamination of the air could result from re-suspension of soil particles and volatilization of VOCs or semi-VOCs from soils. Both re-suspension and volatilization could be driven by wind and by human activities. Once the air is contaminated, potential exposure could result through inhalation, which is quantified and evaluated in this report. Airborne dust particles could be transported beyond the initial contaminated area and be deposited on clean ground or surface water surfaces; however, compared with the initial contamination, the secondary contamination caused by the deposition is relatively small and, therefore, is not quantified in this report.

### **3.2.2 Surface-Water and Groundwater Contamination**

At each site, existing surface-water and groundwater contamination should be evaluated and addressed separately from soil contamination. Because workers at the solar energy facility are assumed not to ingest onsite water (either surface water or groundwater), and the general public is assumed to have no access to the solar energy facility and to typically live at a distance from the facility, imminent exposures to contaminants in onsite surface water or groundwater likely would not occur. If contaminated surface water or groundwater were used during construction (e.g., for dust control), additional soil contamination could result and would need to be accounted for in assessing potential health risks associated with soil contamination. While it is possible that VOCs or semi-VOCs in water could volatilize into the air, particularly if they are present in water used for construction, this is considered to be a minor exposure pathway. The focus of this report is on risks associated with soil contamination. Potential exposures associated with contaminated surface water and groundwater are not quantified in this report.

Transport of groundwater contaminants across the site boundary would not be interrupted by solar energy development activities. Therefore, the potential for future exposures of the offsite general public to contaminated groundwater could exist. If the contaminated site includes groundwater contamination, the design of the solar facility should take into account the area required for groundwater treatment so that the treatment will not be interfered with or prohibited by development of the solar facility.



## **4 DEVELOPMENT OF A GENERAL METHODOLOGY FOR ASSESSING HUMAN HEALTH RISKS ASSOCIATED WITH SOLAR ENERGY FACILITIES**

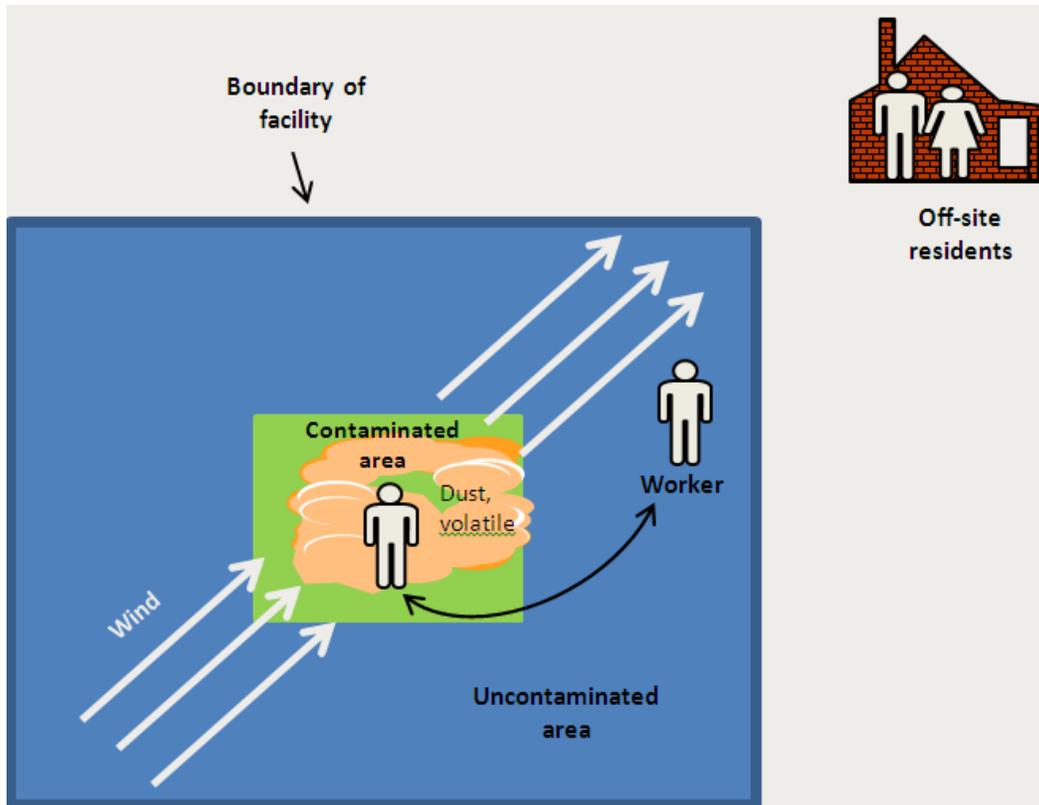
Potential human health risks associated with the development of utility-scale solar energy facilities on contaminated sites would vary with the scale (area) of the facilities, the size of the contaminated area, the distance to surrounding communities, and the geographic locations of the contaminated sites. They can also change with time as solar energy development progresses from one stage to another. Even within the same stage of development, exposures and corresponding impacts on health could vary from day to day as the same activities are conducted at different locations within the facility. The risk assessment methodology presented in this paper can be used to evaluate potential human health risks under different conditions at different times. Due to the general nature of the methodology, which requires minimum site-specific information and adopts conservatism to deal with uncertainty wherever it arises, the best use of the methodology would be to obtain preliminary estimates of potential human health risks to assist in evaluating the feasibility of developing a particular contaminated site.

Section 4.1 provides an overview of the conceptual model and calculation framework of the general methodology. Sections 4.2–4.7 contain detailed technical discussions concerning the development of the methodology, including the equations used and the calculations required to implement the methodology. These technical discussions are intended for risk assessors who are familiar with EPA’s human health risk assessment guidance and the SSL equations and who would be required to perform assessments of potential human health risks to evaluate a contaminated site. An example demonstrating step-by-step implementation of the methodology is provided in Appendix A of this report.

### **4.1 ESTABLISHMENT OF CALCULATION FRAMEWORK**

#### **4.1.1 Conceptual Model and the Daily Risk Approach**

Figure 4-1 illustrates the conceptual model on which the methodology was developed. For model development purposes, the shapes of both the contaminated area and the entire solar energy facility are assumed to be square, with the contaminated area located at the center of the facility. Potential exposures to contaminants could occur via the inhalation of dust or volatiles pathway, incidental soil ingestion pathway, and dermal absorption pathway. Because contaminated dust particles and volatiles emitted from the contaminated area can be blown to surrounding areas by wind, even if a receptor is not working or living on the contaminated area, he or she can still be exposed when the wind blows in their direction. Two categories of receptors are considered in the methodology: facility workers and the general public living in the surrounding area. Potential risks are assessed for a representative individual of each category.



**FIGURE 4-1 Conceptual Model for Human Exposures to Contamination in a Solar Energy Facility**

The assumption that the contaminated area is located at the center of the solar facility would result in a greater average air concentration over the entire facility being estimated than if the contaminated area is located off-center. This greater average concentration would lead to conservative estimates of the potential exposures of facility workers. On the other hand, the central location of the contaminated area may result in a greater exposure distance for the offsite general public than if the contaminated area is located off-center; however, in that case, the actual exposure distance of the offsite general public can be used to replace the distance calculated on the basis of the central location assumption.

Potential human health risks are assessed for three different phases of solar energy development: construction, operation, and decommissioning. The physical footprints of solar energy facilities are assumed to be the entire site, which includes both contaminated and non-contaminated areas. Therefore, facility workers would experience different levels of chemical exposures when working in different parts of the facility. Similarly, for the general public living in surrounding areas, the exposures incurred could also vary when activities are conducted in different parts of the facility.

To streamline the calculations of potential human health risks and to account for the variation in exposure that a receptor could experience over the course of each phase, the calculation of the total risk that a receptor could incur during each phase is broken down by separately evaluating the contributions from individual activities that would occur at different locations and different times. These contributions to the total risk are obtained with the use of daily risks,<sup>7</sup> which are risks associated with the conduct of individual activities for one day. The daily risks associated with each activity are then multiplied by the duration of the activity, and the resulting products are summed over the activities to provide estimates of the total risk experienced by the receptor as a result of solar energy development. This methodology is applied individually for each contaminant of concern.

#### **4.1.2 Basic Assumptions**

Utility-scale solar energy facilities require large land areas. Depending on the capacity, or energy output, of a facility, the land area occupied can range from a few hundred to a few thousand acres. The duration of the construction period can also vary from a few months for a small facility to 2–3 yrs for a large facility. Based on the data on construction durations for existing utility-scale solar energy facilities (BLM 2010a–e, 2011; Calico Solar, LLC 2011), it is estimated that the progress of construction averages about 4 acres per day. This average value is used to characterize the area of soil disturbance per day. It is also used to estimate the duration of construction for an individual solar energy facility with a specific footprint, and the number of days the construction-related soil disturbance would occur over the contaminated area within the facility. Because decommissioning activities are expected to be similar to construction activities, the same rate of progress would be applied when evaluating human health risks associated with decommissioning activities.

It is assumed that the construction of a solar energy facility would involve grading with bulldozers or other tractors with blades to level the ground surface; clearing the land to get rid of solid debris and/or foreign objects; and digging holes to erect support structures for the subsequent installation of solar equipment. The emission of dust particles and volatiles is greatly enhanced during these land-disturbing activities. When the contaminated area is disturbed, the release of contaminants to the air on any given day is dependent on the amount of contaminated land included in the construction area (i.e., the 4-acre zone of soil disturbance). Although contaminants also might be released by wind from contaminated land not located within the construction area, compared to the release caused by land-disturbing activities, this wind-driven release would be relatively small and, therefore, is not included in the calculation. When the contaminated area is not disturbed, the release of contaminants to the air on any given day is driven by wind from the entire contaminated area. This is based on the assumption that access routes to the construction area will not go through the contaminated lands; thus, the

---

<sup>7</sup> In this methodology, the calculated daily risk is a surrogate for daily exposure; summing the risks to arrive at total risk over an exposure period of months to years makes the use of toxicity factors for chronic exposure periods valid.

contaminated lands would remain undisturbed except when directly involved in the construction activities.

The methodology assumes that workers involved in construction, operation, or decommissioning of utility-scale solar facilities do not wear PPE, employ engineering controls, or follow work safety practices designed specifically to protect them from exposure to chemical contaminants (i.e., COCs at the site).<sup>8</sup> As a result, this methodology calculates conservative estimates of potential human health risks. If an initial risk assessment assuming the absence of specific protective measures indicates that the potential exposures to workers could be unacceptably high, the developer may decide to incorporate protective measures to ensure that target risk limits are not exceeded. Similarly, it may be possible to avoid unacceptably high potential exposures to the general public through engineering controls. To account for the reduction in exposures associated with the use of PPE or engineering controls, the potential risks calculated for each exposure pathway can be lowered by a factor that reflects the efficiency of the protective measures in that pathway. The reduction factors associated with the same protective measure may not be the same for different pathways, and may require different values for different site-specific conditions. The reduced risks from different exposure pathways can then be summed to provide a more realistic estimate of the total risk corresponding to the use of protective measures.

#### **4.1.3 Estimating Daily Risks with Solar Facility Soil Concentration Limits (SFSCSLs)**

The calculation of potential daily risks can be achieved by using the equations developed by EPA for deriving SSLs (EPA 1996a,b). The SSL equations derive soil concentration limits corresponding to selected target risk levels by evaluating chemical exposures and the associated risks for various exposure pathways, including direct soil ingestion, inhalation of volatiles, inhalation of particulates, and dermal absorption. Potential risks that would result from specific soil concentration levels can be obtained by scaling the soil concentrations with the derived concentration limits. To calculate potential daily risks as required to streamline the risk assessment approach outlined in Section 4.1.1, the input parameters used in the SSL equations need to be tailored to reflect the daily exposure conditions experienced by facility workers of and the general public living around a solar facility. However, direct, full-scale calculations with the SSL equations to obtain daily risks are not necessary because of the availability of EPA's RSLs, which were also developed with the SSL equations.

Under an interagency agreement between EPA and DOE's Oak Ridge National Laboratory (ORNL), ORNL applied the EPA SSL equations to derive generic regional screening levels (RSLs) for contaminated soil, air, and water considering standard residential and worker exposure scenarios. The intention was to have a nationally-consistent RSL table and calculator for use in contaminated site remediation. The RSL table is distributed among three regions,

---

<sup>8</sup> It is assumed that workers will use safety practices that are standard for construction projects and operation of solar facilities (i.e., hard hats, safety glasses, steel-toed boots, lock-out/tag-out procedures, confined space entry procedures).

Regions 3, 6, and 9, to update the Region 3 risk-based concentrations (RBCs), the Region 6 human health medium-specific screening limits (HHMSSLs), and the Region 9 preliminary remediation goals (PRGs). The RSLs were derived for more than 700 chemicals and can be accessed online (EPA 2013b). They are updated twice a year, once in spring and once in fall. Because the risk assessments concerning solar energy development need to take into account the activities conducted by solar energy facility workers, and the nature and duration of these activities differ from the default assumptions on activities used to develop the RSLs, modifications to RSLs are necessary. The proposed modifications to RSLs would yield soil concentration limits (referred to as SFSCSLs in this report) that consider daily exposures of receptors associated with activities conducted in the solar facility and correspond to the specified target risk levels ( $1 \times 10^{-6}$  for carcinogenic risks and a hazard quotient of 1 for non-carcinogenic risks). Therefore, the potential daily risks associated with a specific chemical of concern are equivalent to the multiplication product of the target risk level and the ratio between the soil concentration of that chemical and its SFSCSL. A detailed discussion on the exposure pattern modification factors (MF<sub>e</sub>s) that are applied to obtain SFSCSLs is provided in Sections 4.2–4.5.

The SSL equations consider chemical exposures to workers and the general public working or living in the contaminated area during regular (non-construction) conditions; therefore, wind is the primary driving force for the release of soil particles and volatiles from contaminated soils to the air. In contrast, the exposure conditions for facility workers and the general public during construction of a solar facility would not always conform to the regular conditions defined in the SSL equations. Furthermore, for solar facilities, the exposures concerned would not always occur in the contaminated area. Therefore, corrections for exposure locations and contaminant releases need to be incorporated into the modification of RSLs, as well. The correction for exposure locations is implemented with the use of distance modification factors (MF<sub>d</sub>s), which, for facility workers working in non-contaminated areas, are the ratios of the average contaminant concentrations in the air over the contaminated area to the average concentrations over the entire footprint of the solar energy facility. For the general public, MF<sub>d</sub>s are the ratios of the average air concentrations over the contaminated area to the concentrations at the offsite locations where the general public resides. The correction for the release of particulates or volatiles during construction or decommissioning is implemented with the use of activity level modification factors (MF<sub>a</sub>s), which are the ratios of the contaminant release rates caused by construction or decommissioning activities to the release rates driven by wind as considered in the SSL equations. Sections 4.6.1, 4.6.2, 4.7.1, and 4.7.2 provide further discussions on the development of MF<sub>a</sub>s for volatiles, MF<sub>a</sub>s for particulates, MF<sub>d</sub>s for facility workers, and MF<sub>d</sub>s for offsite residents, respectively.

The SFSCSLs are calculated for each individual pathway and each category of receptor concerning daily exposures associated with the following activities: (1) construction and decommissioning activities conducted over the contaminated area, (2) construction and decommissioning activities conducted over the non-contaminated area, (3) operation activities conducted over the contaminated area, and (4) operation activities conducted over the non-contaminated area. Sections 4.2 through 4.7 provide detailed discussions and guidance on the evaluations of SFSCSLs needed for estimating the total risks associated with the development of a solar energy facility on a contaminated site.

#### 4.1.4 Calculation of Total Risk

As discussed in the previous section, the SFSCSLs associated with each individual activity can be obtained by modifying the RSLs derived by EPA. Once the SFSCSLs are calculated, the daily risks associated with individual activities can be obtained with an easy calculation (i.e., by multiplying the target risk level with the ratio between the measured soil concentrations and the SFSCSLs). Because potential risks could be incurred through multiple pathways, the daily risks from each exposure pathway should be summed to give the total daily risk associated with a specific activity. Equation (1) illustrates the calculation of total daily cancer risk (i.e., cancer risk associated with the conducting of a specific activity for one day) from exposure to a hazardous chemical. The equation can be applied to either facility worker or offsite resident receptors during the construction, operation, or decommissioning phase.

$$DRisk = \sum_p TR \times \left( \frac{C_m}{C_{sfscsl}} \right)_p = TR \times \sum_p \left( \frac{C_m}{C_{rsl} \times MF} \right)_p \quad (1)$$

$$MF = MF_e \times \frac{MF_d}{MF_a}$$

where

DRisk = Daily cancer risk,

TR = Target cancer risk level ( $10^{-6}$ ),

$C_m$  (mg/kg) = Measured or estimated soil concentration of a hazardous chemical in the contaminated area within the solar energy facility,

$C_{sfscsl}$  (mg/kg) = SFSCSL for pathway p based on daily exposure =  $C_{rsl} \times MF$ ,

$C_{rsl}$  (mg/kg) = RSL derived by EPA for pathway p,

p = Index for pathway,

MF = Overall modification factor,

$MF_e$  = Modification factor for exposure patterns,

$MF_d$  = Modification factor for exposure distance, and

$MF_a$  = Modification factor for the activity level.

Equation (2) illustrates the calculation of daily hazard indexes (i.e., indexes for non-carcinogenic risks contributed by conducting a specific activity for one day). The sum of the individual hazard quotients (HQs) is called a hazard index (HI).

$$\begin{aligned}
DHI &= \sum_p THQ \times \left( \frac{C_m}{C_{sfsc1}} \right)_p \\
&= THQ \times \sum_p \left( \frac{C_m}{C_{rsl} \times MF} \right)_p
\end{aligned} \tag{2}$$

where

DHI = Daily hazard index, and

THQ = Target hazard quotient (1).

The total risk a receptor would receive can then be obtained by multiplying the daily risk for a specific activity by the duration of that activity, then summing the products over all the activities that would affect the receptor.

$$Total Risk = \sum_{\substack{activity \\ (in\ specific\ area)}} (DRisk \times EDay)_{activity} \tag{3}$$

where

activity = Index for activities conducted in a specific area within the solar energy facility,

DRisk = Daily risk associated with an activity, and

EDay = Duration (i.e., number of days) of an activity.

$$Total HI = \sum_{\substack{activity \\ (in\ specific\ area)}} (DHI \times EDay)_{activity} \tag{4}$$

where

DHI = Daily hazard index associated with an activity, and

EDay = Duration (number of days) of an activity.

The following example illustrates the application of the above equations. Assuming that the total risk to a construction worker from exposure to a specific chemical is to be evaluated, the activities that could affect the health of the worker would include both construction activities conducted over the contaminated area and construction activities conducted over the non-

contaminated area. The SFSCs for soil ingestion, inhalation of particulates, inhalation of volatiles (if the chemical of concern would volatilize), and dermal absorption pathways would need to be calculated and converted to risk, and then the risks from all the pathways would need to be added together to give the daily risk values (using Eq. [1] for carcinogenic chemicals or Eq. [2] for non-carcinogenic chemicals)—one for working in the contaminated area and one for working in the non-contaminated area.

The number of days the workers would work in the contaminated area could be calculated based on the size of the contaminated area (as described in Section 4.1.2), followed by the number of days the worker would work in the non-contaminated area. For example, if the footprint of the facility to be constructed is 2,000 acres, and the average construction progress is 4 acres per day, the total construction would last for 500 days. Therefore, if the contaminated area within the facility is 20 acres, the construction in the contaminated area would last for 5 days. Assuming that construction would start in the contaminated area, within the first year the worker would work 245 days in the non-contaminated area, and within the second year the worker would work all 250 days (5 days per week for 50 weeks per year, the EPA default value for workers [EPA 1996a,b, 2012a]) in the non-contaminated area. Because of the soil disturbance in the contaminated area and the time spent working there, the risk incurred during the first year would be greater than the risk incurred during the second year.

If the chemical of concern is non-carcinogenic, then the total hazard index would be calculated by multiplying the daily risk associated with construction in the contaminated area by 5, multiplying the daily risk associated with construction in the non-contaminated area by 245, and adding the products together. If the chemical of concern is carcinogenic, then the total risk would be calculated by multiplying the daily risk associated with construction in the contaminated area by 5, but multiplying the daily risk associated with construction in the non-contaminated area by 495, and adding the multiplication products together. The reason 495 (found by  $500 - 5$ ) is used for calculating the total carcinogenic risk is that cancer risk accumulates over one's lifetime and is not calculated by year as the hazard index is.

#### **4.2 DEVELOPMENT OF SFSCS FOR EXPOSURES OF FACILITY WORKERS BASED ON CARCINOGENIC RISKS**

The following sections present the SSL equations and exposure parameter values used by ORNL to derive RSLs based on carcinogenic risks associated with worker exposures (EPA 2013c). These sections also provide detailed discussions regarding the calculations of modification factors that should be used to modify the RSLs to obtain SFSCs.

## 4.2.1 Soil Ingestion Pathway

### 4.2.1.1 SSL Equation and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{TR \times AT_c \times BW_a}{EF_o \times ED_o \times \frac{IRS_o \times CSF_o}{10^6 \frac{\text{mg}}{\text{kg}}}} \quad (5)$$

where

TR = Target cancer risk ( $10^{-6}$ ),

AT<sub>c</sub> (days) = Averaging time—carcinogens (25,550; i.e., 70 yrs),

BW<sub>a</sub> (kg) = Bodyweight—adults (70),

EF<sub>o</sub> (days/yr) = Exposure frequency—occupational (250; i.e., 5 days/week for 50 weeks/yr),

ED<sub>o</sub> (yr) = Exposure duration—occupational (25),

IRS<sub>o</sub> (mg/day) = Soil ingestion—occupational (100), and

CSF<sub>o</sub> [(mg/kg-day)<sup>-1</sup>] = Cancer slope factor—oral, contaminant-specific.

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

### 4.2.1.2 Modification of RSLs to Obtain SFSCSLs

Modification factors that should be used to adjust the RSLs in order to obtain the SFSCSLs required for assessing risks to facility workers from the soil ingestion pathway are presented in Tables 4-1 through 4-4. The value of the exposure modification factor, MF<sub>e</sub>, is determined from the ratios of exposure parameters used for the derivation of RSLs to those that would be used for the derivation of SFSCSLs. Only exposure parameters that assume different values in the two derivations are listed in the tables. Table 4-1 shows the risk that could be incurred during construction in the contaminated area. Table 4-2 shows the risk that could be incurred during construction in the non-contaminated area. Tables 4-3 and 4-4 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is assumed that the potential risks associated with the decommissioning of the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-1 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr) <sup>a</sup>	250	1	0.004
ED <sub>o</sub> (yr) <sup>a</sup>	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>b</sup>	100	330	3.3
MF <sub>e</sub> (exposure) <sup>c</sup>	– <sup>d</sup>	–	1894
MF <sub>d</sub> (distance) <sup>e</sup>	–	–	1
MF <sub>a</sub> (activity level) <sup>f</sup>	–	–	1
MF (overall) <sup>g</sup>	–	–	1894

- <sup>a</sup> A value of 1 should be used for both EF<sub>o</sub> and ED<sub>o</sub> to obtain SFSCSL, because SFSCSL is the soil concentration limit corresponding to the exposure to a specific chemical in 1 day.
- <sup>b</sup> For IRS<sub>o</sub>, a larger ingestion rate than the RSL value is used to account for greater chance of incidental ingestion during construction, when more soil could be dispersed to deposit on exposed skin. This value is also consistent with EPA’s suggested value for construction workers (EPA 2002).
- <sup>c</sup> The exposure modification factor MF<sub>e</sub> adjusts the average intake of a chemical by considering a different exposure pattern for construction workers than that of industrial workers, as assumed in the derived RSLs. The value of MF<sub>e</sub> is determined by multiplying or dividing the ratios of exposure parameters (between the SFSCSL value and the RSL value) according to each parameter’s role in the SSL equation. For the soil ingestion pathway, the value of MF<sub>e</sub> is dependent on the ratio of EF<sub>o</sub>, the ratio of ED<sub>o</sub>, and the ratio of IRS<sub>o</sub>. Because these exposure parameters all fall in the denominator of Equation (5), the MF<sub>e</sub> is the reciprocal of the product of the ratios and can be calculated as  $1/[\text{Ratio}(\text{EF}_o) \times \text{Ratio}(\text{ED}_o) \times \text{Ratio}(\text{IRS}_o)]$ .
- <sup>d</sup> “–” indicates “does not apply.”
- <sup>e</sup> Because the exposure is taking place in the contaminated area, no modification is implemented for the MF for distance (MF<sub>d</sub>).
- <sup>f</sup> Because the consequences caused by the vigorous construction activities are implicitly included in the higher value used for IRS<sub>o</sub>, no further modification is implemented for the value of the MF for activity level (MF<sub>a</sub>).
- <sup>g</sup> The overall modification factor, MF, can be calculated as  $\text{MF}_e \times \text{MF}_d / \text{MF}_a$ .

**TABLE 4-2 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>a</sup>	100	0	0
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance) <sup>d</sup>	–	–	1
MF <sub>a</sub> (activity level) <sup>e</sup>	–	–	1
MF (overall)	–	–	~

<sup>a</sup> The soil ingestion pathway considers direct ingestion of contaminated soil. Because construction is conducted outside the contaminated area, there is no significant direct contact with contaminated soil, so the SFSC value for IRS<sub>o</sub> is set to zero. Indirect ingestion of soil particles is possible for soil particles transported by wind erosion from the contaminated area, deposited on the ground surface, and subsequently ingested by workers in the non-contaminated area. However, this pathway is considered to result in very minimal exposure to workers in the non-contaminated area and is not quantified in this report. However, exposure and risk for construction workers in the non-contaminated area through the inhalation pathway is quantified in Section 4.2.3.

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, which results from the fact that no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

<sup>d</sup> Although construction is conducted in the non-contaminated area, the value of IRS<sub>o</sub> concerns direct intake of soil from the contaminated area; therefore, adjustment of soil concentration is not needed when evaluating potential chemical intake, which is subsequently used to estimate potential risk so that soil concentration limit can be derived. Because adjustment of soil concentration is not needed, the value of MF<sub>d</sub> is set to 1.

<sup>e</sup> The reason for setting MF<sub>a</sub> to 1 is the same as that stated in Table 4-1 (see footnote f).

**TABLE 4-3 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>a</sup>	100	50	0.5
MF <sub>e</sub> (exposure) <sup>b</sup>	– <sup>c</sup>	–	12,500
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level) <sup>d</sup>	–	–	1
MF (overall)	–	–	12,500

<sup>a</sup> The ingestion rate, IRS<sub>o</sub>, is reduced to half of the RSL value because the activities conducted during the operation phase are unlikely to result in direct soil ingestion.

<sup>b</sup> The value of MF<sub>e</sub> can be calculated as  $1/[\text{Ratio}(\text{EF}_o) \times \text{Ratio}(\text{ED}_o) \times \text{Ratio}(\text{IRS}_o)]$ .

<sup>c</sup> “–” indicates “does not apply.”

<sup>d</sup> The value of IRS<sub>o</sub> concerns direct soil ingestion and has taken into account rigorousness of the activities; therefore, no further adjustment is needed with MF<sub>a</sub>.

**TABLE 4-4 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Non-contaminated Area**

Parameter	SSL Default Value	SFSCSL Value	Ratio (SFSCSL/SSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>a</sup>	100	0	0
MF <sub>e</sub> (exposure)	— <sup>b</sup>	—	~ <sup>c</sup>
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	~

<sup>a</sup> As with the consideration for construction in the non-contaminated area, there is no direct soil ingestion when performing operational activities in the non-contaminated area. Thus, the SFSCSL value for IRS<sub>o</sub> is again set to zero.

<sup>b</sup> “—” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, which results from the fact that no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

## 4.2.2 Inhalation of Volatiles Pathway

### 4.2.2.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s (\text{mg/kg}) = \frac{TR \times AT_c}{EF_o \times ED_o \times \frac{URF_i \times 10^3}{VF_s} \times \frac{ET_o}{24 (\text{hr/d})}} \quad (6)$$

$$VF_s (\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{\frac{1}{2}}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \left( \frac{\text{m}^2}{\text{cm}^2} \right) \quad (7)$$

$$D_A = \frac{[(\theta_a^{\frac{10}{3}} D_i H' + \theta_w^{\frac{10}{3}} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'} \quad (8)$$

where

TR = Target cancer risk ( $10^{-6}$ ),

AT<sub>c</sub> (days) = Averaging time—carcinogens (25,550, i.e., 70 yr),

EF<sub>o</sub> (days/yr) = Exposure frequency—occupational (250),

ED<sub>o</sub> (yr) = Exposure duration—occupational (25),

VF<sub>s</sub> (m<sup>3</sup>/kg) = Volatilization factor for soil, chemical-specific,

URF<sub>i</sub> [(μg/m<sup>3</sup>)<sup>-1</sup>] = Unit risk factor inhaled, chemical-specific,

ET<sub>o</sub> (hr/d) = Exposure time (8),

Q/C (g/m<sup>2</sup>-s per kg/m<sup>3</sup>) = Inverse of the mean concentration at the center of a 0.5-acre square source (68.81),

D<sub>A</sub> (cm<sup>2</sup>/s) = Apparent diffusivity, chemical-specific,

T(s) = Exposure interval ( $9.5 \times 10^8$ , 30 yr),

ρ<sub>b</sub> (g/cm<sup>3</sup>) = Dry soil bulk density (1.5),

θ<sub>a</sub> = Air-filled soil porosity (0.28 or n-θ<sub>w</sub>),

D<sub>i</sub> (cm<sup>2</sup>/s) = Diffusivity in air, chemical-specific,

$H'$  = Dimensionless Henry's Law Constant (calculated from  $H$  by multiplying by 41), chemical-specific,

$H$  ( $\text{atm}\cdot\text{m}^3/\text{mol}$ ) = Henry's Law Constant, chemical-specific,

$\theta_w$  = Water-filled soil porosity (0.15),

$D_w$  ( $\text{cm}^2/\text{s}$ ) = Diffusivity in water, chemical-specific,

$n$  (0.43) = Total soil porosity (or  $1-\rho_b/\rho_s$ ),

$K_d$  ( $\text{cm}^3/\text{g}$ ) = Soil-water partition coefficient =  $K_{oc} f_{oc}$ ,

$K_{oc}$  ( $\text{cm}^3/\text{g}$ ) = Soil organic carbon-water partition coefficient, and

$f_{oc}$  = Fraction of organic carbon in soil (0.006; i.e., 0.6%).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### 4.2.2.2 Modification of RSLs to Obtain SFSCs

Tables 4-5 through 4-8 present modification factors that should be used to adjust the RSLs in order to obtain the SFSCs required for assessing risks to facility workers from the inhalation of volatiles pathway. Table 4-5 shows risk that could be incurred during construction in the contaminated area. Table 4-6 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-7 and 4-8 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is again assumed that the potential risks associated with the decommissioning of the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-5 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr) <sup>a</sup>	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d) <sup>b</sup>	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg) <sup>c</sup>			3.85 × 10 <sup>-3</sup>
T (s) <sup>d</sup>	9.50 × 10 <sup>8</sup>	2.88 × 10 <sup>4</sup>	3.03 × 10 <sup>-5</sup>
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>e</sup>	68.81	48.13	0.6995
MF <sub>e</sub> (exposure) <sup>f</sup>	— <sup>g</sup>	—	24.07
MF <sub>d</sub> (distance) <sup>h</sup>	—	—	1
MF <sub>a</sub> (activity level) <sup>i</sup>	—	—	Chemical-specific (see Section 4.6.1.3 for the calculation of its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> For EF<sub>o</sub>, a value of 1 day is used to derive the SFSCSL because the risk associated with one day's exposure is concerned

<sup>b</sup> An exposure time of 8 hours per day is used to derive SFSCSL, consistent with the value used for deriving RCLs.

<sup>c</sup> The ratio of VF<sub>s</sub> is dependent on the ratio of T and the ratio of Q/C, and can be calculated as [Ratio(T)]<sup>1/2</sup> × Ratio(Q/C)], according to Equation (6).

<sup>d</sup> Regarding T (exposure interval in seconds), the SFSCSL value is equivalent to 8 hrs (1 workday), assuming construction of the solar facility would start in the contaminated area. This assumption would result in a conservative estimate of exposure point concentration of a volatile chemical (i.e., air concentration of a volatile chemical above the contaminated area), because the volatilization rate is dependent on the concentration of the chemical in soil pores, so its value would decrease over time as the chemical concentration in the soil gradually decreased.

<sup>e</sup> The Q/C parameter represents the ratio of the release rate of a chemical from soil to the atmosphere to the air concentration of that chemical above the center of the release source. The inverse of this value quantifies the dispersion by wind of the chemical after its release. Therefore, the Q/C value depends on the area and location of the release source. The SFSCSL value for Q/C corresponds to an area of 4 acres, the soil disturbance land area assumed for daily construction activities. To obtain an estimate of this value, the Q/C values calculated by EPA for the location selected for developing the RSLs (i.e., Los Angeles), for six different sizes of contaminated areas (Table 3 of EPA 1996b) were fitted using an exponential equation, which was then used to obtain the Q/C value for an area of 4 acres. EPA selected Los Angeles as the reference location because its Q/C value is in the 90th percentile among the values calculated for 29 different locations for a release source of 0.5 acres. This reference location is applicable for calculating the SFSCSLs, because it is likely to result in a conservative estimate of the exposure point concentration, regardless of the actual location of the solar facility.

**Footnotes continued on next page.**

**TABLE 4-5 (Continued)**

---

- <sup>f</sup> The value of MF for exposure pattern ( $MF_e$ ) can be calculated as the reciprocal of [ $\text{Ratio}(EF_o) \times \text{Ratio}(ED_o) \times \text{Ratio}(ET_o) / \text{Ratio}(VF_s)$ ], according to Equation (6).
- <sup>g</sup> “–” indicates “does not apply.”
- <sup>h</sup> Because the exposure is taking place in the contaminated area, no MF for distance ( $MF_d$ ) is needed, and this value is set to 1.
- <sup>i</sup> The activity level modification factor,  $MF_a$ , corrects the exposure point concentration by considering an increase in volatile emissions due to construction activities. It is calculated as the ratio of the volatile emission rate under construction to the volatile emission rate due to wind, which is considered in the derivation of RSLs. The value of  $MF_a$  is dependent on the volatility of the chemicals. Section 4.6.1.3 provides instructions on obtaining the values for different volatile compounds.

**TABLE 4-6 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg) <sup>a</sup>			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s) <sup>b</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × (A <sub>total</sub> /4/250)	Ratio(T)
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>c</sup>	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure) <sup>d</sup>	— <sup>e</sup>	—	6,250 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>f</sup>	—	—	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

- <sup>a</sup> The ratio for VF<sub>s</sub> is the product of the ratio for Q/C and the square root of the ratio for T, according to Equation (7).
- <sup>b</sup> The SFSCSL value for T corresponds to the number of days needed to finish constructing the entire facility, including weekends. The value is used to obtain the average volatile concentration at the center of the contaminated zone over the entire construction period under normal condition (i.e., when no soil disturbance activities are being conducted). Under normal condition, dispersion of a volatile chemical released from soil is facilitated by wind, which is nonstop year-round. Facility workers are assumed to work 5 days per week for 50 weeks per year (EPA 1996a,b, 2012b). The number of construction days needed to complete the work can be calculated as A<sub>total</sub>/4, where A<sub>total</sub> is the total area of the solar energy facility in acres, and 4 (acres) is the daily soil disturbance area for construction. The ratio between the SFSCSL value of T and the RSL value of T would therefore depend on A<sub>total</sub>.
- <sup>c</sup> When construction is conducted in the non-contaminated area, the volatile emission from the entire contaminated area would be driven mainly by wind blowing the volatile chemical to the location of the receptor. The SFSCSL value for Q/C considers dispersion of the volatile emission within the contaminated area. A<sub>cont</sub> is the area of contamination in acres. The ratio between the SFSCSL value and the SSL default value is a function of A<sub>cont</sub>.
- <sup>d</sup> The value of MF for exposure pattern (MF<sub>e</sub>) can be calculated as the reciprocal of [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>) / Ratio(VF<sub>s</sub>)], according to Equation (6). After plugging the values of the first three ratios, MF<sub>e</sub> is equivalent to 6,250 × Ratio(VF<sub>s</sub>).
- <sup>e</sup> “—” indicates “does not apply.”
- <sup>f</sup> The distance modification factor MF<sub>d</sub> is calculated as the ratio of average concentration over the contaminated area to the average concentration over the entire footprint of the facility, both resulting from the emission from the contaminated area. The average concentration over the contaminated area is what EPA’s SSL equations model. To obtain the SFSCSLs, the average concentration over the entire footprint of the facility is needed. To calculate MF<sub>d</sub>, an EPA air dispersion model - SCREEN3 (EPA 1995a) was employed. More discussions on the use of SCREEN3 and the calculation of MF<sub>d</sub> are provided in Section 4.7.1.

**TABLE 4-7 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d) <sup>a</sup>	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s) <sup>b</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × ED <sub>op</sub>	Ratio(T)
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> )	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure)	— <sup>c</sup>	—	6,250 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>d</sup>	—	—	1
MF <sub>a</sub> (activity level) <sup>e</sup>	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> Regarding ET<sub>o</sub>, the SFSCSL value accounts for an exposure time of 8 hours per day that the solar operation worker would spend outdoors within the footprint of a solar energy facility. This is a conservative assumption, because in reality, the worker may spend some time indoors, where the air concentrations of contaminants would be less than the outdoor levels.

<sup>b</sup> The SFSCSL value for T corresponds to the operation period of the solar facility. It is used to obtain the average concentration over the entire operation period. ED<sub>op</sub> is the operation duration in terms of years, which depends on the size of the solar facility.

<sup>c</sup> “—” indicates “does not apply.”

<sup>d</sup> The SFSCSL to be calculated concerns facility workers incurring chemical exposures while working in the contaminated area. Therefore, the air concentration of a chemical modeled by the SSL equation can be used as the exposure point concentration for assessing potential exposure and health risk. Adjusting the air concentration to account for dilution associated with exposure distance is not necessary, so the value of MF<sub>d</sub> is set to 1.

<sup>e</sup> The operational activities are expected to involve little soil disturbance and essentially would not enhance volatilization of chemicals. Therefore, the value of MF<sub>a</sub> is set to 1.

**TABLE 4-8 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Operation in the Non-contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s)	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × ED <sub>op</sub>	Ratio(T)
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> )	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>c</sub> (exposure)	— <sup>a</sup>	—	6,250 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>b</sup>	—	—	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for the value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>c</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> “—” indicates “does not apply.”

<sup>b</sup> The only difference in the modification factors in Table 4-7 and Table 4-8 is the value for the distance MF, MF<sub>d</sub>, which needs to be determined using the values of the total footprint of the facility, A<sub>total</sub>, and the area of contamination, A<sub>cont</sub>, both in units of acres. Section 4.7.1 provides further instructions on calculating MF<sub>d</sub> with A<sub>total</sub> and A<sub>cont</sub>.

### 4.2.3 Inhalation of Particulate Pathway

#### 4.2.3.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{TR \times AT_c}{EF_o \times ED_o \times \frac{URF_i \times 10^3}{PEF} \times \frac{ET_o}{24 (\text{hr/d})}} \quad (9)$$

$$PEF \left( \frac{m^3}{kg} \right) = \frac{Q}{C} \times \frac{3600 \text{ s/h}}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)} \quad (10)$$

where

TR = Target cancer risk (10<sup>-6</sup>),

AT<sub>c</sub> (days) = Averaging time—carcinogens (25,550; i.e., 70 yr),

EF<sub>o</sub> (days/yr) = Exposure frequency—occupational (250; i.e., 5 days/week for 50 weeks/yr),

$ED_o$  (yr) = Exposure duration—occupational (25),

$PEF$  ( $m^3/kg$ ) = Particulate emission factor ( $1.316 \times 10^9$ ),

$URF_i$  [ $(\mu g/m^3)^{-1}$ ] = Unit risk factor inhaled, chemical-specific,

$ET_o$  (hr/d) = Exposure time (8),

$Q/C$  ( $g/m^2$ -s per  $kg/m^3$ ) = Inverse of the mean concentration at the center of a 0.5-acre square source (90.80),

$V$  = Fraction of vegetative cover (0.5),

$U_m$  (m/s) = Mean annual wind speed (4.69),

$U_t$  (m/s) = Equivalent threshold value of wind speed at 7 m (11.32),  
and

$F(x)$  = Function dependent on  $U_m/U_t$  derived using Cowherd et al. (1985) (0.194).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.2.3.2 Modification of RSLs to Obtain SFSCSLs**

Tables 4-9 through 4-12 present modification factors that should be used to adjust the RSLs in order to obtain the SFSCSLs required for assessing risks to facility workers from the inhalation of particulate pathway. Table 4-9 shows risk that could be incurred during construction in the contaminated area. Table 4-10 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-11 and 4-12 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. As before, it is assumed that the potential risks associated with decommissioning the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-9 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr) <sup>a</sup>	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg) <sup>b</sup>			0.352
1-V <sup>c</sup>	0.5	1.0	2.00
Q/C <sup>d</sup>	90.8	63.92	0.704
U <sub>m</sub> (m/s) <sup>e</sup>	4.69	4.69	1
X <sup>f</sup>	2.14	2.14	1
F(x) <sup>f</sup>	0.194	0.194	1
MF <sub>e</sub> (exposure) <sup>g</sup>	— <sup>h</sup>	—	2200
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level) <sup>i</sup>	—	—	Chemical-specific (see Section 4.6.2.3 for its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> An SFSCSL value of 1 day is used because it concerns the risk from one day's exposure...

<sup>b</sup> The ratio for PEF can be calculated as  $\{\text{Ratio}(Q/C) / \text{Ratio}(1-V) / \text{Ratio}(U_m)^3 / \text{Ratio}[F(x)]\}$ , according to Equation (10).

<sup>c</sup> Assuming all vegetative groundcover is removed during construction (i.e., V = 0); higher particulate emission rates would be obtained.

<sup>d</sup> The Q/C parameter quantifies the dispersion by wind of a chemical after its release, and the value depends on the area and location of the release source. The SFSCSL value for Q/C corresponds to an area of 4 acres, the land disturbance area assumed for daily construction activities. To obtain an estimate of this value, the Q/C values calculated by EPA for the location selected for developing the RSLs (i.e., Minneapolis) for six different sizes of contaminated areas (Table 3 of EPA 1996b) were fitted using an exponential equation, which was then used to obtain the Q/C value for an area of 4 acres. Minneapolis was selected as the reference location by EPA because its particulate emission factor, PEF, which determines the average concentration above the center of the release source and depends on the values of Q/C, U<sub>m</sub>/U<sub>t</sub>, and F(x), is in the 90th percentile among the PEFs calculated for 29 different locations for a release source of 0.5 acres. This reference location is applicable for calculating the SFSCSLs, because it is likely to result in a conservative estimate of the exposure point concentration, regardless of the actual location of the solar facility.

**Footnotes continued on next page.**

**TABLE 4-9 (Continued)**

---

- <sup>e</sup> Although annual average wind speeds,  $U_{ms}$ , are different for different locations, the value used by EPA for the development of RSLs is also used in deriving the SFSCs to maintain consistency with the selection for Q/C. This is because annual average wind speed would affect the value of Q/C, so the selection of a value should correlate with the selection of Q/C. The RSL value of 4.69 m/s is the average annual wind speed in Minneapolis.
- <sup>f</sup> X is defined as  $0.886 \times U_t / U_m$  (Cowherd et al. 1985). Because the values for  $U_t$  and  $U_m$  are not changed, the values for x and F(x), which is a function of x, would stay the same.
- <sup>g</sup> The modification factor for exposure pattern,  $MF_e$ , can be calculated as the reciprocal of the product of [Ratio( $EF_o$ )  $\times$  Ratio( $ED_o$ )  $\times$  Ratio( $ET_o$ ) / Ratio(PEF)], according to Equation (9).
- <sup>h</sup> “–” indicates “does not apply.”
- <sup>i</sup> The construction activities will result in more emissions of particulates due to the vigorous disturbing of soils as a result of grading and installing solar equipment. The activity level modification factor,  $MF_a$ , corrects the exposure point concentration by considering the increase in particulate emissions due to construction activities, as compared to the emissions caused by the wind, which is considered in EPA’s SSL model. The value of  $MF_a$  is provided in Section 4.6.2.3.

**TABLE 4-10 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg) <sup>a</sup>			Ratio(Q/C) / 2
1-V	0.5	1.0	2.00
Q/C <sup>b</sup>	90.8	$79.909 \times A_{\text{cont}}^{-0.161}$	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure) <sup>a</sup>	— <sup>c</sup>	—	$6,250 \times \text{Ratio(PEF)}$
MF <sub>d</sub> (distance) <sup>d</sup>	—	—	$F(A_{\text{total}}, A_{\text{cont}})$ (see Section 4.7.1 for the value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall) <sup>a</sup>	—	—	$\text{MF}_e \times \text{MF}_d / \text{MF}_a$

<sup>a</sup> The ratio for Q/C must be calculated before the ratio for PEF [which is half of Ratio(Q/C)], can be calculated. The calculated ratio for PEF is used to obtain the value of the exposure MF, MF<sub>e</sub>, which can be calculated as [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>) / Ratio(PEF)]. MF<sub>e</sub> is then used to calculate the overall modification factor, MF.

<sup>b</sup> The SFSCSL value for Q/C considers dispersion of the particulate emissions from the total contaminated area (which could be different from 4 acres, the assumed daily soil disturbance area for construction). Its value depends on the area of contamination, A<sub>cont</sub>, in acres. The equation listed was obtained by fitting the values calculated by EPA (Table 3 of EPA 1996b) for different areas.

<sup>c</sup> “—” indicates “does not apply.”

<sup>d</sup> Section 4.7.1 provides a discussion on the dependence of MF<sub>d</sub> on A<sub>total</sub> and A<sub>cont</sub>.

**TABLE 4-11 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Contaminated Area**

Parameter	RSL Default Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg)			0.67 × Ratio(Q/C)
1-V <sup>a</sup>	0.5	0.75	1.5
Q/C	90.8	$79.909 \times A_{\text{cont}}^{-0.161}$	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
X	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure)	— <sup>b</sup>	—	6,250 × Ratio(PEF)
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> It is assumed that 25% of the ground surface is covered by vegetation (V) during the operation phase so that emission of particulates is suppressed in 25% of the contaminated area.

<sup>b</sup> “—” indicates “does not apply.”

**TABLE 4-12 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Non-contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg)	— <sup>a</sup>	—	0.67 × Ratio(Q/C)
1-V	0.5	0.75	1.5
Q/C	90.8	79.909 × A <sub>cont</sub> <sup>-0.161</sup>	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
X	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure)	—	—	6,250 × Ratio(PEF)
MF <sub>d</sub> (distance) <sup>b</sup>	—	—	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> “—” indicates “does not apply.”

<sup>b</sup> The only difference in the listed modifications between Table 4-11 and Table 4-12 is the value for the distance MF, MF<sub>d</sub>, which needs to be determined using the values of the total footprint of the facility, A<sub>total</sub>, and the area of contamination, A<sub>cont</sub>, both in units of acres. Because the SFSC to be calculated concerns exposure incurred in the non-contaminated area, the air concentration of chemical at the center of the contaminated area that SSL equation models would need to be adjusted to obtain the average concentration over the entire solar facility for assessing the potential chemical exposure and resulting risk. Section 4.7.1 discusses the calculation of MF<sub>d</sub> as a function of A<sub>total</sub> and A<sub>cont</sub>.

## 4.2.4 Dermal Absorption Pathway

### 4.2.4.1 SSL Equation and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{TR \times AT_c \times BW_a}{EF_o \times ED_o \times \frac{SA_a \times AF_a \times ABS}{10^6 \text{ mg}} \times \frac{CSF_o}{GIABS}} \quad (11)$$

where

TR = Target cancer risk (10<sup>-6</sup>),

AT<sub>c</sub> (days) = Averaging time—carcinogens (25,550; i.e., 70 yr),

$BW_a$  (kg) = Bodyweight—adults (70),

$EF_o$  (days/yr) = Exposure frequency—occupational (250),

$ED_o$  (yr) = Exposure duration—occupational (25),

$SA_a$  (cm<sup>2</sup>/day) = Exposed surface area for soil/dust—adult worker (3300),

$AF_a$  (mg/cm<sup>2</sup>) = Adherence factor—soils (0.2),

ABS = Skin absorption (0.1 for semi-volatile organics),

$CSF_o$  [(mg/kg-day)<sup>-1</sup>] = Cancer slope factor—oral, contaminant-specific, and

GIABS = Gastrointestinal tract absorption fraction, contaminant-specific.

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.2.4.2 Modification of RSLs to Obtain SFSCs**

Tables 4-13 through 4-16 present modification factors that should be used to adjust the RSLs in order to obtain the SFSCs required for assessing risks to the facility workers from the dermal absorption pathway. Table 4-13 shows risk that could be incurred during construction in the contaminated area. Table 4-14 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-15 and 4-16 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is assumed that the potential risks associated with decommissioning the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-13 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr) <sup>a</sup>	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>b</sup>	0.2	0.3	1.5
MF <sub>e</sub> (exposure) <sup>c</sup>	– <sup>d</sup>	–	4167
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level) <sup>c</sup>	–	–	1
MF (overall)	–	–	4167

- <sup>a</sup> For EF<sub>o</sub>, an SFSCSL value of 1 day instead of 0.33 day (i.e., 8 hrs) was used because the values of SA<sub>a</sub> and AF<sub>a</sub> are for exposure incurred during each working day and already reflect the typical 8-hr work shift.
- <sup>b</sup> The SFSCF value for AF<sub>a</sub> (EPA 2002) is increased from the RSL value to account for higher emissions of particulate during construction that could result in an increase in skin deposition.
- <sup>c</sup> The modification factor for exposure pattern, MF<sub>e</sub>, can be calculated as the reciprocal of [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(SA<sub>a</sub>) × Ratio(AF<sub>a</sub>)], according to Equation (11).
- <sup>d</sup> “–” indicates “does not apply.”
- <sup>e</sup> The consequences of construction activities are implicitly included in the higher value used for AF<sub>a</sub>; therefore, no further modification is implemented with the value of the activity level MF, MF<sub>a</sub>.

**TABLE 4-14 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1.00	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0	0
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	~

<sup>a</sup> The particulates adhering to skin would mainly come from the working area, which is not contaminated when working in the non-contaminated area. Therefore, it is assumed that there is no significant dermal absorption of chemical contaminant when working in the non-contaminated area (i.e., the AF<sub>a</sub> value would be 0). The rationale for this assumption for the dermal exposure pathway is similar to that presented for the soil ingestion pathway (see Table 4-2 footnotes).

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, because no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

**TABLE 4-15 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0.1	0.50
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	12500
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	12500

<sup>a</sup> With 25% of the ground surface assumed to be covered by vegetation in the operation phase, the possibility for contaminated soil to get onto exposed skin is reduced. Furthermore, the types of activities conducted are also assumed to be less vigorous than the activities conducted by industrial workers and would result in less dermal deposition of soil. All these considerations contribute to the use of 0.1 mg/m<sup>2</sup> as the SFSCSL value for AF<sub>a</sub>, which is half of the RSL default value.

<sup>b</sup> “–” indicates “does not apply.”

**TABLE 4-16 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>o</sub> (days/yr)	250	1.00	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0	0
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	~

<sup>a</sup> It is assumed that there is no direct dermal absorption when working in the non-contaminated area.

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, because no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

### 4.3 DEVELOPMENT OF SFSCLS FOR EXPOSURES OF FACILITY WORKERS BASED ON NON-CARCINOGENIC RISKS

The following sections present the SSL equations and exposure parameter values used by EPA for the derivation of RSLs based on non-carcinogenic risks associated with worker exposures (EPA 2013c). These sections also provide detailed discussions on the calculation of modification factors that should be used to modify the RSLs to obtain SFSCLS.

#### 4.3.1 Soil Ingestion Pathway

##### 4.3.1.1 SSL Equation and Parameter Values Used to Derive RSLs

$$C_s (\text{mg/kg}) = \frac{THQ \times AT_n \times BW_a}{EF_o \times ED_o \times \frac{IRS_o}{RfD_o \times \frac{10^6 \text{ mg}}{\text{kg}}}} \quad (12)$$

where

THQ = Target hazard quotient (1),

AT<sub>n</sub> (days) = Averaging time—non-carcinogens (9125; i.e., ED<sub>o</sub> × 365),

BW<sub>a</sub> (kg) = Bodyweight—adults (70),

EF<sub>o</sub> (days/yr) = Exposure frequency—occupational (250),

ED<sub>o</sub> (yr) = Exposure duration—occupational (25),

IRS<sub>o</sub> (mg/day) = Soil ingestion—occupational (100), and

RfD<sub>o</sub> (mg/kg-day) = Reference dose oral, contaminant-specific.

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

##### 4.3.1.2 Modification of RSLs to Obtain SFSCLS

Modification factors that should be used to adjust the RSLs in order to obtain the SFSCLS required for assessing risks to facility workers from the soil ingestion pathway are presented in Tables 4-17 through 4-20. The value of the exposure modification factor, MF<sub>e</sub>, is determined from the ratios of exposure parameters used for the derivation of RSLs to those that would be used for the derivation of SFSCLS. Only exposure parameters that assume different values in the

two derivations are listed in the tables. Table 4-17 shows risk that could be incurred during construction in the contaminated area. Table 4-18 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-19 and 4-20 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is assumed that the potential risks associated with decommissioning the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-17 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days) <sup>a</sup>	9125	365	0.04
EF <sub>o</sub> (days/yr) <sup>b</sup>	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>b</sup>	100	330	3.3
MF <sub>e</sub> (exposure) <sup>c</sup>	— <sup>d</sup>	—	76
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level) <sup>c</sup>	—	—	1
MF (overall)	—	—	76

- <sup>a</sup> An SFSCSL value of 365 days is used for AT<sub>n</sub> to find average daily exposure over a 1-yr period (i.e., AT<sub>n</sub> = ED<sub>o</sub> × 365) for comparison with the chronic toxicity value to estimate the potential risk (in terms of hazard quotient). The exposures of construction workers to chemical contaminants are considered chronic (throughout the entire construction phase), although the levels of daily exposures are not constant, since they depend on where construction activities are being conducted.
- <sup>b</sup> The SFSCSL value for soil ingestion rate accounts for direct ingestion of soil by workers per working day (EPA 2002). To correlate with this definition, the SFSCSL exposure frequency (EF<sub>o</sub>) is assigned a value of 1 for obtaining SFSCSLs corresponding to a 1-day exposure.
- <sup>c</sup> The value of MF<sub>e</sub> can be calculated as [Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(IRS<sub>o</sub>)], according to Equation (12).
- <sup>d</sup> “—” indicates “does not apply.”
- <sup>e</sup> The increased exposure caused by soil disturbance during construction is implicitly included in the higher value used for IRS<sub>o</sub> (see Table 4-1 footnotes). Therefore, no further modification is implemented for the activity level MF, MF<sub>a</sub>.

**TABLE 4-18 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>a</sup>	100	0	0
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	~

<sup>a</sup> The soil ingestion pathway considers direct ingestion of contaminated soil. When construction occurs in the non-contaminated area, the direct ingestion rate of contaminated soil (IRS<sub>o</sub>) is assumed to be zero (see Table 4-2 footnotes).

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, because no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

**TABLE 4-19 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>a</sup>	100	50	0.5
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	500
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	500

<sup>a</sup> The SFSCSL value for IRS<sub>o</sub> is set to half the RSL value because operation activities would result in less direct soil ingestion (see Table 4-3 footnotes).

<sup>b</sup> “–” indicates “does not apply.”

**TABLE 4-20 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Soil Ingestion Pathway during Operation in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
IRS <sub>o</sub> (mg/day) <sup>a</sup>	100	0	0
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	~

<sup>a</sup> The soil ingestion pathway considers direct ingestion of contaminated soil. When working in the non-contaminated area, the direct ingestion rate of contaminated soil is assumed to be zero (see Table 4-4 footnotes).

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, because no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

### 4.3.2 Inhalation of Volatiles Pathway

#### 4.3.2.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{THQ \times AT_n}{EF_o \times ED_o \times \frac{1}{RfC_i \times VF_s} \times \frac{ET_o}{24 (\text{hr/d})}} \quad (13)$$

$$VF_s(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{\frac{1}{2}}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \left( \frac{\text{m}^2}{\text{cm}^2} \right) \quad (14)$$

$$D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'} \quad (15)$$

where

THQ = Target hazard quotient (1),

AT<sub>n</sub> (days) = Averaging time—noncarcinogens (9125; i.e., ED × 365),

$EF_o$  (days/yr) = Exposure frequency—occupational (250; i.e., 5 days/week for 50 weeks/yr),

$ED_o$  (yr) = Exposure duration—occupational (25),

$VF_s$  ( $m^3/kg$ ) = Volatilization factor for soil, chemical-specific,

$RfC_i$  ( $mg/m^3$ ) = Reference concentration inhaled, chemical-specific,

$Q/C$  ( $g/m^2$ -s per  $kg/m^3$ ) = Inverse of the mean concentration at the center of a 0.5-acre<sup>2</sup> source (68.81),

$ET_o$  (hr/d) = Exposure time, occupational (8),

$D_A$  ( $cm^2/s$ ) = Apparent diffusivity, chemical-specific,

$T$ (s) = exposure interval ( $9.5 \times 10^8$ , about 30 yr),

$\rho_b$  ( $g/cm^3$ ) = Dry soil bulk density (1.5),

$\theta_a$  = Air-filled soil porosity (0.28 or  $n - \theta_w$ ),

$D_i$  ( $cm^2/s$ ) = Diffusivity in air, chemical-specific,

$H'$  = Dimensionless Henry's Law Constant (calculated from  $H$  by multiplying by 41), chemical specific,

$H$  ( $atm \cdot m^3/mol$ ) = Henry's Law Constant, chemical-specific,

$\theta_w$  = Water-filled soil porosity (0.15),

$D_w$  ( $cm^2/s$ ) = Diffusivity in water, chemical-specific,

$n$  = Total soil porosity (0.43 or  $1 - \rho_b/\rho_s$ ),

$K_d$  ( $cm^3/g$ ) = Soil-water partition coefficient =  $K_{oc} f_{oc}$ ,

$K_{oc}$  ( $cm^3/g$ ) = Soil organic carbon-water partition coefficient, and

$f_{oc}$  = Fraction of organic carbon in soil (0.006; i.e., 0.6%).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

### 4.3.2.2 Modification of RSLs to Obtain SFSCs

Tables 4-21 through 4-24 present modification factors that should be used to adjust the RSLs in order to obtain the SFSCs required for assessing risks to the facility workers from the inhalation of volatiles pathway. Table 4-21 shows risk that could be incurred during construction in the contaminated area. Table 4-22 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-23 and 4-24 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is assumed that the potential risks associated with decommissioning the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-21 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg) <sup>a</sup>			$3.85 \times 10^{-3}$
T (s) <sup>b</sup>	$9.50 \times 10^8$	$2.88 \times 10^4$	$3.03 \times 10^{-5}$
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>c</sup>	68.81	48.13	0.6995
MF <sub>e</sub> (exposure) <sup>d</sup>	— <sup>e</sup>	—	0.96
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level) <sup>f</sup>	—	—	Chemical-specific (see Section 4.6.1.3 for its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The ratio for VF<sub>s</sub> is the product of the ratio for Q/C and the square root of the ratio for T, according to Equation (16).

<sup>b</sup> The SFSC value for T is for an 8-hr period, assuming construction of the solar facility would start in the contaminated area (see Table 4-5 footnotes).

<sup>c</sup> The SFSC value for Q/C corresponds to an area of 4 acres, the land disturbance area assumed for daily construction activities. The SFSC value is obtained the same way as described for the SFSC value used in the calculation of carcinogenic risks from inhalation of volatile chemicals (see Table 4-5 footnotes).

<sup>d</sup> The value of MF for exposure pattern (MF<sub>e</sub>) can be calculated as Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>)] × Ratio(VF<sub>s</sub>), according to Equation (13).

<sup>e</sup> “—” indicates “does not apply.”

<sup>f</sup> The value of MF<sub>a</sub> is dependent on the volatility of the chemical contaminant of concern. It is used to consider the enhancement of volatilization due to construction activities. Section 4.6.1.3 provides instructions on obtaining the values for different volatile compounds.

**TABLE 4-22 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg) <sup>a</sup>			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s) <sup>b</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × min(A <sub>total</sub> /4/250,1)	Ratio(T)
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>c</sup>	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure) <sup>d</sup>	— <sup>e</sup>	—	250 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>f</sup>	—	—	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> To obtain the value of Ratio(VF<sub>s</sub>), the values of Ratio(T) and Ratio(Q/C) should be calculated first, then multiply Ratio(Q/C) by Ratio(T)<sup>0.5</sup>.

<sup>b</sup> The SFSCSL value for T corresponds to the duration of construction during the first year, including weekends. This is to obtain the average air concentration over this period for the assessment of total non-carcinogenic risk during the first year. Depending on the footprint of the solar energy facility, it may take more than 1 yr to complete construction; therefore, a limitation is imposed to limit the value of T to 1 yr. Min(A<sub>total</sub>/4/250,1) means the smaller value between A<sub>total</sub>/4/250 and 1. Facility workers are assumed to work 250 days per year.

<sup>c</sup> When construction is conducted in the non-contaminated area, the volatile emission from the entire contaminated area would be driven mainly by wind blowing the volatile chemical to the location of the receptor. The SFSCSL value for Q/C considers dispersion of the volatile emission within the contaminated area. A<sub>cont</sub> is the area of contamination in acres. The ratio between the SFSCSL value and the SSL default value is a function of A<sub>cont</sub>.

<sup>d</sup> The value of MF<sub>e</sub> can be calculated as Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>)] × Ratio(VF<sub>s</sub>). The value of Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>)] is 250.

<sup>e</sup> “—” indicates “does not apply.”

<sup>f</sup> The value of the distance MF, MF<sub>d</sub>, depends on A<sub>total</sub> and A<sub>cont</sub>, which represents the total area of the entire footprint of the facility and the area of contamination, respectively. Equation (49) can be used to calculate the value of MF<sub>d</sub>.

**TABLE 4-23 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatile Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d) <sup>a</sup>	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg) <sup>b</sup>			Ratio(Q/C) × 0.182
T (s) <sup>c</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365	0.033
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>d</sup>	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure) <sup>e</sup>	— <sup>f</sup>	—	250 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> Regarding ET<sub>o</sub>, the SFSC value accounts for an exposure time of 8 hours per day that the solar operation worker would spend outdoors within the footprint of a solar energy facility. This is a conservative assumption, because in reality, the worker may spend some time indoors, where the air concentrations of contaminants would be less than the outdoor levels.

<sup>b</sup> The ratio for VFs can be calculated as Ratio(Q/C) × Ratio(T)<sup>1/2</sup>. The value of Ratio(T)<sup>1/2</sup> is 0.182.

<sup>c</sup> The SFSC value for T corresponds to 1 yr. It is used to obtain average air concentration over the first year of operation because the assessment of total non-carcinogenic risk is for a period of 1 yr.

<sup>d</sup> SFSC value for Q/C corresponds to volatile emission from the contaminated area. See footnote f of Table 4-6 for more information.

<sup>e</sup> MF<sub>e</sub> can be calculated as Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>)] × Ratio(VF<sub>s</sub>). The value of Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(ET<sub>o</sub>)] is 250.

<sup>f</sup> “—” indicates “does not apply.”

**TABLE 4-24 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Operation in the Non-contaminated Area<sup>a</sup>**

Parameter	RSL Default Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × 0.182
T (s)	9.50 × 10 <sup>8</sup>	24 × 3600 × 365	0.033
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> )	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	500 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>c</sup>	–	–	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for its value)
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The modification factors used to obtain SFSCSLs during operation in the non-contaminated area are the same as those used to obtain SFSCSLs during operation in the contaminated area (listed in the previous table), except for the value of the distance modification factor, MF<sub>d</sub>.

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> The distance modification factor MF<sub>d</sub> accounts for dilution in the exposure point concentration based on exposure distance. Its value is determined to be the ratio of the average concentration over the contaminated area to the average concentration over the entire footprint of the facility. Equation (49) can be used to calculate its value.

### 4.3.3 Inhalation of Particulate Pathway

#### 4.3.3.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{THQ \times AT_n}{EF_o \times ED_o \times \frac{1}{RfC_i \times PEF} \times \frac{ET_o}{24 (\text{hr/d})}} \quad (16)$$

$$PEF(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{3600 \text{ s}}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)} \quad (17)$$

where

THQ = Target hazard quotient (1),

$AT_n$  (days) = Averaging time—noncarcinogens (9125; i.e.,  $ED \times 365$ ),

$EF_o$  (days/yr) = Exposure frequency—occupational (250; i.e., 5 days/week for 50 weeks/yr),

$ED_o$  (yr) = Exposure duration—occupational (25),

$RfCi$  ( $mg/m^3$ ) = Reference concentration inhaled, chemical-specific,

$PEF$  ( $m^3/kg$ ) = Particulate emission factor ( $1.316 \times 10^9$ ),

$ET_o$  (hr/d) = Exposure time, occupational (8),

$Q/C$  ( $g/m^2$ -s per  $kg/m^3$ ) = Inverse of the mean concentration at the center of a 0.5-acre<sup>2</sup> source (90.80),

$V$  = Fraction of vegetative cover (0.5),

$U_m$  (m/s) = Mean annual wind speed (4.69),

$U_t$  (m/s) = Equivalent threshold value of wind speed at 7 m (11.32),  
and

$F(x)$  = Function dependent on  $U_m/U_t$  derived using Cowherd et al. (1985) (0.194).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.3.3.2 Modification of RSLs to Obtain SFSCSLs**

Tables 4-25 through 4-28 present modification factors that should be used to adjust the RSLs in order to obtain the SFSCSLs required for assessing risks to facility workers from the inhalation of particulate pathway. Table 4-25 shows risk that could be incurred during construction in the contaminated area. Table 4-26 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-27 and 4-28 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is assumed that the potential risks associated with decommissioning the solar energy facility would be similar to those associated with constructing the facility; therefore, separate tables are not presented for decommissioning activities.

**TABLE 4-25 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr) <sup>a</sup>	250	1	0.004
ED <sub>o</sub> (yr) <sup>a</sup>	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg)			0.352
1-V <sup>a</sup>	0.5	1	2
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>a</sup>	90.8	63.92	0.704
U <sub>m</sub> (m/s) <sup>a</sup>	4.69	4.69	1
x <sup>a</sup>	2.14	2.14	1
F(x) <sup>a</sup>	0.194	0.194	1
MF <sub>e</sub> (exposure)	— <sup>b</sup>	—	88
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level) <sup>c</sup>	—	—	Chemical-specific (see Section 4.6.2.3 for its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSC values for EF<sub>o</sub>, ED<sub>o</sub>, ET<sub>o</sub>, 1-V, Q/C, U<sub>m</sub>, x, and F(x) are the same as those used to consider exposures to carcinogenic chemicals (see Table 4-9 and corresponding footnotes).

<sup>b</sup> “—” indicates “does not apply.”

<sup>c</sup> The value of MF<sub>a</sub> is chemical-dependent. See Section 4.6.2.3 for details on calculation.

**TABLE 4-26 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area<sup>a</sup>**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg) <sup>b</sup>			Ratio(Q/C)/2
1-V	0.5	1	2
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>c</sup>	90.8	$79.909 \times A_{\text{cont}}^{-0.161}$	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
X	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure) <sup>d</sup>	— <sup>e</sup>	—	250 × Ratio(PEF)
MF <sub>d</sub> (distance)	—	—	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSC values for exposure parameters are the same as those listed in Table 4-25, except for Q/C.

<sup>b</sup> The ratio for PEF can be calculated as  $\text{Ratio}(Q/C) / \{\text{Ratio}(1-V) \times \text{Ratio}(U_m)^3 \times \text{Ratio}[F(x)]\}$ . The multiplication product in the denominator is 2.

<sup>c</sup> The reference location for the Q/C value used to derive RSLs for the inhalation of volatiles pathway is Los Angeles, while the reference location for the Q/C value used to derive RSLs for the inhalation of particulate pathway is Minneapolis (see footnotes for Tables 4-5 and 4-9 for the selection of reference locations). For the derivation of the SFSCs, the same reference locations are used to obtain more conservative estimates of potential exposures associated with a solar energy facility. The Q/C value listed in the table accounts for dispersion of particulate emissions averaged over the contaminated area; therefore, it is a function of A<sub>cont</sub>.

<sup>d</sup> The modification factor for exposure pattern, MF<sub>e</sub>, is calculated as  $\text{Ratio}(AT_n) / [\text{Ratio}(EF_o) \times \text{Ratio}(ED_o) \times \text{Ratio}(ET_o)] \times \text{Ratio}(PEF)$ , which is equivalent to  $250 \times \text{Ratio}(PEF)$ .

<sup>e</sup> “—” indicates “does not apply.”

**TABLE 4-27 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d) <sup>a</sup>	8	8	1
PEF (m <sup>3</sup> /kg) <sup>b</sup>			0.67 × Ratio(Q/C)
1-V <sup>c</sup>	0.5	0.75	1.5
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>d</sup>	90.8	79.909 × A <sub>cont</sub> <sup>-0.161</sup>	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure)	— <sup>e</sup>	—	250 × Ratio(PEF)
MF <sub>d</sub> (distance)	—	—	1
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> Regarding ET<sub>o</sub>, the SFSC value accounts for an exposure time of 8 hours per day that the solar operation worker would spend outdoors within the footprint of a solar energy facility. This is a conservative assumption, because in reality, the worker may spend some time indoors, where the air concentrations of contaminants would be less than the outdoor levels.

<sup>b</sup> The ratio for PEF can be calculated as Ratio(Q/C) / {Ratio(1-V) × Ratio(U<sub>m</sub>)<sup>3</sup> × Ratio[F(x)]}, which is equivalent to 0.67 × Ratio(Q/C).

<sup>c</sup> During the operation phase, 25% of the ground surface is assumed to be covered by vegetation, inhibiting the emission of contaminated particulate from the contaminated area (see Table 4-11 footnotes).

<sup>d</sup> The Q/C value listed in the table accounts for dispersion of particulate emissions averaged over the contaminated area; therefore, it is a function of A<sub>cont</sub>.

<sup>e</sup> “—” indicates “does not apply.”

**TABLE 4-28 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Operation in the Non-contaminated Area<sup>a</sup>**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
ET <sub>o</sub> (hr/d)	8	8	1
PEF (m <sup>3</sup> /kg)			0.67 × Ratio(Q/C)
1-V	0.5	0.75	1.5
Q/C (g/m <sup>2</sup> -s per kg/m <sup>3</sup> )	90.8	79.909 × A <sub>cont</sub> <sup>-0.161</sup>	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
X	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure)	— <sup>b</sup>	—	250 × Ratio(PEF)
MF <sub>d</sub> (distance) <sup>c</sup>	—	—	F(A <sub>total</sub> , A <sub>cont</sub> ) (see Section 4.7.1 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The modification factors used to obtain SFSCs during operation in the non-contaminated area are the same as those used to obtain SFSCs during operation in the contaminated area (listed in Table 4-27), except for the value of the distance modification factor, MF<sub>d</sub>.

<sup>b</sup> “—” indicates “does not apply.”

<sup>c</sup> The distance modification factor, MF<sub>d</sub>, is used to adjust the exposure point concentrations due to dilution with exposure distance. The RSLs address exposures in the contaminated area, while the SFSCs address exposures in the non-contaminated area (see Table 4-12 footnotes for more detailed discussion). Section 4.7.1 discusses the value of MF<sub>d</sub> as a function of A<sub>total</sub> and A<sub>cont</sub>.

### 4.3.4 Dermal Absorption Pathway

#### 4.3.4.1 SSL Equation and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{THQ \times AT_n \times BW_a}{EF_o \times ED_o \times \frac{SA_a \times AF_a \times ABS}{RfD_o \times GIABS \times \frac{10^6 \text{mg}}{\text{kg}}}} \quad (18)$$

where

TR = Target cancer risk (10<sup>-6</sup>),

AT<sub>n</sub> (days) = Averaging time—noncarcinogens (ED × 365),

$BW_a$  (kg) = Bodyweight—adults (70),

$EF_o$  (days/yr) = Exposure frequency—occupational (250; i.e., 5 days/week for 50 weeks/yr),

$ED_o$  (yr) = Exposure duration—occupational (25),

$SA_a$  (cm<sup>2</sup>/day) = Exposed surface area for soil/dust—adult worker (3,300),

$AF_a$  (mg/cm<sup>2</sup>) = Adherence factor—soils—adult worker (0.2),

ABS = Skin absorption (0.1 for semi-volatile organics),

RfD<sub>o</sub> (mg/kg-day) = Reference dose oral, contaminant-specific, and

GIABS = Gastrointestinal tract absorption fraction , contaminant-specific.

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.3.4.2 Modification of RSLs to Obtain SFSCSLs**

Tables 4-29 through 4-32 present modification factors that should be used to adjust the SSLs in order to obtain the SFSCSLs required for assessing risks to facility workers from the dermal absorption pathway. Table 4-29 shows risk that could be incurred during construction in the contaminated area. Table 4-30 shows risk that could be incurred during construction in the non-contaminated area. Tables 4-31 and 4-32 show risks incurred working in the contaminated and non-contaminated areas, respectively, during the operation phase. It is assumed that the potential risks associated with decommissioning the solar energy facility would be similar to those associated with constructing the facility; therefore, no separate tables are presented for decommissioning activities.

#### 4.4 DEVELOPMENT OF SFSCLS FOR EXPOSURES OF OFFSITE RESIDENTS BASED ON CARCINOGENIC RISKS

The following sections present the SSL equations and exposure parameter values used by EPA to derive RSLs based on carcinogenic risks associated with residential exposures (EPA 2013c). These sections also provide detailed discussions of the calculation of modification factors used to modify the RSLs to obtain SFSCLS.

Because of the physical distance between offsite residents and the contaminated area within the solar energy facility, potential exposures to chemical contaminants through the direct soil ingestion and dermal absorption pathways are considered negligible. Therefore, only exposures via the inhalation of volatiles and inhalation of particulate pathways are discussed in the following sections.

**TABLE 4-29 Modification Factors for Obtaining SFSCLS Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Contaminated Area**

Parameter	RSL Default Value	SFSCCL Value	Ratio (SFSCCL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0.3	1.5
MF <sub>e</sub> (exposure) <sup>b</sup>	– <sup>c</sup>	–	167
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level) <sup>d</sup>	–	–	1
MF (overall)	–	–	167

<sup>a</sup> As discussed in the Table 4-13 footnotes, the SFSCCL value for AF<sub>a</sub> is one and a half times the value used to derive RSLs; the increased value is used to account for more direct deposition of contaminated soil on skin due to the vigorous soil disturbance associated with construction activities.

<sup>b</sup> The modification factor for exposure pattern, MF<sub>e</sub>, can be calculated as Ratio(AT<sub>n</sub>) / [Ratio(EF<sub>o</sub>) × Ratio(ED<sub>o</sub>) × Ratio(SA<sub>a</sub>) × Ratio(AF<sub>a</sub>)], according to Equation (20).

<sup>c</sup> –” indicates “does not apply.”

<sup>d</sup> The consequences of construction activities are implicitly included in the higher value used for AF<sub>a</sub>; therefore, no further modification is implemented with the value of the activity level MF, MF<sub>a</sub>.

**TABLE 4-30 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0	0
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	~

<sup>a</sup> As discussed in the Table 4-14 footnotes, it is assumed that there is no significant deposition of a chemical contaminant on skin when working in the non-contaminated area (i.e., AF<sub>a</sub> = 0).

<sup>b</sup> “–” indicates “does not apply.”

<sup>c</sup> “~” means the value of the modification factor is infinitely large, because no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

**TABLE 4-31 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0.1	0.5
MF <sub>e</sub> (exposure)	– <sup>b</sup>	–	500
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	500

<sup>a</sup> The parameter value used for AF<sub>a</sub> is the same as that used to consider carcinogenic risks (see Table 4-15 footnotes).

<sup>b</sup> “–” indicates “does not apply.”

**TABLE 4-32 Modification Factors for Obtaining SFSCs Concerning Exposures of Facility Workers to Non-carcinogenic Chemicals through the Dermal Absorption Pathway during Operation in the Non-contaminated Area**

Parameter	RSL Default Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	9125	365	0.04
EF <sub>o</sub> (days/yr)	250	1	0.004
ED <sub>o</sub> (yr)	25	1	0.04
SA <sub>a</sub> (cm <sup>2</sup> /day)	3300	3300	1
AF <sub>a</sub> (mg/cm <sup>2</sup> ) <sup>a</sup>	0.2	0	0.0
MF <sub>c</sub> (exposure)	– <sup>b</sup>	–	~ <sup>c</sup>
MF <sub>d</sub> (distance)	–	–	1
MF <sub>a</sub> (activity level)	–	–	1
MF (overall)	–	–	~

- <sup>a</sup> It is assumed that there is no direct dermal absorption when working in the non-contaminated area (i.e., AF<sub>a</sub> = 0).
- <sup>b</sup> “–” indicates “does not apply.”
- <sup>c</sup> “~” means the value of the modification factor is infinitely large, because no chemical exposure is expected from this specific pathway; therefore, there is no limitation to the soil concentration level.

#### 4.4.1 Inhalation of Volatiles Pathway

##### 4.4.1.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{TR \times AT_c}{EF_r \times (URF_i \times 10^3) \times \frac{1}{VF_s} \times ED_r} \quad (19)$$

$$VF_s(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{\frac{1}{2}}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \left( \frac{\text{m}^2}{\text{cm}^2} \right) \quad (20)$$

$$D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'} \quad (21)$$

where

TR = Target cancer risk (10<sup>-6</sup>),

AT<sub>c</sub> (days) = Averaging time—carcinogens (25,550; i.e., 70 yr),

$EF_r$  (days/yr) = Exposure frequency—residential (350),  
 $VF_s$  (m<sup>3</sup>/kg) = Volatilization factor for soil, chemical-specific,  
 $URF_i$  [(μg/m<sup>3</sup>)<sup>-1</sup>] = Unit risk factor inhaled, chemical-specific,  
 $ED_r$  (yr) = Exposure duration—residential (30),  
 $Q/C$  (g/m<sup>2</sup>-s per kg/m<sup>3</sup>) = Inverse of the mean concentration at the center of a  
 0.5-acre<sup>2</sup> source (68.81),  
 $D_A$  (cm<sup>2</sup>/s) = Apparent diffusivity, chemical specific,  
 $T$ (s) = Exposure interval ( $9.5 \times 10^8$ , about 30 yr),  
 $\rho_b$  (g/cm<sup>3</sup>) = Dry soil bulk density (1.5),  
 $\theta_a$  = Air-filled soil porosity (0.28 or  $n - \theta_w$ ),  
 $D_i$  (cm<sup>2</sup>/s) = Diffusivity in air, chemical-specific,  
 $H'$  = Dimensionless Henry's Law Constant (calculated from  
 $H$  by multiplying by 41), chemical specific,  
 $H$  (atm-m<sup>3</sup>/mol) = Henry's Law Constant, chemical-specific,  
 $\theta_w$  = Water-filled soil porosity (0.15),  
 $D_w$  (cm<sup>2</sup>/s) = Diffusivity in water, chemical-specific,  
 $n$  (0.43) = Total soil porosity (or  $1 - \rho_b/\rho_s$ ),  
 $K_d$  (cm<sup>3</sup>/g) = Soil-water partition coefficient =  $K_{oc} f_{oc}$ ,  
 $K_{oc}$  (cm<sup>3</sup>/g) = Soil organic carbon-water partition coefficient, and  
 $f_{oc}$  = Fraction of organic carbon in soil (0.006; i.e., 0.6%).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### 4.4.1.2 Modification of RSLs to Obtain SFSCSLs

Modification factors that should be used to adjust the RSLs in order to obtain the SFSCSLs required for assessing inhalation-of-volatiles risks for the offsite general public living close to a

solar energy facility are presented in Tables 4-33 through 4-35. The value of the exposure modification factor,  $MF_e$ , is determined from the ratios of exposure parameters used for the derivation of RSLs to those that would be used for the derivation of SFSCSLs. Only exposure parameters that assume different values in the two derivations are listed in the tables. Table 4-33 shows the risks that could be incurred when construction is conducted in the contaminated area. Table 4-34 shows the risks that could be incurred when construction is conducted in the non-contaminated area. Table 4-35 shows risks that could be incurred during the operation phase. The potential risks that could be incurred during the decommissioning phase are assumed to be similar to those during the construction phase; therefore, separate tables are not presented for the decommissioning phase.

**TABLE 4-33 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
$EF_r$ (days/yr) <sup>a</sup>	350	0.33	0.0009
$ED_r$ (yr) <sup>b</sup>	30	1	0.033
$VF_s$ (m <sup>3</sup> /kg)			$3.85 \times 10^{-3}$
$T$ (s) <sup>c</sup>	$9.50 \times 10^8$	$2.88 \times 10^4$	$3.03 \times 10^{-5}$
$Q/C$ (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>d</sup>	68.81	48.13	0.6995
$MF_e$ (exposure) <sup>e</sup>	— <sup>f</sup>	—	122.55
$MF_d$ (distance) <sup>g</sup>	—	—	$F(D_{res}, A_{total})$ (see Section 4.7.2) for its value
$MF_a$ (activity level) <sup>h</sup>	—	—	Chemical-specific (see Section 4.6.1.3 for its value)
$MF$ (overall)	—	—	$MF_e \times MF_d / MF_a$

<sup>a</sup> The SFSCSL value for  $EF_r$  assumes that construction activities last for 8 hr per working day, which is equivalent to 0.33 days. Exposures incurred by offsite residents during the 8-hr period when construction is actively undertaken would be much higher than during the remaining 16 hr when construction is not occurring, because a much higher emission of volatile compounds would be generated by vigorous construction activities. Therefore, the evaluation of daily exposure focuses on the exposure incurred during the 8-hr construction period.

**Footnotes continued on next page.**

**TABLE 4-33 (Continued)**

---

- <sup>b</sup> The SFSCCL concerns the risk incurred during a day. The value of one year for  $ED_r$  is used with the selected value of  $EF_r$  to achieve that consideration.
- <sup>c</sup> The construction of a solar facility is assumed to start in the contaminated area; therefore, the SFSCCL value for T is set to 28,800 seconds, which is equivalent to 8 hr.
- <sup>d</sup> The SFSCCL value for Q/C corresponds to an area of 4 acres, which is the assumed daily soil disturbance area for construction. See footnote e of Table 4-5 for more explanation.
- <sup>e</sup> The value of MF for exposure ( $MF_e$ ) can be calculated as the reciprocal of  $\text{Ratio}(EF_r) \times \text{Ratio}(ED_r) / \text{Ratio}(VF_s)$ , according to Equation (19).
- <sup>f</sup> “–” indicates “does not apply.”
- <sup>g</sup> The distance MF,  $MF_d$ , adjusts the air concentration of volatiles above the construction area to obtain the exposure point concentration at an offsite location where offsite residents are located. Therefore, the value of  $MF_d$  is dependent on the distance from the edge of the solar energy facility to the residence,  $D_{res}$ , as well as the footprint of the facility,  $A_{total}$ . Section 4.7.2 provides equations to calculate the value of  $MF_d$ .
- <sup>h</sup> The activity level MF,  $MF_a$ , includes the enhancement of volatilization caused by construction activities. Its value is chemical-specific. Section 4.6.1.3 provides instructions to determine the values for various volatile compounds.

**TABLE 4-34 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>r</sub> (days/yr) <sup>a</sup>	350	1	0.0029
ED <sub>r</sub> (yr)	30	1	0.033
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s) <sup>b</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × (A <sub>total</sub> /4/250)	Ratio(T)
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>c</sup>	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure) <sup>d</sup>	— <sup>e</sup>	—	10,500 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>f</sup>	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> Although for this calculation, construction is assumed to occur in the non-contaminated area, emissions of volatile compounds would continue under the influence of wind over the contaminated area and would persist 24 hr/day. Therefore, the exposures of offsite residents from this pathway would also be continuous throughout an entire day. As such, the SFSC value for EF<sub>r</sub> is set to 1 (day).

<sup>b</sup> The SFSC value for T corresponds to the time needed to complete construction of the entire solar energy facility (including weekends), which is dependent on the scale of the facility. Therefore, the SFSC value is a function of the total footprint of the facility, A<sub>total</sub>. This SFSC value allows the calculation of an average concentration over the entire construction period which is used to estimate total chemical intake during construction in the non-contaminated area. The total chemical intake then contributes to the total lifetime carcinogenic risk.

<sup>c</sup> The SFSC value for Q/C corresponds to the entire contaminated area.

<sup>d</sup> The value of MF for exposure (MF<sub>e</sub>) can be calculated as the reciprocal of Ratio(EF<sub>r</sub>) × Ratio(ED<sub>r</sub>) / Ratio(VF<sub>s</sub>), according to Equation (19). The reciprocal of the product of the first two ratios is 10,500.

<sup>e</sup> “—” indicates “does not apply.”

<sup>f</sup> The distance MF, MF<sub>d</sub>, adjusts the air concentration of volatiles above the contaminated area to obtain the exposure point concentration at an offsite location where offsite residents are located. Section 4.7.2 provides equations to calculate the value of MF<sub>d</sub>.

**TABLE 4-35 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Volatiles Pathway during the Operation Phase<sup>a</sup>**

Parameter	RSL Default Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>r</sub> (yr)	30	1	0.033
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s) <sup>b</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × ED <sub>op</sub>	Ratio(T)
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> )	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure)	— <sup>c</sup>	—	10,500 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The parameter values listed in this table are the same as those listed Table 4-34, except for the SFSCSL value for T.

<sup>a</sup> The SFSCSL value for T corresponds to the operation period of the solar energy facility so that the average concentration over the entire operation period is used for assessing the potential exposures.

<sup>b</sup> “—” indicates “does not apply.”

## 4.4.2 Inhalation of Particulate Pathway

### 4.4.2.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{TR \times AT_c}{EF_r \times (URF_i \times 10^3) \times \frac{1}{PEF} \times ED_r} \quad (22)$$

$$PEF(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{\frac{3600 \text{ s}}{\text{h}}}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)} \quad (23)$$

where

TR = Target cancer risk (10<sup>-6</sup>),

AT<sub>c</sub> (days) = Averaging time—carcinogens (25,550; i.e., 70 yr),

EF<sub>r</sub> (days/yr) = Exposure frequency—residential (350),

PEF (m<sup>3</sup>/kg) = Particulate emission factor (1.316 × 10<sup>9</sup>),

$URF_i [(\mu\text{g}/\text{m}^3)^{-1}]$  = Unit risk factor inhaled, chemical-specific,

$ED_r$  (yr) = Exposure duration—residential (30),

$Q/C$  ( $\text{g}/\text{m}^2\text{-s}$  per  $\text{kg}/\text{m}^3$ ) = Inverse of the mean concentration at the center of a 0.5-acre<sup>2</sup> source (68.81),

$V$  = Fraction of vegetative cover (0.5),

$U_m$  (m/s) = Mean annual wind speed (4.69),

$U_t$  (m/s) = Equivalent threshold value of wind speed at 7 m (11.32),  
and

$F(x)$  = Function dependent on  $U_m/U_t$  derived using Cowherd et al. (1985) (0.194).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.4.2.2 Modification of RSLs to Obtain SFSCSLs**

Tables 4-36 through 4-38 present modification factors used to adjust the RSLs in order to obtain the SFSCSLs required for assessing risks to the offsite general public living close to a solar energy facility from the inhalation of particulate pathway. Table 4-36 shows risks that could be incurred when construction is conducted in the contaminated area. Table 4-37 shows the risks that could be incurred when construction is conducted in the non-contaminated area. Table 4-38 shows risks that could be incurred during the operation phase. The potential risks that could be incurred during the decommissioning phase are assumed to be similar to those during the construction phase; therefore, separate tables are not presented for the decommissioning phase.

### **4.5 DEVELOPMENT OF SFSCSLs FOR OFFSITE RESIDENTS BASED ON NON-CARCINOGENIC RISKS**

The following sections present the SSL equations and the exposure parameter values used by EPA for the derivation of RSLs based on non-carcinogenic risks associated with residential exposures (EPA 2013c). These sections also provide detailed discussions of the calculation of modification factors that should be used to modify the RSLs to obtain SFSCSLs.

Because of the physical distance between offsite residents and the contaminated area within the solar energy facility, potential exposures to chemical contaminants through the direct soil ingestion and dermal absorption pathways are considered negligible. Therefore, only

exposures via the inhalation of volatiles and inhalation of particulate pathways are discussed in the following sections.

**TABLE 4-36 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
EF <sub>r</sub> (days/yr) <sup>a</sup>	350	0.33	0.0009
ED <sub>r</sub> (yr) <sup>b</sup>	30	1	0.033
PEF (m <sup>3</sup> /kg) <sup>c</sup>			3.52 × 10 <sup>-1</sup>
1-V <sup>d</sup>	0.5	1.0	2
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>e</sup>	90.8	63.92	0.7040
U <sub>m</sub> (m/s) <sup>f</sup>	4.69	4.69	1
x <sup>f</sup>	2.14	2.14	1
F(x) <sup>f</sup>	0.194	0.1940	1
MF <sub>e</sub> (exposure)	— <sup>g</sup>	—	11,200
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level)	—	—	Chemical-specific (see Section 4.6.2.3 for its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The reason for setting the SFSCSL value of EF<sub>r</sub> to 0.33 is to focus on the exposures associated with the enhanced emissions of particulate during the assumed 8-hr construction period per day (see Table 4-33 footnote a).

<sup>b</sup> The SFSCSL concerns the risk incurred during a day. The value of one year for ED<sub>r</sub> is used with the selected value of EF<sub>r</sub> to achieve that consideration.

<sup>c</sup> The ratio for PEF can be calculated as Ratio(Q/C) / {Ratio(1-V) × Ratio(U<sub>m</sub>)<sup>3</sup> × Ratio[F(x)]}.

<sup>d</sup> No vegetative cover in the ground surface is assumed during construction.

<sup>e</sup> The SFSCSL value for Q/C corresponds to an area of 4 acres, which is the assumed daily soil disturbance area for construction. See footnote d of Table 4-9 for more detailed explanation.

<sup>f</sup> The values of U<sub>m</sub>, x, and F(x) used for SFSCSL derivation are the same as those used for RSL derivation. See footnotes d, e, and f of Table 4-9 for more explanations.

<sup>g</sup> “—” indicates “does not apply.”

**TABLE 4-37 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>r</sub> (yr) <sup>a</sup> <sub>r</sub>	30	1	0.033
PEF (m <sup>3</sup> /kg) <sup>b</sup>			Ratio(Q/C)/2
1-V	0.5	1.0	2
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>c</sup>	90.8	$79.909 \times A_{\text{cont}}^{-0.161}$	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure) <sup>d</sup>	— <sup>e</sup>	—	10,500 × Ratio(PEF)
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSC concerns the risk incurred during a day. The value of one year for ED<sub>r</sub> is used with the selected value of EF<sub>r</sub> to achieve that consideration.

<sup>b</sup> The ratio for PEF can be calculated as Ratio(Q/C) / Ratio(1-V) / Ratio(U<sub>m</sub>)<sup>3</sup> / Ratio[F(x)], which is equivalent to Ratio(Q/C)/2.

<sup>c</sup> The SFSC value for Q/C concerns the dispersion over the contaminated area. As stated in the Table 4-9 footnotes, the equation is obtained by fitting the Q/C data for Minneapolis in EPA's technical background document for SSLs (Table 3 of EPA 1996b).

<sup>d</sup> The modification factor MF<sub>e</sub> can be calculated as Ratio(PEF) / Ratio(EF<sub>r</sub>) / Ratio(ED<sub>r</sub>), which is equivalent to 10,500 × Ratio(PEF).

<sup>e</sup> “—” indicates “does not apply.”

**TABLE 4-38 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Carcinogenic Chemicals through the Inhalation of Particulate Pathway during the Operation Phase<sup>a</sup>**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>r</sub> (yr) <sub>r</sub>	30	1	0.033
PEF (m <sup>3</sup> /kg) <sup>b</sup>			0.67 × Ratio(Q/C)
1-V <sup>c</sup>	0.5	0.75	1.5
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> )	90.8	79.909 × A <sub>cont</sub> <sup>-0.161</sup>	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	1
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure)	— <sup>d</sup>	—	10,500 × Ratio(PEF)
MF <sub>d</sub> (distance) <sup>e</sup>	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The parameter values are the same as those listed in the preceding table, Table 4-37, except for the values of PEF and 1-V.

<sup>b</sup> The ratio for PEF can be calculated as Ratio(Q/C) / Ratio(1-V) / Ratio(U<sub>m</sub>)<sup>3</sup> / Ratio[F(x)], which is equivalent to 0.67 × Ratio(Q/C).

<sup>c</sup> It is assumed that 25% of the ground surface is covered by vegetation (V) during the operation phase so that emission of particulates is suppressed in 25% of the contaminated area.

<sup>d</sup> “—” indicates “does not apply.”

<sup>e</sup> The distance MF, MF<sub>d</sub>, adjusts the air concentration of particulates above the contaminated area to obtain the exposure point concentration at the location of offsite residents. Therefore, the value of MF<sub>d</sub> is dependent on the distance from the edge of the solar energy facility to the residence, D<sub>res</sub>, as well as the footprint of the facility, A<sub>total</sub>. Section 4.7.2 provides equations to calculate the value of MF<sub>d</sub>.

## 4.5.1 Inhalation of Volatiles Pathway

### 4.5.1.1 SSL Equations and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{THQ \times AT_n}{EF_r \times ED_c \times \frac{1}{RfCi \times VF_s}} \quad (24)$$

$$VF_s(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{\frac{1}{2}}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \left( \frac{\text{m}^2}{\text{cm}^2} \right) \quad (25)$$

$$D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'} \quad (26)$$

where

THQ = Target hazard quotient (1),

AT<sub>n</sub> (days) = Averaging time—noncarcinogens (2190; i.e., ED × 365),

EF<sub>r</sub> (days/yr) = Exposure frequency—residential (350),

ED<sub>c</sub> (yr) = Exposure duration—child (6),

VF<sub>s</sub> (m<sup>3</sup>/kg) = Volatilization factor for soil, chemical-specific,

RfCi (mg/m<sup>3</sup>) = Reference concentration inhaled, chemical-specific,

Q/C (g/m<sup>2</sup>-s per kg/m<sup>3</sup>) = Inverse of the mean concentration at the center of a 0.5-acre<sup>2</sup> source (68.81),

D<sub>A</sub> (cm<sup>2</sup>/s) = Apparent diffusivity, chemical-specific,

T (s) = Exposure interval (9.5 × 10<sup>8</sup>, about 30 yr),

ρ<sub>b</sub> (g/cm<sup>3</sup>) = Dry soil bulk density (1.5),

θ<sub>a</sub> = Air-filled soil porosity (0.28 or n-θ<sub>w</sub>),

D<sub>i</sub> (cm<sup>2</sup>/s) = Diffusivity in air, chemical-specific,

$H'$  = Dimensionless Henry's Law Constant (calculated from  $H$  by multiplying by 41), chemical-specific,

$H$  (atm-m<sup>3</sup>/mol) = Henry's Law Constant, chemical-specific,

$\theta_w$  = Water-filled soil porosity (0.15),

$D_w$  (cm<sup>2</sup>/s) = Diffusivity in water, chemical-specific,

$n$  = Total soil porosity (0.43 or  $1 - \rho_b/\rho_s$ ),

$K_d$  (cm<sup>3</sup>/g) = Soil-water partition coefficient =  $K_{oc} f_{oc}$ ,

$K_{oc}$  (cm<sup>3</sup>/g) = Soil organic carbon-water partition coefficient, and

$f_{oc}$  = Fraction of organic carbon in soil (0.006; i.e., 0.6%).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.5.1.2 Modification of RSLs to Obtain SFSCs**

Tables 4-39 through 4-41 present modification factors to adjust the RSLs in order to obtain the SFSCs required for assessing risks from the inhalation of volatiles pathway to the offsite general public living close to a solar energy facility. Table 4-39 shows risks that could be incurred when construction is conducted in the contaminated area. Table 4-40 shows risks that could be incurred when construction is conducted in the non-contaminated area. Table 4-41 shows risks that could be incurred during the operation phase. The potential risks that could be incurred during the decommissioning phase are assumed to be similar to those during the construction phase; therefore, separate tables are not presented for the decommissioning phase.

**TABLE 4-39 Modification Factors for Obtaining SFSCSLs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSCSL Value	Ratio (SFSCSL/RSL)
AT <sub>n</sub> (days)	2190	365	0.167
EF <sub>r</sub> (days/yr) <sup>a</sup>	350	0.33	0.0009
ED <sub>c</sub> (yr) <sup>a</sup>	6	1	0.167
VF <sub>s</sub> (m <sup>3</sup> /kg) <sup>a</sup>			0.0039
T (s) <sup>a</sup>	9.50 × 10 <sup>8</sup>	2.88 × 10 <sup>4</sup>	3.03 × 10 <sup>-5</sup>
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>a</sup>	68.81	48.13	0.6995
MF <sub>e</sub> (exposure) <sup>b</sup>	— <sup>c</sup>	—	4.08
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level)	—	—	Chemical-specific (see Section 4.6.1.3 for its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSCSL values for EF, ED, VF<sub>s</sub>, T, and Q/C are the same as those listed in Table 4-33 concerning exposures to carcinogenic chemicals. See the footnotes of Table 4-33 for explanations of the SFSCSL values.

<sup>b</sup> The value of MF<sub>e</sub> can be calculated as Ratio(AT<sub>n</sub>) / Ratio(EF<sub>r</sub>) / Ratio(ED<sub>c</sub>) × Ratio(VF<sub>s</sub>), according to Equation (24).

<sup>c</sup> “—” indicates “does not apply.”

**TABLE 4-40 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during Construction in the Non-contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	2190	365	0.167
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>c</sub> (yr)	6	1	0.167
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × Ratio(T) <sup>0.5</sup>
T (s) <sup>a</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365 × min(A <sub>total</sub> /4/250, 1)	Ratio(T)
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> )	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure)	— <sup>b</sup>	—	350 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance) <sup>c</sup>	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSC value for T corresponds to the duration of construction during the first year, including weekends. This is to obtain the average air concentration over this period for the assessment of total non-carcinogenic risk over the first year. Depending on the footprint of the solar energy facility, it may take more than 1 yr to complete construction; therefore, a limitation is imposed to limit the value of T to 1 yr. The term min(A<sub>total</sub>/4/250, 1) means the smaller value between A<sub>total</sub>/4/250 and 1. Facility workers are assumed to work 250 days per year.

<sup>b</sup> “—” indicates “does not apply.”

<sup>c</sup> The distance modification factor MF<sub>d</sub> accounts for dilution in the exposure point concentration due to exposure distance; therefore, it is a function of the distance from the offsite residence to the edge of the facility, D<sub>res</sub>, and the footprint of the facility, A<sub>total</sub>. Section 4.7.2 provides instruction on the calculation of MF<sub>d</sub>.

**TABLE 4-41 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Volatiles Pathway during the Operation Phase**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	2190	365	0.167
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>c</sub> (yr)	6	1	0.167
VF <sub>s</sub> (m <sup>3</sup> /kg)			Ratio(Q/C) × 0.18
T (s) <sup>a</sup>	9.50 × 10 <sup>8</sup>	24 × 3600 × 365	0.033
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>b</sup>	68.81	60.42 × A <sub>cont</sub> <sup>-0.164</sup>	Ratio(Q/C)
MF <sub>e</sub> (exposure)	— <sup>c</sup>	—	350 × Ratio(VF <sub>s</sub> )
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSC value for T is equivalent to 1 yr. It is used to obtain an average air concentration for the first year to facilitate the assessment of total non-carcinogenic risks over 1 yr.

<sup>b</sup> The SFSC value for Q/C accounts for dispersion of the volatile emissions over the contaminated area, A<sub>cont</sub>.

<sup>c</sup> “—” indicates “does not apply.”

## 4.5.2 Inhalation of Particulate Pathway

### 4.5.2.1 SSL Equation and Parameter Values Used to Derive RSLs

$$C_s(\text{mg/kg}) = \frac{THQ \times AT_n}{EF_r \times ED_c \times \frac{1}{RfC_i \times PEF}} \quad (27)$$

$$PEF(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{\frac{3600 \text{ s}}{\text{h}}}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)} \quad (28)$$

where

THQ = Target hazard quotient (1),

AT<sub>n</sub> (days) = Averaging time—noncarcinogens (2190; i.e., ED × 365),

$EF_r$  (days/yr) = Exposure frequency—residential (350),

$ED_c$  (yr) = Exposure duration—child (6),

$RfCi$  ( $mg/m^3$ ) = Reference concentration inhaled, chemical-specific,

$PEF$  ( $m^3/kg$ ) = Particulate emission factor ( $1.316 \times 10^9$ ),

$Q/C$  ( $g/m^2$ -s per  $kg/m^3$ ) = Inverse of the mean concentration at the center of a 0.5-acre<sup>2</sup> source (90.80),

$V$  = Fraction of vegetative cover (0.5),

$U_m$  (m/s) = Mean annual wind speed (4.69),

$U_t$  (m/s) = Equivalent threshold value of wind speed at 7 m (11.32),  
and

$F(x)$  = Function dependent on  $U_m/U_t$  derived using Cowherd et al. (1985) (0.194).

The numbers in parenthesis in the parameter explanations are the values used in the derivation of RSLs.

#### **4.5.2.2 Modification of RSLs to Obtain SFSCSLs**

Tables 4-42 through 4-44 present modification factors used to adjust the RSLs in order to obtain the SFSCSLs required for assessing risks from the inhalation of particulate pathway to the offsite general public living close to a solar energy facility. Table 4-42 shows risks that could be incurred when construction is conducted in the contaminated area. Table 4-43 shows risks that could be incurred when construction is conducted in the non-contaminated area. Table 4-44 shows risks that could be incurred during the operation phase. The potential risks that could be incurred during the decommissioning phase are assumed to be similar to those during the construction phase; therefore, separate tables are not presented for the decommissioning phase.

**TABLE 4-42 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Contaminated Area**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	2190	365	0.167
EF <sub>r</sub> (days/yr)	350	0.33	0.0009
ED <sub>c</sub> (yr)	6	1	0.167
PEF (m <sup>3</sup> /kg)			0.352
1-V <sup>a</sup>	0.5	1.0	2
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>b</sup>	90.8	63.92	0.704
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure) <sup>c</sup>	— <sup>d</sup>	—	373
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for its value)
MF <sub>a</sub> (activity level) <sup>c</sup>	—	—	Chemical-specific (see Section 4.6.2.3 for its value)
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The SFSC value for 1-V assumes that the vegetative groundcover is removed (i.e., V = 0) during the construction phase, which would yield greater particulate emissions.

<sup>b</sup> The SFSC value for Q/C concerns the dispersion of emissions over the daily soil disturbance area for construction, which is assumed to be 4 acres.

<sup>c</sup> The value of MF<sub>e</sub> can be calculated as Ratio(AT<sub>n</sub>) / Ratio(EF<sub>r</sub>) / Ratio(ED<sub>c</sub>) × Ratio(PEF), according to Equation (27).

<sup>d</sup> “—” indicates “does not apply.”

<sup>e</sup> The level of enhancement of particulate emissions by construction activities is chemical-specific; instructions for calculating the value of the activity level modification factor, MF<sub>a</sub>, can be found in Section 4.6.2.3.

**TABLE 4-43 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during Construction in the Non-contaminated Area<sup>a</sup>**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	2190	365	0.167
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>c</sub> (yr)	6	1	0.167
PEF (m <sup>3</sup> /kg)			Ratio(Q/C)/2
1-V	0.5	1.0	2
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> ) <sup>b</sup>	90.8	$79.909 \times A_{\text{cont}}^{-0.161}$	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	
F(x)	0.194	0.194	1
MF <sub>c</sub> (exposure)	— <sup>c</sup>	—	$350 \times \text{Ratio(PEF)}$
MF <sub>d</sub> (distance)	—	—	$F(D_{\text{res}}, A_{\text{total}})$ (see Section 4.7.2 for the value)
MF <sub>a</sub> (activity level) <sup>d</sup>	—	—	1
MF (overall)	—	—	$\text{MF}_c \times \text{MF}_d / \text{MF}_a$

<sup>a</sup> The SFSC values for exposure parameters are the same as those listed in Table 4-42, except for Q/C and PEF.

<sup>b</sup> The SFSC value for Q/C during construction in the non-contaminated area concerns the dispersion of emissions over the contaminated area, A<sub>cont</sub>, rather than over the 4-acre daily soil disturbance area for construction.

<sup>c</sup> “—” indicates “does not apply.”

<sup>d</sup> Because construction is conducted in the non-contaminated area, the emission of particulates from the contaminated area is driven mainly by wind; therefore, the activity level modification factor MF<sub>a</sub> is set to 1.

**TABLE 4-44 Modification Factors for Obtaining SFSCs Concerning Exposures of Offsite Residents to Non-carcinogenic Chemicals through the Inhalation of Particulate Pathway during the Operation Phase<sup>a</sup>**

Parameter	RSL Value	SFSC Value	Ratio (SFSC/RSL)
AT <sub>n</sub> (days)	2190	365	0.167
EF <sub>r</sub> (days/yr)	350	1	0.0029
ED <sub>c</sub> (yr)	6	1	0.167
PEF (m <sup>3</sup> /kg)			0.67 × Ratio(Q/C)
1-V <sup>b</sup>	0.5	0.75	1.5
Q/C (m <sup>2</sup> -s per kg/m <sup>3</sup> )	90.8	79.909 × A <sub>cont</sub> <sup>-0.161</sup>	Ratio(Q/C)
U <sub>m</sub> (m/s)	4.69	4.69	1
x	2.14	2.14	
F(x)	0.194	0.194	1
MF <sub>e</sub> (exposure)	— <sup>c</sup>	—	350 × Ratio(PEF)
MF <sub>d</sub> (distance)	—	—	F(D <sub>res</sub> , A <sub>total</sub> ) (see Section 4.7.2 for its value)
MF <sub>a</sub> (activity level)	—	—	1
MF (overall)	—	—	MF <sub>e</sub> × MF <sub>d</sub> / MF <sub>a</sub>

<sup>a</sup> The exposure parameter values listed in Table 4-43 and Table 4-44 are the same except for the SFSC values for 1-V and PEF. The value of PEF is dependent on the value of 1-V.

<sup>b</sup> During the operation phase, it is assumed 25% of the facility area is covered by vegetation (i.e., V = 0.25), which would inhibit particulate emissions to some extent.

<sup>c</sup> “—” indicates “does not apply.”

#### 4.6 VALUES OF THE ACTIVITY LEVEL MODIFICATION FACTOR, MF<sub>a</sub>

EPA’s SSL equations for the inhalation of volatiles and inhalation of particulate pathways model the potential exposures associated with the release of volatiles and contaminated soil particles using average annual meteorological conditions (i.e., without the influence of mechanical driving forces). During the construction and decommissioning phases of solar energy development, however, extensive land-disturbing activities and increases in vehicular traffic are expected to enhance the releases, thereby increasing the potential chemical exposures. To account for this enhancement in release, an activity level modification factor, MF<sub>a</sub>, is introduced for use in the modification of the RSLs to find SFSCs. The value of MF<sub>a</sub> is the ratio of the enhanced release rate to the release rate modeled by the SSL equation. Section 4.6.1 discusses the calculation of MF<sub>a</sub> for the release of volatiles, and Section 4.6.2 discusses the calculation of MF<sub>a</sub> for the release of particulates.

## 4.6.1 MF<sub>a</sub> for Release of Volatiles

### 4.6.1.1 Release by Construction

Very few models and data are available for estimating the emissions of VOCs from mechanical handling operations. This is because mechanical handling operations are dynamic in nature, so the physical conditions that facilitate volatilization are continuously changing during operations, which could make theoretical modeling impractical. Therefore, the available models are either empirical or a combination of theoretical or mass balance with empirical models. Because the empirical models were developed with limited measurement data under very specific handling conditions, the accuracy of applying these models to a broader range of mechanical handling operations cannot be verified. As such, the volatilization rates estimated using these models for the construction and decommissioning activities involved in solar energy development could include a high degree of uncertainty.

In its Air/Superfund national technical guidance study series, EPA published a few models for estimating emission rates from Superfund remedial actions (EPA 1993). Although none of these models were developed explicitly for estimating the emission rates associated with the soil grading, digging, and covering expected during the construction or decommissioning of a solar energy facility, the soil excavation and removal work addressed by one of the models is considered to be similar to the ground-disturbing activities associated with installation or decommissioning of a solar energy facility; therefore, it is used in developing the activity level MF, MF<sub>a</sub>, in this section.

The emission rates of VOCs modeled for soil excavation and removal operations (EPA 1993) assumed that soil would be excavated and placed into a temporary holding area and then handled one or two more times on site. The emissions of VOCs result from the exchange of contaminant-laden soil-pore gas with the atmosphere when soil is disturbed, and from the diffusion of contaminants through the soil. The emission rates depend on a number of factors, including the type of compounds present in soils, the concentrations and distribution of those compounds, and the porosity and moisture content of the soil. The key operational parameters are the duration and vigorousness of the handling, and the size of equipment used. The longer or more energetic the moving and handling of soils, the greater the likelihood VOCs will be volatilized. Unfortunately, control technologies for large-area sources such as excavation are relatively difficult to apply and are often much less effective than controls for point sources (EPA 1993).

A simple check of the potential total emissions from a contaminated site under construction can be made with the use of Equation (36) listed below, which divides the estimated total mass of contaminants within the excavated soils by the projected duration of the activity. Equation (37) calculates the upper bound of the emission rate of compound *i* by assuming the total amount of compound *i* in the contaminated soil within the daily construction area would be lost through volatilization.

$$ER_{max} = \frac{S_v \times C_s \times \rho_b \times 1.0}{t} \quad (29)$$

$$ER'_{max} = \frac{A \times d_{cont} \times C_s \times \rho_b \times 1.0}{t} \quad (30)$$

where

$ER_{max}$  (g/s) = Maximum average emission rate of compound *i* from excavation,

$ER'_{max}$  (g/s) = Maximum average emission rate of compound *i*, if the total inventory of compound *i* within the daily soil disturbance area for construction is available for emission,

$S_v$  (m<sup>3</sup>) = Total volume of soil being moved (per day) (2420),

$C_s$  (μg/g) = Concentration of chemical compound *i* in soil (1),

$\rho_b$  (g/cm<sup>3</sup>) = Dry soil bulk density (1.5),

1.0 (g/10<sup>6</sup> μg × 10<sup>6</sup> cm<sup>3</sup>/m<sup>3</sup>) = constant,

$t$  (s) = Duration of construction (per day) (28,800; i.e., 8 hr),

$A$  (m<sup>2</sup>) = Daily soil disturbance area for construction = 4046 m<sup>2</sup>/acre ×  $A_{daily}$ ,

$A_{daily}$  (acre) = Daily soil disturbance area for construction (4), and

$d_{cont}$  (m) = Depth of contamination (2).

As before, the numbers in parenthesis in the above explanations for parameters are the values used in the analysis. A contamination depth of 2 m is assumed in the calculation of the upper bound of emission rate,  $ER'_{max}$ . This upper bound is used later for comparison with the estimated total emission rate to see how much of the initial inventory in contaminated soils would remain after the construction.

The value of  $S_v$  is determined to be about 2,420 m<sup>3</sup>, which is obtained with an assumed excavation rate,  $Q_{exc}$ , of 0.084 m<sup>3</sup>/s. In the EPA (1993) report, the default and expected range of  $Q_{exc}$  for soil remediation are provided. The default value is 0.042 m<sup>3</sup>/s (150 m<sup>3</sup>/hr or 1,200 m<sup>3</sup>/day), with a range of 0.014–0.067 m<sup>3</sup>/s (50–240 m<sup>3</sup>/hr or 400–1,920 m<sup>3</sup>/day). Considering that the construction of a solar energy facility would involve both grading of the area and digging for erecting supporting structures, a value of twice the default suggested for

remediation (i.e., 0.084 m<sup>3</sup>/s) is used in the analysis. With this assumed excavation rate, the total volume of soil moved, S<sub>v</sub>, is estimated to be about 2,420 m<sup>3</sup> during the 8-hr construction period each day. To put this value into perspective, it is equivalent to excavating the entire soil disturbance area for construction (4 acres/day) to a depth of 0.15 m.

Equation (31) below gives the sum of emission rates from the soil pore space, predicted by Equation (32), and from diffusion, predicted by Equation (33):

$$ER = ER_{ps} + ER_{DIFF} \quad (31)$$

$$ER_{ps} = P \times Q_{exc} \times 0.98 \quad (32)$$

$$ER_{DIFF} = \frac{C_{ms} \times 10,000 \times SA}{\left(1.22 \times 10^6 \times \frac{C_{ms}}{P}\right) + (1.79 \times 10^9 \times \frac{C_{ms}}{P})^{1/2}} \quad (33)$$

where

ER (g/s) = Total soil emission rate of compound i through volatilization,

ER<sub>PS</sub> (g/s) = Soil porosity emission rate of compound i,

ER<sub>DIFF</sub> (g/s) = Diffusion emission rate of compound i,

P (mm Hg) = Saturated vapor pressure of compound i,

Q<sub>exc</sub> (m<sup>3</sup>/s) = Excavation rate (m<sup>3</sup>/s) (0.084),

0.98 (g/mm Hg-m<sup>3</sup>) = Conversion factor,

C<sub>ms</sub> (g/cm<sup>3</sup>) = Mass loading of compound i in soil,

10,000 (cm<sup>2</sup>/m<sup>2</sup>) = Conversion factor,

SA (m<sup>2</sup>) = Area of emitting surface (m<sup>2</sup>) (580),

1.22 × 10<sup>6</sup> (cm<sup>2</sup>-s-mm Hg/g) = Conversion factor, and

1.79 × 10<sup>9</sup> (s<sup>2</sup>-cm-mm Hg/g) = Conversion factor.

A value of 580 m<sup>2</sup> is selected for SA, which is twice the default value (290 m<sup>2</sup>) suggested by EPA for remediation activities. This selection for SA is made in accordance with the selection for Q<sub>exc</sub>.

The mass loading for compound i,  $C_{ms}$ , used in Equation (33) can be estimated with the following equation:

$$C_{ms} = C_s \times \rho_b \times 10^{-6} \quad (34)$$

where

$C_{ms}$  (g/cm<sup>3</sup>) = Mass loading of compound i in soil,

$C_s$  (μg/g) = Concentration of chemical compound i in soil (1),

$\rho_b$  (g/cm<sup>3</sup>) = Dry soil bulk density (1.5), and

10 (g/μg) = Conversion factor.

If  $ER_{PS}$  calculated with Equation (32) is greater than 1/3 of  $M$ , the total mass of compound i in excavated soil, which can be calculated with Equation (36), then it should be replaced with  $ER_{PS}'$  in Equation (35):

$$ER_{PS}' = M \times \frac{0.33}{t_{sv}} \quad (35)$$

$$M = S_v \times 10^6 \times C_{ms} \quad (36)$$

where

$ER_{PS}'$  (g/s) = Maximum of soil porosity emission rate of compound i,

$M$  (g) = Total mass of contaminant in excavated soil,

$t_{sv}$  (s) = Time to excavate a given volume,  $S_v$ , of soil (28,800; i.e., 8 hr),

$S_v$  (m<sup>3</sup>) = Volume of soil excavated (2,420),

$10^6$  (cm<sup>3</sup>/m<sup>3</sup>) = Conversion factor, and

$C_{ms}$  (g/cm<sup>3</sup>) = Mass loading of compound i in soil.

The saturated vapor pressure,  $P$ , of compound i, used to calculate the diffusion emission rate in Equation (33), could result in overpredicting emissions if the partial pressure of compound i in the soil is far below the published saturated vapor pressure of the compound. In that case, the partial pressure should be used to calculate the emissions. The partial pressure can be calculated as follows:

$$C_v = \frac{C_s \times \rho_b \times 10^6}{E_a} = 2.7 \times 10^6 \times C_s \quad (37)$$

where

$C_v$  ( $\mu\text{g}/\text{m}^3$ ) = Concentration in soil pore space,

$C_s$  ( $\mu\text{g}/\text{g}$ ) = Concentration of chemical compound *i* in soil (1),

$\rho_b$  ( $\text{g}/\text{cm}^3$ ) = Dry soil bulk density (1.5),

$10^6$  ( $\text{cm}^3/\text{m}^3$ ) = Conversion factor,

$E_a$  = Air-filled porosity (0.55), and

$2.7 \times 10^6$  ( $\text{g}/\text{m}^3$ ) = Conversion factor.

$$P_i = \frac{C_v \times 62,361 \times 298 \times 10^{-12}}{MW} = \frac{C_v \times 1.86 \times 10^{-5}}{MW} \quad (38)$$

where

$P_i$  (mm Hg) = Partial pressure of compound *i*,

62,361 ( $\text{mm Hg}\cdot\text{cm}^3/\text{mol}\cdot^\circ\text{K}$ ) = Gas constant *R*,

298 ( $^\circ\text{K}$ ) = Assumed temperature,

$10^{-12}$  ( $\text{g}\cdot\text{m}^3/\mu\text{g}\cdot\text{cm}^3$ ) = Conversion factor,

$1.86 \times 10^{-5}$  ( $\text{mm Hg}\cdot\text{g}\cdot\text{m}^3/\text{mol}\cdot\mu\text{g}$ ) = Conversion factor, and

$MW$  ( $\text{g}/\text{mol}$ ) = Molecular weight of compound *i*.

Table 4-45 lists the detailed calculation results using the excavation and removal model from EPA (EPA 1993). The chemical compounds listed are the VOCs identified from the chemical list used by EPA to derive RSLs. For most VOCs, the soil porosity emission rates,  $ER_{PS}$  (calculated with Eq. [32]), exceed the maximum values,  $ER_{PS}'$  (obtained with Eq. [35]), so the maximum values are used to estimate the total emission rate during construction. At a temperature of 25°C, the saturated vapor pressures,  $P_{sat}$ , far exceed the partial pressures calculated with Equation (38), so the values of the partial pressure were used in Equation (33) to obtain the diffusion emission rate,  $ER_{DIFF}'$ . The sum of  $ER_{PS}'$  or  $ER$  (whichever is smaller) and  $ER_{DIFF}'$  is listed as  $ER$ , which gives the estimated total emission rates from porosity and diffusion emissions.

The calculated ER values, as listed in Table 4-45, are then compared with the maximum emission rate,  $ER_{max}$ , which is calculated with Equation (29). The maximum emission rate,  $ER_{max}$ , is calculated to be 0.126 g/s, which is exceeded by the calculated values of the ERs. This means during construction, all the volatile compounds contained in the excavated or moved soils would be volatilized. Therefore, the value of  $ER_{max}$  is selected as the total emission rate under construction,  $ER_{const}$ . Comparing the value of  $ER_{const}$  with that of  $ER_{max}$ , calculated to be 1.69 g/s using Equation (30), the amount of VOCs that would be volatilized by construction activities is less than 10% of the total inventory in the contaminated soils.

#### 4.6.1.2 Release by Wind

The SSL equation for the inhalation of volatiles pathway contains the flux rate calculation under annual average meteorological conditions. Therefore, the average emission rate of VOCs can be obtained by multiplying the flux rate by the contaminated area, which in this case is 4 acres (i.e., the assumed daily soil disturbance area for construction). The average emission rate over an 8-hr period can be obtained with Equation (40):

$$VF_s(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} \left( \frac{\text{m}^2}{\text{cm}^2} \right) \quad (39)$$

$$ER_w = \frac{2 \times \rho_b \times D_A \times A \times C_s \times 10^{-6}(\text{g}/\mu\text{g})}{(3.14 \times D_A \times T)^{1/2} \times 10^{-4}(\text{m}^2/\text{cm}^2)}, \text{ and} \quad (40)$$

$$D_A = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a H'} \quad (41)$$

where

$VF_s$  ( $\text{m}^3/\text{kg}$ ) = Volatilization factor, chemical-specific,

$Q/C$  ( $\text{g/s-m}^2$  per  $\text{kg/m}^3$ ) = Inverse of the mean concentration at the center of the contamination area,

$D_A$  ( $\text{cm}^2/\text{s}$ ) = Apparent diffusivity, chemical-specific,

$\rho_b$  ( $\text{g/cm}^3$ ) = Dry soil bulk density (1.5),

$T$  (s) = Exposure interval (28,800; i.e., 8 hr),

$C_s$  ( $\mu\text{g/g}$ ) = Concentration of chemical compound  $i$  in soil (1),

$ER_w$  ( $\text{g/s}$ ) = Soil emission rate of compound  $i$  through volatilization,

$A$  ( $m^2$ ) = Daily soil disturbance area for construction (16,184; i.e., 4 acres),

$D_A$  ( $cm^2/s$ ) = Apparent diffusivity, chemical-specific,

$\theta_a$  = Air-filled soil porosity (0.28 or  $n - \theta_w$ ),

$D_i$  ( $cm^2/s$ ) = Diffusivity in air, chemical-specific,

$H'$  = Dimensionless Henry's Law Constant (calculated from  $H$  by multiplying by 41), chemical-specific,

$H$  ( $atm \cdot m^3/mol$ ) = Henry's Law Constant, chemical-specific,

$\theta_w$  = Water-filled soil porosity (0.15),

$D_w$  ( $cm^2/s$ ) = Diffusivity in water, chemical-specific,

$n$  (0.43) = Total soil porosity (or  $1 - \rho_b/\rho_s$ ),

$K_d$  ( $cm^3/g$ ) = Soil-water partition coefficient =  $K_{oc} f_{oc}$ ,

$K_{oc}$  ( $cm^3/g$ ) = Soil organic carbon-water partition coefficient, and

$f_{oc}$  = Fraction of organic carbon in soil (0.006; i.e., 0.6%).

As before, the numbers in parenthesis in the above explanations for parameters are the values used in the analysis. The apparent diffusivity and the emission rate,  $ER_w$ , calculated for each VOC are also listed in Table 4-45.

#### 4.6.1.3 Values of $MF_a$

With the release rates of volatiles associated with construction activities and under annual average meteorological conditions, the value of  $MF_a'$ , the modification factor accounting for the enhancement of volatilization during construction on a 4-acre contaminated area, can be calculated as the ratio of the two release rates. The last column of Table 4-45 lists the values of  $MF_a$ s for different VOCs.

TABLE 4-45 Calculation of the Emission Rates for Volatile Organic Compounds (VOCs) and the Value of MF<sub>a</sub>'

Volatile chemicals	CAS No.	Calculation of ER Caused by Construction							Calculation of ER Caused by Wind Blowing		MF <sub>a</sub> ' Based on 4-acre Contamination
		P <sub>sat</sub> (mm Hg) at 25°C	P <sub>i</sub> (mm Hg)	ER <sub>PS</sub> (g/s)	ER <sub>PS</sub> ' (g/s)	ER <sub>DIFF</sub> ' (g/s)	ER = ER <sub>PS</sub> ' (or ER <sub>PS</sub> ) + ER <sub>DIFF</sub> '	ER <sub>const</sub>	D <sub>A</sub>	ER <sub>w</sub> (g/s)	
Acetaldehyde	75-07-0	760	1.14E+00	6.26E+01	4.16E-02	1.74E-01	2.15E-01	1.26E-01	1.65E-05	6.57E-03	1.92E+01
Acetone	67-64-1	266	8.65E-01	2.19E+01	4.16E-02	1.50E-01	1.92E-01	1.26E-01	3.23E-06	2.90E-03	4.34E+01
Acetone Cyanohydrin	75-86-5		5.90E-01					1.26E-01	2.22E-06	2.41E-03	5.24E+01
Acetonitrile	75-05-8	90	1.22E+00	7.41E+00	4.16E-02	1.80E-01	2.22E-01	1.26E-01	2.08E-06	2.33E-03	5.41E+01
Acetophenone	98-86-2		4.18E-01					1.26E-01	2.89E-08	2.74E-04	4.59E+02
Acrolein	107-02-8	244.2	8.96E-01	2.01E+01	4.16E-02	1.53E-01	1.95E-01	1.26E-01	2.64E-05	8.29E-03	1.52E+01
Acrylonitrile	107-13-1	114	9.46E-01	9.38E+00	4.16E-02	1.58E-01	1.99E-01	1.26E-01	3.88E-06	3.18E-03	3.96E+01
Allyl Chloride	107-05-1	368	6.56E-01	3.03E+01	4.16E-02	1.30E-01	1.72E-01	1.26E-01	5.50E-05	1.20E-02	1.05E+01
Azobenzene	103-33-3		2.76E-01		4.16E-02			1.26E-01	2.87E-10	2.74E-05	4.61E+03
Benzaldehyde	100-52-7	1	4.73E-01	8.23E-02	4.16E-02	1.10E-01	1.51E-01	1.26E-01	3.83E-07	9.99E-04	1.26E+02
Benzene	71-43-2	95.2	6.43E-01	7.84E+00	4.16E-02	1.29E-01	1.71E-01	1.26E-01	7.24E-06	4.34E-03	2.90E+01
Benzenethiol	108-98-5		4.56E-01					1.26E-01	2.22E-07	7.61E-04	1.66E+02
Benzotrchloride	98-07-7		2.57E-01					1.26E-01	1.73E-08	2.12E-04	5.93E+02
Benzyl Chloride	100-44-7	1.21	3.97E-01	9.96E-02	4.16E-02	1.00E-01	1.42E-01	1.26E-01	1.25E-07	5.70E-04	2.21E+02
Biphenyl, 1,1'-	92-52-4	—	3.26E-01					1.26E-01	6.02E-09	1.25E-04	1.01E+03
Bis(2-chloro-1-methylethyl) ether	108-60-1		2.94E-01					1.26E-01	7.64E-08	4.46E-04	2.82E+02
Bis(2-chloroethyl)ether	111-44-4	1.4	3.51E-01	1.15E-01	4.16E-02	9.39E-02	1.35E-01	1.26E-01	6.52E-08	4.12E-04	3.06E+02
Bis(chloromethyl)ether	542-88-1		4.37E-01					1.26E-01	7.19E-05	1.37E-02	9.20E+00
Bromo-2-chloroethane, 1-	107-04-0		3.50E-01					1.26E-01	3.21E-06	2.89E-03	4.36E+01
Bromobenzene	108-86-1		3.20E-01					1.26E-01	1.21E-06	1.77E-03	7.11E+01
Bromochloromethane	74-97-5		3.88E-01					1.26E-01	1.12E-05	5.40E-03	2.33E+01
Bromodichloromethane	75-27-4		3.07E-01					1.26E-01	7.94E-06	4.55E-03	2.77E+01
Bromomethane	74-83-9	—	5.29E-01					1.26E-01	1.17E-04	1.75E-02	7.21E+00
Butadiene, 1,3-	106-99-0	2100	9.28E-01	1.73E+02	4.16E-02	1.56E-01	1.98E-01	1.26E-01	3.90E-04	3.19E-02	3.95E+00
Butylbenzene, n-	104-51-8		3.74E-01					1.26E-01	1.20E-06	1.77E-03	7.11E+01
Carbon Disulfide	75-15-0	366	6.60E-01	3.01E+01	4.16E-02	1.31E-01	1.72E-01	1.26E-01	1.49E-04	1.97E-02	6.40E+00
Carbon Tetrachloride	56-23-5	113	3.26E-01	9.30E+00	4.16E-02	9.04E-02	1.32E-01	1.26E-01	7.59E-05	1.41E-02	8.96E+00
Chloro-1,1-difluoroethane, 1-	75-68-3		5.00E-01					1.26E-01	2.26E-04	2.43E-02	5.19E+00
Chloro-1,3-butadiene, 2-	126-99-8	273	5.67E-01	2.25E+01	4.16E-02	1.21E-01	1.62E-01	1.26E-01	1.64E-04	2.07E-02	6.10E+00
Chloroacetaldehyde, 2-	107-20-0		6.40E-01					1.26E-01	3.62E-06	3.07E-03	4.10E+01
Chlorobenzene	108-90-7	11.8	4.46E-01	9.71E-01	4.16E-02	1.07E-01	1.48E-01	1.26E-01	2.04E-06	2.30E-03	5.47E+01
Chlorobenzotrifluoride, 4-	98-56-6		2.78E-01					1.26E-01	1.77E-06	2.15E-03	5.87E+01
Chlorobutane, 1-	109-69-3		5.43E-01					1.26E-01	3.85E-05	1.00E-02	1.26E+01
Chlorodifluoromethane	75-45-6	—	5.81E-01					1.26E-01	2.77E-04	2.69E-02	4.69E+00
Chloroform	67-66-3	208	4.21E-01	1.71E+01	4.16E-02	1.03E-01	1.45E-01	1.26E-01	1.88E-05	7.00E-03	1.80E+01
Chloromethane	74-87-3	3830	9.95E-01	3.15E+02	4.16E-02	1.62E-01	2.03E-01	1.26E-01	1.74E-04	2.13E-02	5.92E+00

TABLE 4-45 (Cont.)

Volatile chemicals	CAS No.	Calculation of ER Caused by Construction							Calculation of ER Caused by Wind Blowing		MF <sub>a</sub> ' Based on 4-acre Contamination
		P <sub>sat</sub> (mm Hg) at 25°C	P <sub>1</sub> (mm Hg)	ER <sub>PS</sub> (g/s)	ER <sub>PS'</sub> (g/s)	ER <sub>DIFF'</sub> (g/s)	ER = ER <sub>PS'</sub> (or ER <sub>PS</sub> ) + ER <sub>DIFF'</sub>	ER <sub>const</sub>	D <sub>A</sub>	ER <sub>w</sub> (g/s)	
Chloromethyl Methyl Ether	107-30-2		6.24E-01					1.26E-01	1.13E-05	5.43E-03	2.32E+01
Chloronaphthalene, Beta-	91-58-7		3.09E-01					1.26E-01	1.23E-08	1.79E-04	7.04E+02
Chlorophenol, 2-	95-57-8		3.91E-01					1.26E-01	5.34E-09	1.18E-04	1.07E+03
Chloropicrin	76-06-2		3.06E-01					1.26E-01	5.09E-06	3.64E-03	3.46E+01
Chlorotoluene, o-	95-49-8		3.97E-01					1.26E-01	1.25E-06	1.80E-03	6.99E+01
Chlorotoluene, p-	106-43-4		3.97E-01					1.26E-01	1.55E-06	2.01E-03	6.26E+01
Crotonaldehyde, trans-	123-73-9		7.17E-01					1.26E-01	2.13E-06	2.35E-03	5.35E+01
Cumene	98-82-8	10.9	4.18E-01	8.97E-01	4.16E-02	1.03E-01	1.44E-01	1.26E-01	2.11E-06	2.35E-03	5.37E+01
~Thiocyanate	463-56-9		8.50E-01					1.26E-01	8.17E-06	4.61E-03	2.73E+01
Cyclohexane	110-82-7	100	5.97E-01	8.23E+00	4.16E-02	1.24E-01	1.66E-01	1.26E-01	1.73E-04	2.13E-02	5.93E+00
Dibromo-3-chloropropane, 1,2-	96-12-8		2.12E-01					1.26E-01	8.71E-08	4.77E-04	2.64E+02
Dibromochloromethane	124-48-1		2.41E-01					1.26E-01	1.91E-06	2.23E-03	5.64E+01
Dibromoethane, 1,2-	106-93-4	14	2.67E-01	1.15E+00	4.16E-02	8.13E-02	1.23E-01	1.23E-01	1.50E-06	1.98E-03	6.37E+01
Dibromomethane (Methylene Bromide)	74-95-3		2.89E-01					1.26E-01	4.42E-06	3.39E-03	3.71E+01
Dichloro-2-butene, 1,4-	764-41-0		4.02E-01					1.26E-01	7.14E-07	1.36E-03	9.24E+01
Dichloro-2-butene, cis-1,4-	1476-11-5		4.02E-01					1.26E-01	7.14E-07	1.36E-03	9.24E+01
Dichloro-2-butene, trans-1,4-	110-57-6		4.02E-01					1.26E-01	7.12E-07	1.36E-03	9.25E+01
Dichlorobenzene, 1,2-	95-50-1	1	3.42E-01	8.23E-02	4.16E-02	9.25E-02	1.34E-01	1.26E-01	5.99E-07	1.25E-03	1.01E+02
Dichlorobenzene, 1,4-	106-46-7	1.2	3.42E-01	9.88E-02	4.16E-02	9.25E-02	1.34E-01	1.26E-01	7.51E-07	1.40E-03	9.00E+01
Dichlorodifluoromethane	75-71-8		4.15E-01					1.26E-01	1.19E-03	5.57E-02	2.26E+00
Dichloroethane, 1,1-	75-34-3	234	5.07E-01	1.93E+01	4.16E-02	1.14E-01	1.56E-01	1.26E-01	3.13E-05	9.03E-03	1.40E+01
Dichloroethane, 1,2-	107-06-2	80	5.07E-01	6.59E+00	4.16E-02	1.14E-01	1.56E-01	1.26E-01	5.42E-06	3.76E-03	3.35E+01
Dichloroethylene, 1,1-	75-35-4	600	5.18E-01	4.94E+01	4.16E-02	1.15E-01	1.57E-01	1.26E-01	1.49E-04	1.97E-02	6.39E+00
Dichloroethylene, 1,2- (Mixed Isomers)	540-59-0		5.18E-01					1.26E-01	1.92E-05	7.07E-03	1.78E+01
Dichloroethylene, 1,2-cis-	156-59-2		5.18E-01					1.26E-01	1.93E-05	7.09E-03	1.78E+01
Dichloroethylene, 1,2-trans-	156-60-5	324	5.18E-01	2.67E+01	4.16E-02	1.15E-01	1.57E-01	1.26E-01	1.91E-05	7.06E-03	1.78E+01
Dichloropropane, 1,2-	78-87-5	42	4.44E-01	3.46E+00	4.16E-02	1.06E-01	1.48E-01	1.26E-01	7.23E-06	4.34E-03	2.90E+01
Dichloropropane, 1,3-	142-28-9		4.44E-01					1.26E-01	2.12E-06	2.35E-03	5.36E+01
Dichloropropene, 1,3-	542-75-6	43	4.53E-01	3.54E+00	4.16E-02	1.07E-01	1.49E-01	1.26E-01	7.96E-06	4.56E-03	2.77E+01
Dicyclopentadiene	77-73-6		3.80E-01					1.26E-01	4.89E-06	3.57E-03	3.53E+01
Difluoroethane, 1,1-	75-37-6		7.60E-01					1.26E-01	1.38E-04	1.89E-02	6.65E+00
Dihydrosafrole	94-58-6		3.06E-01					1.26E-01	1.07E-04	1.67E-02	7.56E+00
Diisopropyl Ether	108-20-3		4.91E-01					1.26E-01	1.55E-05	6.37E-03	1.98E+01
Diisopropyl Methylphosphonate	1445-75-6		2.79E-01					1.26E-01	1.32E-07	5.87E-04	2.15E+02
Dimethylaniline, N,N-	121-69-7	—	4.14E-01					1.26E-01	9.66E-08	5.02E-04	2.51E+02

TABLE 4-45 (Cont.)

Volatile chemicals	CAS No.	Calculation of ER Caused by Construction							Calculation of ER Caused by Wind Blowing		MF <sub>a</sub> ' Based on 4-acre Contamination
		P <sub>sat</sub> (mm Hg) at 25°C	P <sub>i</sub> (mm Hg)	ER <sub>PS</sub> (g/s)	ER <sub>PS'</sub> (g/s)	ER <sub>DIFF'</sub> (g/s)	ER = ER <sub>PS'</sub> (or ER <sub>PS</sub> ) + ER <sub>DIFF'</sub>	ER <sub>const</sub>	D <sub>A</sub>	ER <sub>w</sub> (g/s)	
Dimethylterephthalate	120-61-6		2.59E-01					1.26E-01	2.63E-07	8.28E-04	1.52E+02
Dimethylvinylchloride	513-37-1		5.55E-01					1.26E-01	2.28E-04	2.44E-02	5.17E+00
Dithiane, 1,4-	505-29-3		4.18E-01					1.26E-01	4.81E-08	3.54E-04	3.56E+02
EPTC	759-94-4		2.65E-01					1.26E-01	6.25E-09	1.28E-04	9.87E+02
Epichlorohydrin	106-89-8	17	5.43E-01	1.40E+00	4.16E-02	1.18E-01	1.60E-01	1.26E-01	5.81E-07	1.23E-03	1.02E+02
Epoxybutane, 1,2-	106-88-7	—	6.96E-01					1.26E-01	3.56E-06	3.05E-03	4.14E+01
Ethyl Acetate	141-78-6	100	5.70E-01	8.23E+00	4.16E-02	1.21E-01	1.63E-01	1.26E-01	4.14E-06	3.28E-03	3.84E+01
Ethyl Acrylate	140-88-5	40	5.02E-01	3.29E+00	4.16E-02	1.13E-01	1.55E-01	1.26E-01	5.00E-06	3.61E-03	3.49E+01
Ethyl Chloride	75-00-3	1200	7.78E-01	9.88E+01	4.16E-02	1.42E-01	1.84E-01	1.26E-01	1.12E-04	1.71E-02	7.38E+00
Ethyl Ether	60-29-7		6.78E-01					1.26E-01	2.27E-05	7.70E-03	1.64E+01
Ethyl Methacrylate	97-63-2		4.40E-01					1.26E-01	4.75E-06	3.52E-03	3.58E+01
Ethylbenzene	100-41-4	10	4.73E-01	8.23E-01	4.16E-02	1.10E-01	1.51E-01	1.26E-01	2.57E-06	2.59E-03	4.87E+01
Ethylene Oxide	75-21-8	1250	1.14E+00	1.03E+02	4.16E-02	1.74E-01	2.15E-01	1.26E-01	1.27E-05	5.74E-03	2.19E+01
Ethyleneimine	151-56-4	—	1.17E+00					1.26E-01	3.84E-07	1.00E-03	1.26E+02
~Dibenzofuran	132-64-9		2.99E-01					1.26E-01	2.03E-09	7.28E-05	1.73E+03
~Furan	110-00-9	596	7.38E-01	4.91E+01	4.16E-02	1.39E-01	1.80E-01	1.26E-01	1.47E-05	6.19E-03	2.03E+01
~Tetrahydrofuran	109-99-9	72.1	6.96E-01					1.26E-01	1.32E-06	1.86E-03	6.78E+01
Hexamethylene Diisocyanate, 1,6-	822-06-0		2.99E-01					1.26E-01	8.66E-10	4.75E-05	2.65E+03
Hexane, N-	110-54-3	150.3	5.83E-01	1.24E+01	4.16E-02	1.23E-01	1.64E-01	1.26E-01	1.92E-03	7.08E-02	1.78E+00
Hexanone, 2-	591-78-6		5.01E-01					1.26E-01	9.28E-07	1.56E-03	8.10E+01
Methacrylonitrile	126-98-7		7.49E-01					1.26E-01	3.86E-06	3.17E-03	3.97E+01
Methyl Acetate	79-20-9	235	6.78E-01	1.93E+01	4.16E-02	1.33E-01	1.74E-01	1.26E-01	7.42E-06	4.40E-03	2.86E+01
Methyl Acrylate	96-33-3	—	5.83E-01					1.26E-01	6.13E-06	4.00E-03	3.15E+01
Methyl Ethyl Ketone (2-Butanone)	78-93-3	100	6.96E-01	8.23E+00	4.16E-02	1.34E-01	1.76E-01	1.26E-01	2.41E-06	2.51E-03	5.02E+01
Methyl Isobutyl Ketone	108-10-1	19.31	5.01E-01	1.59E+00	4.16E-02	1.13E-01	1.55E-01	1.26E-01	1.62E-06	2.05E-03	6.14E+01
Methyl Isocyanate	624-83-9	348	8.80E-01	2.86E+01	4.16E-02	1.52E-01	1.93E-01	1.26E-01	5.78E-06	3.88E-03	3.25E+01
Methyl Methacrylate	80-62-6	39	5.02E-01	3.21E+00	4.16E-02	1.13E-01	1.55E-01	1.26E-01	5.51E-06	3.79E-03	3.32E+01
Methyl Styrene (Mixed Isomers)	25013-15-4		4.25E-01					1.26E-01	6.13E-07	1.26E-03	9.97E+01
Methyl tert-Butyl Ether (MTBE)	1634-04-4	245	5.70E-01	2.02E+01	4.16E-02	1.21E-01	1.63E-01	1.26E-01	8.06E-06	4.58E-03	2.75E+01
Methylene Chloride	75-09-2	362	5.91E-01	2.98E+01	4.16E-02	1.23E-01	1.65E-01	1.26E-01	3.16E-05	9.08E-03	1.39E+01
Methylstyrene, Alpha-	98-83-9	118.18	4.25E-01	9.73E+00	4.16E-02	1.04E-01	1.45E-01	1.26E-01	4.89E-07	1.13E-03	1.12E+02
Mineral oils	8012-95-1		2.95E-01					1.26E-01	2.20E-04	2.40E-02	5.26E+00
Nitrobenzene	98-95-3		4.08E-01					1.26E-01	1.56E-08	2.02E-04	6.25E+02
Nitromethane	75-52-5		8.23E-01					1.26E-01	7.05E-07	1.36E-03	9.30E+01
Nitropropane, 2-	79-46-9	12.9	5.64E-01	1.06E+00	4.16E-02	1.20E-01	1.62E-01	1.26E-01	6.96E-07	1.35E-03	9.36E+01
Nitroso-di-N-butylamine, N-	924-16-3		3.17E-01					1.26E-01	2.05E-09	7.30E-05	1.73E+03

TABLE 4-45 (Cont.)

Volatile chemicals	CAS No.	Calculation of ER Caused by Construction							Calculation of ER Caused by Wind Blowing		MF <sub>a</sub> ' Based on 4-acre Contamination
		P <sub>sat</sub> (mm Hg) at 25°C	P <sub>i</sub> (mm Hg)	ER <sub>PS</sub> (g/s)	ER <sub>PS'</sub> (g/s)	ER <sub>DIFF'</sub> (g/s)	ER = ER <sub>PS'</sub> (or ER <sub>PS</sub> ) + ER <sub>DIFF'</sub>	ER <sub>const</sub>	D <sub>A</sub>	ER <sub>w</sub> (g/s)	
Nitrotoluene, o-	88-72-2		3.66E-01					1.26E-01	4.36E-09	1.07E-04	1.18E+03
Nonane, n-	111-84-2	128.26	3.92E-01	1.06E+01	4.16E-02	9.94E-02	1.41E-01	1.26E-01	4.52E-04	3.43E-02	3.67E+00
Pentane, n-	109-66-0	513	6.96E-01	4.22E+01	4.16E-02	1.34E-01	1.76E-01	1.26E-01	2.67E-03	8.34E-02	1.51E+00
Phosgene	75-44-5	1394	5.08E-01	1.15E+02	4.16E-02	1.14E-01	1.56E-01	1.26E-01	2.58E-03	8.21E-02	1.54E+00
~Aroclor 1221	11104-28-2		2.66E-01					1.26E-01	1.08E-08	1.68E-04	7.52E+02
~Aroclor 1232	11141-16-5		2.66E-01					1.26E-01	1.08E-08	1.68E-04	7.52E+02
~Acenaphthene	83-32-9		3.26E-01					1.26E-01	3.95E-09	1.01E-04	1.24E+03
~Anthracene	120-12-7	1.30E-06	2.82E-01	1.07E-07	4.16E-02	8.36E-02	8.36E-02	8.36E-02	2.85E-10	2.72E-05	4.63E+03
~Fluorene	86-73-7		3.02E-01					1.26E-01	9.87E-10	5.07E-05	2.48E+03
~Methylnaphthalene, 1-	90-12-0		3.53E-01					1.26E-01	2.28E-08	2.44E-04	5.17E+02
~Methylnaphthalene, 2-	91-57-6		3.53E-01					1.26E-01	2.33E-08	2.47E-04	5.11E+02
~Naphthalene	91-20-3	0.023	3.92E-01	1.89E-03	4.16E-02	9.95E-02	1.01E-01	1.01E-01	3.67E-08	3.09E-04	4.07E+02
~Pyrene	129-00-0		2.48E-01					1.26E-01	1.38E-11	6.00E-06	2.10E+04
Propionaldehyde	123-38-6		8.65E-01					1.26E-01	1.57E-05	6.40E-03	1.97E+01
Propyl benzene	103-65-1		4.18E-01					1.26E-01	1.65E-06	2.07E-03	6.07E+01
Propylene	115-07-1		1.19E+00					1.26E-01	1.96E-03	7.15E-02	1.76E+00
Propylene Oxide	75-56-9	524.5	8.65E-01	4.32E+01	4.16E-02	1.50E-01	1.92E-01	1.26E-01	3.05E-06	2.82E-03	4.47E+01
Pyridine	110-86-1	20	6.35E-01	1.65E+00	4.16E-02	1.28E-01	1.70E-01	1.26E-01	3.13E-08	2.86E-04	4.41E+02
Styrene	100-42-5	7.3	4.82E-01	6.01E-01	4.16E-02	1.11E-01	1.53E-01	1.26E-01	9.32E-07	1.56E-03	8.08E+01
Tetrachloroethane, 1,1,1,2-	630-20-6		2.99E-01					1.26E-01	2.97E-06	2.78E-03	4.53E+01
Tetrachloroethane, 1,1,1,2,2-	79-34-5	6.5	2.99E-01	5.35E-01	4.16E-02	8.63E-02	1.28E-01	1.26E-01	4.02E-07	1.02E-03	1.23E+02
Tetrachloroethylene	127-18-4	19	3.03E-01	1.56E+00	4.16E-02	8.68E-02	1.28E-01	1.26E-01	2.00E-05	7.21E-03	1.75E+01
Tetrafluoroethane, 1,1,1,2-	811-97-2		4.92E-01					1.26E-01	1.01E-04	1.62E-02	7.76E+00
Toluene	108-88-3	30	5.45E-01	2.47E+00	4.16E-02	1.18E-01	1.60E-01	1.26E-01	4.69E-06	3.50E-03	3.60E+01
Trichloro-1,2,2-trifluoroethane, 1,1,2-	76-13-1	300	2.68E-01	2.47E+01	4.16E-02	8.14E-02	1.23E-01	1.23E-01	2.09E-04	2.33E-02	5.40E+00
Trichlorobenzene, 1,2,3-	87-61-6		2.77E-01					1.26E-01	7.60E-08	4.45E-04	2.83E+02
Trichlorobenzene, 1,2,4-	120-82-1		2.77E-01					1.26E-01	8.82E-08	4.79E-04	2.63E+02
Trichloroethane, 1,1,1-	71-55-6	123	3.76E-01	1.01E+01	4.16E-02	9.74E-02	1.39E-01	1.26E-01	5.37E-05	1.18E-02	1.06E+01
Trichloroethane, 1,1,2-	79-00-5	25	3.76E-01	2.06E+00	4.16E-02	9.74E-02	1.39E-01	1.26E-01	1.93E-06	2.24E-03	5.62E+01
Trichloroethylene	79-01-6	75	3.82E-01	6.17E+00	4.16E-02	9.82E-02	1.40E-01	1.26E-01	2.36E-05	7.85E-03	1.61E+01
Trichlorofluoromethane	75-69-4	667	3.66E-01	5.49E+01	4.16E-02	9.59E-02	1.37E-01	1.26E-01	3.01E-04	2.80E-02	4.50E+00
Trichloropropane, 1,1,2-	598-77-6		3.41E-01					1.26E-01	4.06E-07	1.03E-03	1.22E+02
Trichloropropane, 1,2,3-	96-18-4	3.1	3.41E-01	2.55E-01	4.16E-02	9.24E-02	1.34E-01	1.26E-01	3.62E-07	9.71E-04	1.30E+02
Trichloropropene, 1,2,3-	96-19-5		3.45E-01					1.26E-01	1.90E-05	7.05E-03	1.79E+01
Trimethylbenzene, 1,2,3-	526-73-8	—	4.18E-01					1.26E-01	9.04E-07	1.54E-03	8.21E+01
Trimethylbenzene, 1,2,4-	95-63-6	—	4.18E-01					1.26E-01	1.29E-06	1.84E-03	6.86E+01

TABLE 4-45 (Cont.)

Volatile chemicals	CAS No.	Calculation of ER Caused by Construction							Calculation of ER Caused by Wind Blowing		MF <sub>a</sub> ' Based on 4-acre Contamination
		P <sub>sat</sub> (mm Hg) at 25°C	P <sub>i</sub> (mm Hg)	ER <sub>PS</sub> (g/s)	ER <sub>PS</sub> ' (g/s)	ER <sub>DIFF</sub> ' (g/s)	ER = ER <sub>PS</sub> ' (or ER <sub>PS</sub> ) + ER <sub>DIFF</sub> '	ER <sub>const</sub>	D <sub>A</sub>	ER <sub>w</sub> (g/s)	
Trimethylbenzene, 1,3,5-	108-67-8	1.86	4.18E-01	1.53E-01	4.16E-02	1.03E-01	1.44E-01	1.26E-01	1.86E-06	2.20E-03	5.72E+01
Vinyl Acetate	108-05-4	115	5.83E-01	9.47E+00	4.16E-02	1.23E-01	1.64E-01	1.26E-01	1.62E-05	6.50E-03	1.94E+01
Vinyl Bromide	593-60-2	895	4.70E-01	7.37E+01	4.16E-02	1.09E-01	1.51E-01	1.26E-01	1.03E-04	1.64E-02	7.70E+00
Vinyl Chloride	75-01-4	2660	8.04E-01	2.19E+02	4.16E-02	1.45E-01	1.86E-01	1.26E-01	2.87E-04	2.74E-02	4.60E+00
Xylene, P-	106-42-3	9.5	4.73E-01	7.82E-01	4.16E-02	1.10E-01	1.51E-01	1.26E-01	2.67E-06	2.64E-03	4.78E+01
Xylene, m-	108-38-3	8	4.73E-01	6.59E-01	4.16E-02	1.10E-01	1.51E-01	1.26E-01	2.78E-06	2.69E-03	4.68E+01
Xylene, o-	95-47-6	7	4.73E-01	5.76E-01	4.16E-02	1.10E-01	1.51E-01	1.26E-01	1.98E-06	2.27E-03	5.54E+01
Xylenes	1330-20-7		4.73E-01					1.26E-01	2.44E-06	2.52E-03	5.00E+01

In reality, the contamination within the daily soil disturbance area for construction could be less than 4 acres; in that situation, the modification factor  $MF_a'$  should be reduced accordingly to find the final  $MF_a$  for use in the modification of RSLs to obtain SFSCSLs.

$$MF_a = \min(A_{cont}/4, 1) \times MF_a' \quad (42)$$

where

$MF_a$  = Activity-level modification factor for use to modify RSLs,  
chemical-specific,

$MF_a'$  = Activity-level modification factor based on 4-acre contamination,  
listed in the last column of Table 4-45,

$A_{cont}$  (acre) = Area of contamination,

4 (acre) = Daily soil disturbance area for construction, and

$\min(A_{cont}/4, 1)$  = The smaller value between  $A_{cont}/4$  and 1.

The value of  $MF_a$  is chemical-specific. Based on the calculation results for a contaminated area of 4 acres ( $MF_a$  would equal  $MF_a'$ , which is listed in the last column of Table 4-45), the value ranges from 1.51 for n-pentane to 21,000 for pyrene. In general, the enhancement of volatilization as a result of construction activities is greater for a less-volatile compound than for a more-volatile compound, and so is the value of  $MF_a$ . A compound with a higher saturated vapor pressure under normal conditions would volatilize more easily than a compound with a lower saturated vapor pressure.

## 4.6.2 $MF_a$ for Release of Particulates

### 4.6.2.1 Release by Construction

Included in EPA's Air/Superfund national technical guidance study series is a report (EPA 1993) that contains a few mathematical models suggested by EPA for estimating emission rates of particulates associated with Superfund remediation actions. These models were selected by reviewing a comprehensive list of models available and identifying those that met the modeling needs of EPA's Air/Superfund Program. Two of the models estimate particulate emissions associated with grading and transfer operations, which are similar to the construction activities for a solar energy facility. Therefore, these two models are used for determining the enhanced emission rates of particulates associated with construction in the contaminated area within a solar energy facility.

The emission of compound  $i$  attaching to particulate matter from transfer operations is expressed in the following equation:

$$ER_{tran} = \frac{C_s \times 10^{-6} \left(\frac{g}{\mu g}\right) \times Z \times k \times 0.0016 \times M \times \left(\frac{U_m}{2.2}\right)^{1.3}}{\left(\frac{X_{H2O}}{2}\right)^{1.4} \times t} \quad (43)$$

where

$ER_{tran}$  (g/s) = Emission rate of compound i with  $PM_{10}$  particulates associated with transfer activities,

$C_s$  ( $\mu g/g$ ) = Concentration of chemical compound i in soil (1),

$Z$  = Enrichment factor (1, except for some metals listed in Table 4-46),

$k$  = Particle size multiplier (0.35 for  $PM_{10}$ ),

0.0016 (g/kg) = Empirical constant,

$M$  (kg) = Mass of soil handled ( $3.63 \times 10^6$ ),

$U_m$  (m/s) = Mean wind speed (4.69),

2.2 (m/s) = Empirical constant,

$X_{H2O}$  (%) = Percent moisture content (10), and

$t$  (s) = Average time (28,800).

The numbers in parenthesis in the above explanations for parameters are the values used in the analysis. The mass of soil handled ( $M$ ) was estimated to be the total mass of soil excavated during construction, as considered in the emission of volatiles calculation (see Section 4.6.1.1). The mean wind speed of 4.69 m/s was selected to be consistent with the assumption used in EPA's RSL calculations. The average time,  $t$ , corresponds to the 8-hr daily construction period. The other parameters are set at EPA suggested values. The calculated emission rate for transfer operations,  $ER_{tran}$ , is  $1.98 \times 10^{-8} \times Z$  g/s, where the value of  $Z$  is listed in Table 4-46. The  $Z$  factor is greater than 1 for metals because, in general, the dust and silt at a site will contain a higher fraction of the metal species than the bulk soil at the site (i.e., the particulate matter is enriched with the metals) (EPA 1993).

The emission of compound i, which attaches to particulate matter released through the grading of soils by a bulldozer or any other tractor with a blade, can be expressed using the following equation:

$$ER_{grad} = \frac{C_s \times 10^{-6} \left(\frac{g}{\mu g}\right) \times Z \times 0.094 \times s^{1.5}}{X_{H_2O}^{1.4}} \quad (44)$$

**TABLE 4-46 Metal Concentration and Enrichment Data (Z)**

Metal	Median Enrichment Ratio (Z)
Arsenic (As)	1.28
Barium(Ba)	1.85
Cadmium (Cd)	1.31
Chromium (Cr)	4.72
Lead (Pb)	7.34
Mercury (Hg)	3
Selenium (Se)	2
Silver (Ag)	1

Source: EPA (1993).

where

$ER_{grad}$  (g/s) = Emission rate of compound i on  $PM_{10}$  particulates associated with grading,

$C_s$  ( $\mu g/g$ ) = Concentration of chemical compound i in soil (1),

Z = Enrichment factor (1, except for some metals listed in Table 4-46),

0.094 (g/s) = Empirical constant,

S (%) = Percent silt content (8), and

$X_{H_2O}$  (%) = Percent moisture content (10).

Applying EPA suggested default values, the emissions rate of compound i via particulate matter associated with grading,  $ER_{grad}$ , is calculated as  $8.47 \times 10^{-8} \times Z$  g/s.

Assuming grading is conducted during 50% of the construction period, then the total emission rate of compound i with particulate matter during construction on the contaminated area can be calculated as follows:

$$ER_{cont} = ER_{trans} + 0.5 \times ER_{grad} = 6.22 \times 10^{-8} \times Z \text{ (g/s)} \quad (45)$$

#### 4.6.2.2 Release by Wind

The SSL equation for the inhalation of particulates pathway contains the flux rate calculation under average annual meteorological conditions. Therefore, the emission rate of compound *i* with particulate matter can be obtained by multiplying the flux rate by the contaminated area, which in this case is 4 acres (i.e., the assumed daily soil disturbance area for construction). The average emission rate over an 8-hr period can be obtained with Equation (47):

$$PEF(\text{m}^3/\text{kg}) = \frac{Q}{C} \times \frac{3600 \text{ s/hr}}{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x)} \quad (46)$$

$$ER_w = \frac{0.036 \times (1 - V) \times (U_m/U_t)^3 \times F(x) \times A \times C_s \times 10^{-6}(\text{g}/\mu\text{g})}{3600 \text{ (s/h)}} \quad (47)$$

where

PEF ( $\text{m}^3/\text{kg}$ ) = Particulate emission factor,

$Q/C$  ( $\text{g/s}\cdot\text{m}^2$  per  $\text{kg}/\text{m}^3$ ) = Inverse of the mean concentration at the center of the contamination area,

$V$  = Fraction of vegetative cover (0),

$U_m$  (m/s) = Mean annual wind speed (4.69),

$U_t$  (m/s) = Equivalent threshold value of wind speed at 7 m (11.32),

$F(x)$  = Function dependent on  $U_m/U_t$  derived using Cowherd et al. (1985) (0.194),

$C_s$  ( $\mu\text{g}/\text{g}$ ) = Concentration of chemical compound *i* in soil (1),

$ER_w$  (g/s) = Soil emission rate of compound *i* in particulates associated with wind erosion, and

$A$  ( $\text{m}^2$ ) = Daily constructed area (16,184; i.e., 4 acres).

The numbers in parenthesis in the above explanations for parameters are the values used in the analysis. The calculated emission rate of compound *i* under normal wind conditions is estimated to be  $2.22 \times 10^{-9}$  g/s.

### 4.6.2.3 Values of $MF_a$

The value of  $MF_a'$ , the modification factor accounting for the enhancement of particulate emissions during construction on a 4-acre contaminated area, can be calculated as the ratio of  $ER_{const}$ , as obtained with Equation (45), to  $ER_w$ , as obtained using Equation (47). The value of  $MF_a'$  is calculated as  $28 \times Z$ .

In reality, the contamination within the daily soil disturbance area for construction could be less than 4 acres; in that situation, the modification factor  $MF_a'$  should be reduced accordingly to find the final  $MF_a$  for use in the modification of SSLs to obtain SFSCSLs.

$$MF_a = \min(A_{cont}/4, 1) \times 28 \times Z \quad (48)$$

where

$MF_a$  = Activity-level modification factor for use to modify RSLs,  
chemical-specific,

$A_{cont}$  (acres) = Area of contamination,

4 (acres) = Daily construction area,

$\min(A_{cont}/4, 1)$  = The smaller value between  $A_{cont}/4$  and 1, and

$Z$  = Enrichment factor (1, except for some metals listed in  
Table 4-46),

For most chemicals, if the contaminated area is 4 acres, the value of  $MF_a$  is 28. For a few metals listed in Table 4-46, the value of  $MF_a$  would be greater than 28. Therefore, construction activities would greatly enhance the particulate emissions.

## 4.7 VALUES FOR THE DISTANCE MODIFICATION FACTOR, $MF_d$

A utility-scale solar energy facility would occupy a large land area (600 to over 10,000 acres); therefore, it is expected that the footprint of the entire facility would be much greater than the area of contamination within the facility. As such, worker activities could be conducted in the contaminated area as well as outside the contaminated area. For the general public, the potential chemical exposures would only be incurred outside the contaminated area, because their residences are assumed to be outside the footprint of the facility. Because the SSL equations model the air concentrations above the contaminated area, it is necessary to introduce a modification so that air concentrations outside the contaminated area can be obtained to evaluate the corresponding chemical exposures for both facility workers and the general public. This section discusses the distance modification factor ( $MF_d$ ) that should be used when adjusting the

RSLs in order to obtain the SFSCCLs concerning inhalation exposures incurred outside the contaminated area. Section 4.7.1 discusses the modification for worker exposures. Section 4.7.2 discusses the modification for offsite resident (general public) exposures.

#### 4.7.1 MF<sub>d</sub> for Workers in the Non-contaminated Area

The MF<sub>d</sub> to assess worker exposures incurred in the non-contaminated area is the ratio between the average air concentrations within the contaminated area and the average concentrations over the entire footprint of the facility.

To obtain the value for MF<sub>d</sub>, the EPA screening model for evaluating air quality impact, SCREEN3, was used. SCREEN3 (EPA 1995a) is a single-source Gaussian plume model that can be used to provide maximum ground-level concentrations for point, area, flare, and volume sources. It is a screening version of the more complex and refined model ISC3 (EPA 1995b,c). The SCREEN3 model was used to calculate air concentrations at different distances from the center of an emission source. The air concentrations at different locations within a specified area were then used to obtain the average concentration within that area. In the calculations, both the emission source and the specified area were assumed to be square in shape and share the same center point. Five sets of calculations concerning an emission source of different areas (1, 4, 10, 20, and 30 acres) were performed to account for the fact that the contamination areas within solar energy facilities could be of different sizes. Emissions within each source were assumed to be uniform across the entire area. In each calculation, the air concentrations at different locations—from the center of the emission area to a distance of 5,000 m away from the emission center—were obtained so that the average concentration could be calculated for an area up to 25,000 acres. To obtain the air concentrations, it is assumed that the wind would blow equally and simultaneously in each direction with a fixed speed and a stability of Class D (neutral), which is more frequent than stability classes A–C combined (unstable), or E–F combined (stable), in many parts of the United States. This stability class D assumption is typically used for screening purposes. Considering annual-average wind speeds in most U.S. cities, the wind speed was selected to range from 1 m/s to 6 m/s in the calculations.

In each calculation, the ratio of the average air concentration within a specified area to the average air concentration within the source area was plotted against the size of each specified area. The curve was then fitted to the equation  $DF = a / (1 + b \times A_{total}^c)$ , where DF is the ratio of average concentrations,  $A_{total}$  is the size (in acres) of the specified area, and a, b, and c are coefficients obtained with curve fitting. From the resulting plot, it is found that DF values are independent of the assumed wind speed. The values of coefficients a, b, and c would vary with the size of the source area. Because five different source areas were assumed, there were five sets of coefficients; the five values of each coefficient were plotted against the source area for another curve fitting. This time a power function was used to describe the relationship,  $coeff = m \times A_{cont}^n$ , where coeff is each of the coefficients a, b, and c;  $A_{cont}$  is the area of the contamination source; and m and n are coefficients from the curve fitting. Through these curve fittings, a final equation that provides the value of DF as a function of  $A_{cont}$  and  $A_{total}$  was

obtained. The distance modification factor,  $MF_d$ , for use in modifying the RSLs in order to obtain the SFSCSLs, can be calculated as  $1/DF$ :

$$MF_d = \frac{1}{DF} = \frac{1 + b \times A_{total}^c}{a} \quad (49)$$

$$a = 1.5811 \times A_{cont}^{0.102}$$

$$b = 0.5322 \times A_{cont}^{-0.195}$$

$$c = 0.4714 \times A_{cont}^{-0.032}$$

where

$MF_d$  = Distance modification factor for use to modify the RSLs to obtain SFSCSLs,

$DF$  = Ratio of average concentration over  $A_{total}$  to average concentration over  $A_{cont}$ ,

$A_{total}$  (acres) = Footprint of the solar energy facility, and

$A_{cont}$  (acres) = Area of contamination within the solar energy facility.

#### 4.7.2 $MF_d$ for Offsite Resident Exposures

The  $MF_d$  used to assess offsite resident (general public) exposures is the ratio of the average air concentration above the contaminated area to the air concentration at the location of the offsite residence.

In the SCREEN3 calculations, as described in the previous section, air concentrations at different locations—from the center of the emission area to a distance of 5,000 m from the emission center—were obtained. The ratio of air concentrations at different locations to the average air concentration within the source area was plotted against the distance of the resident location to the edge of the emission source. The curve was then fitted to the equation  $DF = a / (1 + b \times L'^c)$ , where  $DF$  is the ratio of concentrations,  $L'$  is the distance (in meters) to the edge of the emission source, and  $a$ ,  $b$ , and  $c$  are coefficients obtained with curve fitting. The values of coefficients  $a$ ,  $b$ , and  $c$  vary with the size of the source area (see Table 4-47). The distance modification factor,  $MF_d$ , can be calculated as the inverse of  $DF$ :

$$MF_d = \frac{1}{DF} = \frac{1 + b \times L'^c}{a} \quad (50)$$

$$L' = L + 31.8 \times (\sqrt{A_{total}} - \sqrt{A_{cont}}) \quad (51)$$

**TABLE 4-47 Values of Coefficients a, b, and c for Different Contaminated Areas**

Contaminated Area (acre)	Coefficient		
	a	b	c
1	0.528	0.006	1.263
4	0.899	0.041	0.902
10	0.736	0.019	0.929
20	0.750	0.021	0.868
30	0.829	0.029	0.805

where

$MF_d$  = Distance modification factor for use to modify the RSLs to obtain SFSCSLs,

DF = Ratio of concentration at a distance  $L'$  from the edge of the contaminated area to the average concentration over  $A_{cont}$ ,

$A_{cont}$  (acres) = Area of contamination within the solar energy facility,

$A_{total}$  (acres) = Total footprint of the solar energy facility,

$L'$  (m) = Distance from the edge of the contaminated area to the offsite residence, and

$L$  (m) = Distance from the edge of the solar energy facility to the offsite residence.

Table 4-47 provides the values of coefficients a, b, and c for five different sizes (1, 4, 10, 20, and 30 acres) of contamination. For a contaminated area with a size other than the listed values, the  $MF_d$  can be obtained by linear interpolation using the  $MF_d$ s corresponding to the two listed sizes that bracket the contaminated area of concern. For example, for a contaminated area of 8 acres, the two sizes listed in Table 4-47 that bracket 8 acres are 4 acres and 10 acres. If the values of  $A_{total}$  and  $L$  are assumed to be 2,000 acres and 1,000 m, respectively, the  $MF_d$  for a contaminated area ( $A_{cont}$ ) of 4 acres would be 51.36 and the  $MF_d$  for a contamination area of 10 acres would be 35.93. Then, using linear interpolation, the  $MF_d$  corresponding to an area of 8 acres is estimated to be about 41.

Equation (50) is used with Equation (51) to calculate an  $MF_d$  assuming that the contaminated area is located at the center of the solar energy facility. For cases where the

contaminated area is located at the edge of the facility, the calculation with Equation (51) can be bypassed, and the value of  $L$  can be used as  $L'$  in Equation (50) to obtain a more realistic  $MF_d$ .



## 5 UNCERTAINTIES, APPLICATIONS, AND MITIGATION MEASURES

This chapter provides discussions on the uncertainties associated with the general methodology, use of site-specific data to improve the precision of estimated results, applications of the methodology, and mitigation measures that can be applied to reduce potential exposures during construction/decommissioning of a solar facility.

### 5.1 UNCERTAINTIES AND USE OF SITE-SPECIFIC DATA

Conservative assumptions were adopted and used in the development of the general methodology. Each assumption involves a certain degree of uncertainty, and for some assumptions, the level of uncertainty can be reduced by using site-specific data to replace the generic values.

In general, the assumptions used in the methodology can be divided into four categories. The first category involves assumptions associated with the exposure patterns. The exposure parameters used in the methodology include soil ingestion rate (IRS), skin surface area (SA), and soil adherence factor (AF), all of which are used to determine the daily intake of chemicals. The generic values used for these parameters were primarily EPA default values for analogous types of receptors and activities considered. If the specific receptors and/or activities that would be associated with the exposures are known, the generic values can be replaced with more accurate and representative values that better reflect the exposure conditions. This is especially true for the exposures of facility workers.

The second type of uncertainty is associated with the generalization of site-specific conditions. Input parameters under this category include soil parameters that are used for estimating the emissions of volatile compounds—soil bulk density ( $\rho_b$ ), air-filled porosity ( $\theta_a$ ), water-filled porosity ( $\theta_w$ ), and total porosity ( $n$ )—and weather-related parameters that are used for estimating the emissions of particulates—vegetative cover ( $V$ ) and average wind speed ( $U_m$ ). These soil and weather-related parameters can be assigned site-specific values to improve the precision of the estimated results. Another parameter under this category is  $Q/C$ , the reciprocal of which quantifies the dispersion of the emitted particulate matter and volatile compounds. A larger  $Q/C$  value (smaller  $C/Q$ ) indicates more dispersion, resulting in a lower air concentration for the same emission quantity,  $Q$ . The value of  $Q/C$  is dependent on the meteorological conditions at the contaminated site and, therefore, different values would be assumed for different locations. The reference locations used by EPA were adopted in this methodology to obtain a smaller  $Q/C$  that would yield conservative (higher) estimates of exposure point concentrations. With the knowledge of the actual location of a contaminated site, the  $Q/C$  value can be replaced by a site-specific value. Furthermore, in the methodology, the  $Q/C$  value as developed by EPA for regular conditions (without soil-disturbing activities) is used for construction/decommissioning conditions. In reality, vehicular traffic during construction/decommissioning could enhance air dispersion. The level of enhancement depends on the frequency of vehicular traffic and the relative size of the area used for traffic compared to

the average area considered for the dispersion modeling. Mathematical modeling of this enhanced dispersion would rely on empirical data under similar conditions and would involve a large degree of uncertainty. Using the Q/C under regular conditions for analyses concerning the construction or decommissioning phase would produce more conservative (higher) estimates of the average exposure point concentrations (i.e., air concentrations) to which facility workers would be exposed. In addition to Q/C, the calculation of the distance modification factor,  $MF_d$ , also involves the use of generic assumptions. If site-specific meteorological data (i.e., joint-frequency data) are available, and the locations of offsite residents are known, site-specific  $MF_d$  can be calculated to reduce the uncertainty, and thus the conservatism, associated with using the generic values.

The third type of uncertainty is associated with the key assumption on which the general methodology is based, the daily soil disturbance area of 4 acres for construction based on data on construction duration for existing solar facilities (see Section 4.1.2). Overall, the use of an average daily soil disturbance area simplifies the complicated reality so that potential exposures can be modeled mathematically. In reality, construction or decommissioning activities could progress at different speeds from day to day and with average rates that differ from 4 acres per day. If the daily progress is greater than 4 acres, the total risk estimated with a 4-acre assumption would be an overestimation of the potential risk, because the number of exposure days during the construction phase would be overestimated; conversely, if the daily progress is less than 4 acres, the total risk estimated with a 4-acre assumption would be an underestimation. A simple adjustment would be to estimate the number of exposure days using the actual daily soil disturbance area for construction, and multiply this number with the daily risks estimated with a 4-acre assumption. To further improve the precision of the estimation, the value of Q/C and the activity level modification factor ( $MF_a$ ) can be calculated based on the actual daily soil disturbance area and used for daily risk calculation.

The last type of uncertainty is associated with the calculation of the activity-level modification factor,  $MF_a$ . Empirical mathematical models concerning material handling operations similar to the activities that would be conducted during construction/decommissioning of a solar energy facility were used to estimate the enhanced emissions of volatile compounds and particulate matters due to vigorous soil disturbance. Because the activities that would be conducted at a solar facility are not exactly the same as those assumed in the model, and the actual amount of materials that could be disturbed are unknown, the parameter values used for modeling the enhanced emission rates were selected relying on EPA's suggestion for Superfund remediation activities. For volatilization emissions, the amount of material handled was assumed to be twice the default value suggested by EPA (for volume of soil excavated,  $S_v$ , and for area of emission surface, SA) in order to consider soil disturbance from both grading and digging the contaminated soils. In the case where little grading is required in the actual contaminated area, the amount of soil handled would be reduced. Therefore, the generic value calculated for  $MF_a$  regarding volatilization may be reduced by half to better represent actual conditions. For particulate emissions, the generic value of  $MF_a$  also involves consideration of emissions from grading ( $ER_{grad}$ ). In the case where little grading is expected in a specific contaminated area, the value of  $MF_a$  may be reduced by considering only emissions from material transfer ( $ER_{trans}$ ). The level of uncertainty associated with the generic  $MF_a$  cannot be quantified without actual

measurement data on emissions. However, by adopting best management practices and planning construction or decommissioning activities in advance to reduce the amount and duration of material handling, emissions of particulates and volatile compounds can be controlled and reduced.

## 5.2 APPLICATIONS OF THE METHODOLOGY

In the methodology, the exposure of workers and the general public are considered to be chronic; as such, chronic toxicity values (for non-carcinogenic effects) are used to characterize the potential risks associated with exposures. This use of chronic toxicity values is justified for a large solar energy facility that requires more than one year to construct or decommission. For a smaller facility that can be completely constructed or decommissioned in less than a year, the use of sub-chronic toxicity values to assess potential risks may be more appropriate. In that situation, the general methodology can still be applied to evaluate the total sub-chronic risks incurred by construction/decommissioning workers, except that when calculating the SFSCs, the chronic toxicity values (RfDs and RfCs) would need to be replaced with sub-chronic toxicity values, and the averaging period (AT) of 365 days should be replaced with a value representative of the actual duration of construction/decommissioning.

Due to the significantly higher emissions of volatile compounds and particulate matter during construction/decommissioning in a contaminated area, potential daily exposure of workers could exceed the acute threshold values (i.e., acute RfC) if soil concentrations of contaminants are high and no PPE is utilized. Therefore, comparing daily exposures with the acute RfC may be necessary in addition to the comparison with chronic RfC values as presented in Chapter 4 of this report, in order to see whether daily exposure would exceed the acute threshold value. For this case, the daily risk (in terms of hazard index) during construction in the contaminated area could be calculated using the general methodology, except replacing the chronic toxicity values with appropriate acute values and setting the AT to 1 (day) when calculating the SFSCs. If the resulting daily risk (i.e., hazard index; by combining hazard quotients over all exposure pathways for a specific chemical), exceeds the value of 1, then there is a potential for daily exposure to exceed the acute threshold value. In that case, mitigation measures and/or use of PPE may need to be implemented during construction/decommissioning activities in the contaminated area to reduce the risk incurred by workers.

Measured soil concentrations are required for estimating the potential risks incurred by workers and the general public. The concentrations that represent the contamination situation at the beginning of each stage of solar energy development should be used to estimate the total risks for that stage, since the initial soil concentrations can be different for different stages. The change in soil concentration is not modeled by the general methodology, because the methodology does not perform dynamic modeling and conserve the mass of contaminants that distribute among different environmental media, a feature inherited from the SSL method. Concentrations of volatile chemicals could be reduced substantially after the construction phase. In Section 4.6.1.1, where the calculation of the activity-level modification factor ( $MF_a$ ) for volatile emissions is provided, a comparison of the upper bound emission rate corresponding to

the initial inventory ( $ER_{\max}$ ) (based on the assumption that the contamination depth is 2 m) with the estimated emission rate due to construction was provided. Similar comparisons can be made with actual depth of contamination to estimate the remaining quantity of volatile compounds in soil after construction. Aside from environmental transport (discussed in Chapter 3 of this report), other in-situ mechanisms, such as biodegradation, may also change and/or reduce the contaminant concentrations in soil. Nevertheless, using the soil concentrations obtained from site characterization prior to the development of a solar energy facility for risk assessment for each phase is judged to be a conservative approach (i.e., the total risks would be overestimated without adjusting the measured soil concentrations to account for loss or degradation of contaminants).

The general methodology developed in this report evaluates the daily risks associated with various activities by considering whether each activity would be performed within or outside of the contaminated area. Because of this breakdown in the risk calculation, the methodology can be applied to evaluate a contaminated site with multiple contaminated areas. The potential risks incurred outside the contaminated area(s) would result from air dispersion of contaminants released from the contaminated area(s). Therefore, when multiple contaminated areas are present, the impact incurred outside the contaminated areas would be the sum of the impacts associated with the releases from each contaminated area.

For modeling purposes, the contaminated area is assumed to be at the center of a solar energy facility. This assumption would maximize the estimated average air concentrations over the entire facility for use to assess potential exposures of workers. On the other hand, assuming the location of the contaminated area to be at the center of the site may overestimate the distance between an offsite resident and the contamination source, thereby underestimating the potential exposure to a member of the general public. In that case, the closest distance between the offsite resident and the edge of the solar energy facility ( $L$ ) can be used as  $L'$  in Equation (50) to obtain the value of the distance modification factor,  $MF_d$ , for use in the risk calculation.

### **5.3 MITIGATION MEASURES**

Due to the soil-disturbing activities that would be conducted during the construction/decommissioning phase, significantly higher exposures than those associated with regular, non-soil-disturbing activities could be incurred by construction/decommissioning workers. Common mitigation measures (e.g., spraying with water and best management practices for reducing fugitive dust emissions) can be applied to reduce the potential chemical exposures. In addition, because the area of contamination would be much smaller than the entire footprint of the solar energy facility, advance planning can make sure that trucks and other vehicles avoid driving through contaminated areas when these areas are not involved in construction/decommissioning. For contaminated sites with VOC or semi-VOC contamination, a mitigation measure could be to start the construction/decommissioning in the contaminated area, because the amount of VOCs or semi-VOCs could be reduced substantially after construction, and the exposures that would be incurred in the non-contaminated area could be greatly reduced afterward.

## 6 CONCLUSIONS

As discussed in previous chapters, there are a number of formerly used environmentally contaminated sites in the United States that may provide suitable sites for utility-scale solar facilities per the study undertaken by EPA and NREL under the RE-Powering America's Land Initiative (EPA 2013d,e). Developing these sites may result in fewer environmental impacts than developing on previously undisturbed lands and, importantly, many of the contaminated sites have existing infrastructure and access to transmission and transportation corridors. Potential human health risks for workers and the general public associated with the construction and operation of solar facilities on a contaminated site need to be assessed prior to development. If risks are present, additional remediation or the implementation of protective measures may be needed. This report presents a methodology that can be used to preliminarily assess the potential risks associated with developing a solar energy facility at a contaminated site, based on potential exposures to contaminants in soils (including transport of those contaminants into the air).

Although this methodology was initially developed on the basis of information available for and conditions present at contaminated sites in six southwestern states (Arizona, California, Colorado, Nevada, New Mexico, and Utah), due to the general approach and conservative assumptions used, it is anticipated that the methodology can also be applied to evaluate contaminated sites in other parts of the country. However, the consideration of additional pathways related to potential release of chemicals to an underlying groundwater aquifer would likely need to be included if the contaminated site is located in a wet area.

The methodology described in this report follows EPA guidance on human health risk assessment for exposures to hazardous chemicals (EPA 1989) and utilizes the generic RSLs (EPA 2013b,c) developed by EPA to simplify calculations. A clear understanding of these potential risks is needed to evaluate the feasibility of developing a particular contaminated site, the need for further site remediation and/or use of protective measures, and the associated economic impacts to a project. To allow implementation in the initial evaluation of a site, the methodology requires only a limited number of site-specific parameters critical to the determination of potential human health risk. To account for uncertainty related to the solar energy development activities or site-specific conditions, which may not be known at an early stage, generic conservative assumptions were adopted to set the values of less critical parameters so that potential human health risks would not be underestimated. As such, the calculation results obtained with the methodology should be treated as screening estimates. A calculated hazard index greater than 1 or a cancer risk of more than  $10^{-6}$  obtained using this methodology does not necessarily mean that unacceptable human health risks would result from utility-scale solar energy development on a specific contaminated site. Instead, the exceedance of the target risk levels indicates that a more precise analysis is required with either the use of more site-specific data or use of a more realistic, and more complicated, model. The actual risks could be much lower than those estimated by the methodology because the protection provided by implementation of best management practices or the use of personal protective equipment was not factored into the methodology. On the other hand, a calculated hazard index of less than 1 or a cancer risk of less than  $10^{-6}$  does imply that, most likely, the development of a utility-scale

solar energy facility on a specific contaminated site would not result in unacceptable human health risks; therefore, a more detailed, site-specific analysis would likely not be required.

## 7 REFERENCES

BLM (Bureau of Land Management), 2010a, *Plan Amendment/Final EIS for the Blythe Solar Power Project*, August. Available at [http://www.blm.gov/ca/st/en/fo/palmsprings/Solar\\_Projects/Blythe\\_Solar\\_Power\\_Project.html](http://www.blm.gov/ca/st/en/fo/palmsprings/Solar_Projects/Blythe_Solar_Power_Project.html).

BLM, 2010b, *Draft Environmental Impact Statement for the Silver State Solar Energy Project*, NVN-085077, Las Vegas Field Office. Available at [http://www.blm.gov/pgdata/etc/medialib/blm/nv/field\\_offices/las\\_vegas\\_field\\_office/energy/nextlight\\_silver\\_state12.Par.0314.File.dat/Silver\\_State\\_Solar\\_Project\\_DEIS.pdf](http://www.blm.gov/pgdata/etc/medialib/blm/nv/field_offices/las_vegas_field_office/energy/nextlight_silver_state12.Par.0314.File.dat/Silver_State_Solar_Project_DEIS.pdf).

BLM, 2010c, *California Desert Conservation Area Plan Amendment/Final Environmental Impact Statement for Ivanpah Solar Electric Generating System*, FEIS-10-31, July. Available at [http://www.blm.gov/pgdata/etc/medialib/blm/ca/pdf/needles/lands\\_solar.Par.19048.File.dat/1-CDCA-Ivanpah-Final-EIS.pdf](http://www.blm.gov/pgdata/etc/medialib/blm/ca/pdf/needles/lands_solar.Par.19048.File.dat/1-CDCA-Ivanpah-Final-EIS.pdf).

BLM, 2010d, *Plan Amendment/Final EIS for the Genesis Solar Energy Project*, FES 10-42, BLM/CA/ES-2010-016+1793, August. Available at [http://www.blm.gov/ca/st/en/fo/palmsprings/Solar\\_Projects/Genesis\\_Ford\\_Dry\\_Lake.html](http://www.blm.gov/ca/st/en/fo/palmsprings/Solar_Projects/Genesis_Ford_Dry_Lake.html).

BLM, 2010e, *Final Environmental Impact Statement for the Amargosa Farm Road Solar Energy Project*, NVN-084359, BLM/NV/PA/ES-10/16+1793, Pahrump Field Office, October. Available at [http://www.blm.gov/nv/st/en/fo/lvfo/blm\\_programs/energy/proposed\\_solar\\_millennium/final\\_eis.html](http://www.blm.gov/nv/st/en/fo/lvfo/blm_programs/energy/proposed_solar_millennium/final_eis.html).

BLM, 2011, *Desert Sunlight Solar Farm Project California Desert Conservation Area Plan Amendment and Final Environmental Impact Statement*, CACA # 48649, April. Available at [http://www.blm.gov/ca/st/en/fo/palmsprings/Solar\\_Projects/Desert\\_Sunlight.html](http://www.blm.gov/ca/st/en/fo/palmsprings/Solar_Projects/Desert_Sunlight.html).

BLM and DOE (BLM and U.S. Department of Energy), 2012, *Final Programmatic Environmental Impact Statement for Solar Energy Development in Six Southwestern States*, FES 12-24, DOE/EIS-0403, July.

Calico Solar, LLC, 2011, *Plan of Development Calico Solar Project San Bernardino County, California*, March. Available at [http://www.blm.gov/pgdata/etc/medialib/blm/ca/pdf/Barstow/calico\\_feis.Par.21270.File.dat/Calico%20Final%20Version%20POD%20\(2011-03-28\)%5b2%5d.pdf](http://www.blm.gov/pgdata/etc/medialib/blm/ca/pdf/Barstow/calico_feis.Par.21270.File.dat/Calico%20Final%20Version%20POD%20(2011-03-28)%5b2%5d.pdf).

Cowherd, C., G. Muleski, P. Engelhart, and D. Gillette, 1985, *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination*, EPA/600/8-85/002, prepared for U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC.

EPA (U.S. Environmental Protection Agency), 1989, *Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), Interim Guidance*, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, DC.

EPA, 1993, *Air/Superfund National Technical Guidance Study Series*, EPA-451/R-93-001, Office of Air Quality Planning and Standards, Research Triangle Park, NC, March.

EPA, 1995a, *SCREEN3 Model User's Guide*, EPA-454/B-95-004, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, NC, September.

EPA, 1995b, *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume I – User Instruction*, EPA-454/B-95-003a, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, NC, September.

EPA, 1995c, *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume II – Description of Model Algorithms*, EPA-454/B-95-003b, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, NC, September.

EPA, 1996a, *Soil Screening Guidance: User's Guide*, Second Edition, EPA/540/R—96/018, Office of Solid Waste and Emergency Response, Washington, DC, July.

EPA, 1996b, *Soil Screening Guidance: Technical Background Document*, EPA/540/R95/128, Office of Solid Waste and Emergency Response, Washington, DC, May.

EPA, 1997, *Exposure Factors Handbook, Update to Exposure Factors Handbook*, EPA/600/8-89/043 – May 1989, EPA/600/P-95/002Fa,b&c, Office of Research and Development, National Center for Environmental Assessment, Washington, D.C., August.

EPA, 2002, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*, OSWER 9355.4-24, Office of Emergency and Remedial Response, Washington, DC, December.

EPA, 2010, *Renewable Energy Interactive Mapping Tool*. Available at [http://www.epa.gov/renewableenergyland/mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/mapping_tool.htm). Accessed Summer 2012.

EPA, 2013a, *Handbook on Siting Renewable Energy Projects While Addressing Environmental Issues*, Office of Solid Waste and Emergency Response's Center for Program Analysis. Available at [http://www.epa.gov/renewableenergyland/docs/handbook\\_siting\\_repowering\\_projects.pdf](http://www.epa.gov/renewableenergyland/docs/handbook_siting_repowering_projects.pdf). Accessed Aug. 12, 2013.

EPA, 2013b, *Generic Tables*. Available at [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration\\_table/Generic\\_Tables/index.htm](http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Accessed Aug. 9. 2013.

EPA, 2013c, *User's Guide*. Available at [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration\\_table/usersguide.htm](http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm). Accessed Aug. 9, 2013.

EPA, 2013d, *Data Documentation for Mapping and Screening Criteria for Renewable Energy Potential on EPA and State Tracked Sites RE-Powering America's Land Initiative*, updated July 2013, produced by Office of Solid Waste and Emergency Response, Center for Program Analysis. Available at [http://www.epa.gov/renewableenergyland/rd\\_mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm). Accessed Aug. 13, 2013.

EPA, 2013e, *RE-Powering Screening Dataset*. Available at [http://www.epa.gov/renewableenergyland/rd\\_mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm). Accessed Aug. 12, 2013.

EPA, 2013f, *RE-Powering America's Land: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites, Solar Technologies*. Available at [http://www.epa.gov/renewableenergyland/docs/repower\\_technologies\\_solar.pdf](http://www.epa.gov/renewableenergyland/docs/repower_technologies_solar.pdf). Accessed Aug. 12, 2013.

EPA, 2013g, RE-Powering America's Land Initiative, *Renewable Energy Projects on Potentially Contaminated Lands, Landfills, and Mine Sites*. Available at [http://www.epa.gov/renewableenergyland/docs/tracking\\_matrix.pdf](http://www.epa.gov/renewableenergyland/docs/tracking_matrix.pdf). Accessed Aug. 12, 2013.

EPA, 2013h, Mapping and Screening Tools, RE-Powering Mapper. Available at [http://www.epa.gov/renewableenergyland/rd\\_mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm). Accessed Aug. 12, 2013.



**APPENDIX A**

**DEMONSTRATION OF APPLICATION OF  
THE GENERAL METHODOLOGY**



## APPENDIX A

### DEMONSTRATION OF APPLICATION OF THE GENERAL METHODOLOGY

This appendix provides an example demonstrating the application of the general methodology described in Chapter 4 of this report. The general methodology was developed to provide preliminary estimates of the potential human health risks associated with developing utility-scale solar energy facilities on contaminated sites for screening purposes. In the demonstration, step-by-step guidance is provided to obtain estimates of the potential risks to construction workers, operation workers, and members of the offsite general public living close to a hypothetical contaminated site during construction and operation of a solar energy facility. Potential risks associated with decommissioning a solar energy facility would be expected to be similar to or less than those associated with constructing the facility because the soil concentrations of chemicals in the contaminated area would decrease over the course of the construction and operation phases.

The step-by-step guidance provided in this appendix is intended for use by risk assessors who would be required to perform the assessment of potential human health risks associated with chemical contamination in a contaminated site. The calculation of modification factors for adjusting the regional screening levels (RSLs) to obtain the solar facility soil concentration limits (SFSCSLs) is essential in the implementation of the general methodology; therefore, it is suggested that risk assessors read Chapter 4 of this report, including Sections 4.2–4.7, to acquire understanding of the development of modification factors before following the guidance presented in this appendix.

#### A.1 ASSUMPTIONS FOR THE CONTAMINATED SITE

It is assumed that a hypothetical site has passed the preliminary screening for utility-scale solar energy development by the Environmental Protection Agency (EPA) and National Renewable Energy Laboratory (NREL) under the RE-Powering America's Land initiative (EPA 2013a,b). The site covers about 2,000 acres and includes an area at the center that is contaminated by chemicals from past industrial activities. After preliminary surveys and environmental sampling, it is determined that the chemical contamination is limited to surface and subsurface soils to a depth of about 0.3 m (1ft). The area of contamination is estimated to be about 10 acres, with chloroform, dieldrin, and cadmium being the primary contaminants of concern (COCs). On the basis of sampling data, the 95th-percentile values of soil concentrations are estimated to be 0.29 mg/kg, 0.03 mg/kg, and 1,800 mg/kg for the three chemicals, respectively. There is no residence in the immediate surroundings of the site; the closest residence is located at a distance of 1,000 m from the site boundary.

The initial plan for the solar energy facility is that it will be operated for 30 yr to generate energy to support industrial development of nearby communities.

## **A.2 IMPLEMENTATION OF THE RISK ASSESSMENT METHODOLOGY**

### **A.2.1 Obtain Information on Volatility and Toxicity Values of COCs**

With the area of contamination and soil concentrations known from site survey data, the next step is to determine whether the COCs would volatilize under ambient conditions and to obtain information on the potential health effects (carcinogenic versus non-carcinogenic) these chemicals can cause, and their toxicity values. If a chemical is a volatile organic compound (VOC) or semi-VOC, potential exposure could result from inhalation of the gaseous form. For a carcinogen, toxicity values are usually expressed in terms of unit risk for inhalation exposure and slope factor for ingestion exposure. To quantify non-carcinogenic risks, toxicity values in terms of reference concentration (for inhalation) and reference dose (for ingestion) should be obtained.

The RSL tables available online (EPA 2013c) contain information on volatility and toxicity values for more than 700 hazardous chemicals. There are several RSL tables, each containing soil screening limits derived by EPA for specific exposure scenarios and contaminated media.<sup>1</sup> To implement the risk assessment methodology presented in this report, the traditional composite table that includes RSLs for all the exposure scenarios and contaminated media considered by EPA is required. The composite table consists of eight spreadsheets. The second and the third spreadsheets list RSLs for the standard resident and industrial worker scenario for soil contamination. These RSLs are needed to obtain the solar facility soil screening limits (SFSCSLs) for a utility-scale solar energy facility.

Table A-1 lists the volatility and toxicity information obtained from the RSL tables for the three COCs in this example. Chloroform is a VOC, while dieldrin and cadmium are not. All three chemicals can cause both carcinogenic and non-carcinogenic effects; however, the carcinogenic effect caused by cadmium is primarily through inhalation exposure, and the non-carcinogenic effect caused by dieldrin is primarily through ingestion exposure.

### **A.2.2 Obtain RSLs Developed by EPA**

The composite table downloaded from the EPA Web site (EPA 2013c), as described in the preceding section, contains the RSLs for the standard industrial worker and resident scenarios for soil contamination. Tables A-2 and A-3 list the RSLs associated with an individual exposure pathway and all pathways combined for the three COCs; they were derived with a target cancer risk of  $1 \times 10^{-6}$  or a hazard quotient of 1 using the SSL equations discussed in Chapter 4. The RSLs for all pathways combined are listed in the tables for reference only; they are not needed for obtaining the SFSCSLs. Individual pathway RSLs for a specific chemical were derived only for the exposure pathways that have associated toxicity values. In general, an exposure pathway

---

<sup>1</sup> The tables are presented in both PDF and Excel format. Excel format is recommended when downloading the RSL tables, because calculation with the RSLs can be easily performed using the Excel spreadsheets.

**TABLE A-1 Volatility and Toxicity Values of COCs**

Chemical of Concern	VOC	Toxicity values			
		Carcinogenic		Non-carcinogenic	
		SFO (mg/kg-day) <sup>-1</sup>	IUR (µg/m <sup>3</sup> ) <sup>-1</sup>	RfD <sub>o</sub> (mg/kg-day)	RfC <sub>i</sub> (mg/m <sup>3</sup> )
Chloroform	Yes	0.031	0.000023	0.01	0.098
Dieldrin	No	16	0.0046	0.00005	NA
Cadmium	No	NA	0.0018	0.001	0.00001

Notes: SFO—oral slope factor; IUR—inhalation unit risk; RfD<sub>o</sub>—oral reference dose; RfC<sub>i</sub>—inhalation reference concentration.

**TABLE A-2 RSLs (mg/kg) Corresponding to a Target Cancer Risk of  $1 \times 10^{-6}$**

Receptor & Chemical	Exposure Pathway				
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption	All Pathways
<i>Workers</i>					
Chloroform	92	1.5			1.5
Dieldrin	0.18		3,600	0.27	0.11
Cadmium			9,300		9,300
<i>Residents</i>					
Chloroform	21	0.3			0.29
Dieldrin	0.04		720	0.13	0.03
Cadmium			1,800		1,800

**TABLE A-3 RSLs (mg/kg) Corresponding to a Target Hazard Quotient of 1**

Receptor & Chemical	Exposure Pathway				All Pathways
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption	
<i>Workers</i>					
Chloroform	10,000	1,200			1,100
Dieldrin	51			77	31
Cadmium	1,000		60,000	3,900	800
<i>Residents</i>					
Chloroform	780	290			210
Dieldrin	3.9			14	3.1
Cadmium	78		14,000	700	70

that does not have an associated toxicity value as listed in the RSL tables can be omitted from evaluation, because potential health risk would be dominated by exposures through other pathways. If the chemical is a VOC, the inhalation RSL is derived accounting for exposure through the inhalation of volatile pathway. Otherwise, the inhalation RSL is derived accounting for exposure through the inhalation of particulate pathway.

### A.2.3 Determine the Values of $MF_a$ and $MF_d$

The modification factor for activity level,  $MF_a$ , is needed to account for enhancement of the particulate or volatile emissions from contaminated soils due to construction in the contaminated area.  $MF_a$  for volatile emissions can be calculated with Equation (48) in Section 4.6.1.3, with the use of the  $MF_a'$  values listed in Table 4-45. The  $MF_a$  for volatile emissions is chemical-specific and depends on the area of contamination,  $A_{cont}$ , which is 10 acres in this example. The  $MF_a$  for particulate emission can be calculated with Equation (48) in Section 4.6.2.3 and is also dependent on  $A_{cont}$ . The “Z” factor required for the calculation is 1 for most chemicals, except for a few metals, for which the “Z” factor is listed in Table 4-46. For cadmium, the Z-factor is 1.31. Table A-4 lists the modification factors,  $MF_a$ , for the three COCs in this example.

The modification factor for exposure distance,  $MF_d$ , is used to adjust the air concentration above the contaminated area to obtain the average air concentration over the entire solar energy facility, or the air concentration at an offsite location. The average air concentration over the entire solar facility is needed for evaluating potential exposures of facility workers, while the air concentration at an offsite location is needed for evaluating potential exposures of an offsite resident. Equation (55) can be used to obtain  $MF_d$  for assessing worker exposures; the  $MF_d$  is a function of the entire footprint of the solar energy facility ( $A_{total}$ , 2,000 acres) and the area of contamination ( $A_{cont}$ ). To obtain  $MF_d$  for assessing offsite resident exposures, Equations (50) and (51) and Table 4-47 should be used. The  $MF_d$  is a function of  $A_{total}$  and  $A_{cont}$ , as well as the

**TABLE A-4 Modification Factor for Activity Level (MF<sub>a</sub>) and Modification Factor for Exposure Distance (MF<sub>d</sub>)**

Modification Factor	Sub-category	Chloroform	Dieldrin	Cadmium
MF <sub>a</sub>	Emission of volatile	18.00	1.00	1.00
	Emission of particulate	28.00	28.00	36.68
MF <sub>d</sub>	Worker exposure	5.24	5.24	5.24
	Offsite resident exposure	35.93	35.93	35.93

distance between the offsite residence and the solar energy facility, L. The values of MF<sub>d</sub> for the three COCs in this example are also listed in Table A-4.

#### **A.2.4 Calculate the Composite Modification Factors**

The evaluation of potential human health risks associated with the development of a utility-scale solar energy facility can be accomplished by using SFSCFs, which are soil concentration limits accounting for 1-day exposure of a facility worker or offsite resident resulting from ongoing construction or operational activities within the solar energy facility. The SFSCFs can be obtained by modifying the RSLs developed by EPA. Tables 4-1 through 4-44 provide instructions on the calculation of the overall modification factors, which are equivalent to  $MF_e \times MF_d / MF_a$ , where MF<sub>e</sub> is the modification factor for exposure pattern. After going through the tables one by one, the modification factors calculated can be summarized in Tables A.5–A.8. The modification factor for activity level (MF<sub>a</sub>) and modification factor for exposure distance (MF<sub>d</sub>) from Table A-4 can be used to obtain the overall modification factor. When a receptor is located outside the contaminated area, exposure to a chemical through the direct soil ingestion and dermal absorption pathways would be negligible as discussed in Chapter 4; in that situation, no modification factors are listed for the two exposure pathways.

#### **A.2.5 Modify RSLs to Get SFSCLs**

The SFSCLs required for assessing potential risks that could be incurred by workers of a solar energy facility and offsite residents of the facility can be obtained by multiplying the RSLs for individual pathways with the corresponding overall modification factors, MFs. The RSLs for the standard industrial worker scenario should be used to obtain SFSCLs for solar energy facility workers, and the RSLs for the standard resident scenario should be used to obtain SFSCLs for offsite residents in the surrounding area. Tables A-9 through A-12 list the SFSCLs obtained with the multiplications.

**TABLE A-5 Modification Factors for Use to Adjust RSLs to Obtain SFSCSLs Concerning Carcinogenic Risks Incurred by Workers**

Modification Factor	Exposure Pathway			
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption
<i>Construction in the contaminated area</i>				
MF <sub>e</sub>	1,894	24.07	2,200	4,167
MF <sub>d</sub>	1.00	1.00	1.00	1.00
MF <sub>a</sub>	1.00	chloroform: 18 dieldrin: 1 cadmium: 1	chloroform: 28 dieldrin: 28 cadmium: 36.68	1.00
MF	1,894	chloroform: 1.34 dieldrin: 24.07 cadmium: 24.07	chloroform: 78.57 dieldrin: 78.57 cadmium: 59.98	4,167
<i>Construction in the non-contaminated area</i>				
MF <sub>e</sub>	NA <sup>a</sup>	969.3	1,898	NA
MF <sub>d</sub>	NA	5.24	5.24	NA
MF <sub>a</sub>	NA	1.00	1.00	NA
MF	NA	5,078	9,945	NA
<i>Operation in the contaminated area</i>				
MF <sub>e</sub>	12,500	3,754	2,531	12,500
MF <sub>d</sub>	1	1.00	1.00	1.00
MF <sub>a</sub>	1	1.00	1.00	1.00
MF	12,500	3,754	2,531	12,500
<i>Operation in the non-contaminated area</i>				
MF <sub>e</sub>	NA	3,754	2,543	NA
MF <sub>d</sub>	NA	5.24	5.24	NA
MF <sub>a</sub>	NA	1.00	1.00	NA
MF	NA	19,668	13,321	NA

<sup>a</sup> NA = Not applicable.

**TABLE A-6 Modification Factors for Use to Adjust RSLs to Obtain SFSCs Concerning Non-carcinogenic Risks Incurred by Workers**

Modification Factor	Exposure Pathway			
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption
<i>Construction in the contaminated area</i>				
MF <sub>e</sub>	75.76	0.96	88.00	166.7
MF <sub>d</sub>	1.00	1.00	1.00	1.00
MF <sub>a</sub>	1.00	chloroform: 18 dieldrin: 1 cadmium: 1	chloroform: 28 dieldrin: 28 cadmium: 36.68	1.00
MF	75.76	chloroform: 0.05 dieldrin: 0.96 cadmium: 0.96	chloroform: 3.14 dieldrin: 3.14 cadmium: 2.40	166.7
<i>Construction in the non-contaminated area</i>				
MF <sub>e</sub>	NA <sup>a</sup>	27.42	75.93	NA
MF <sub>d</sub>	NA	5.24	5.24	NA
MF <sub>a</sub>	NA	1.00	1.00	NA
MF	NA	143.6	397.8	NA
<i>Operation in the contaminated area</i>				
MF <sub>e</sub>	500	27.42	101.2	500.0
MF <sub>d</sub>	1	1.00	1.00	1.00
MF <sub>a</sub>	1	1.00	1.00	1.00
MF	500	27.42	101.2	500.0
<i>Operation in the non-contaminated area</i>				
MF <sub>e</sub>	NA	27.42	101.2	NA
MF <sub>d</sub>	NA	5.24	5.24	NA
MF <sub>a</sub>	NA	1.00	1.00	NA
MF	NA	143.6	530	NA

<sup>a</sup> NA = Not applicable.

**TABLE A-7 Modification Factors for Use to Adjust RSLs to Obtain SFSCs Concerning Carcinogenic Risks Incurred by Offsite Residents**

Modification Factor	Exposure Pathway	
	Inhalation of Volatile	Inhalation of Particulate
<i>Construction in the contaminated area</i>		
MF <sub>e</sub>	122.6	11,200
MF <sub>d</sub>	35.93	35.93
MF <sub>a</sub>	chloroform: 18 dieldrin: 1 cadmium: 1	chloroform: 28 dieldrin: 28 cadmium: 36.68
MF	chloroform: 245 dieldrin: 4,403 cadmium: 4,403	chloroform: 11,270,000 dieldrin: 11,270,000 cadmium: 14,760,000
<i>Construction in the non-contaminated area</i>		
MF <sub>e</sub>	1,628	3,189
MF <sub>d</sub>	35.93	35.93
MF <sub>a</sub>	1.00	1.00
MF	58,510	114,600
<i>Operation</i>		
MF <sub>e</sub>	6,307	4,252
MF <sub>d</sub>	35.93	35.93
MF <sub>a</sub>	1.00	1.00
MF	226,600	152,800

**TABLE A-8 Modification Factors for Use to Adjust RSLs to Obtain SFSCSLs Concerning Non-carcinogenic Risks Incurred by Offsite Residents**

Modification Factor	Exposure Pathway	
	Inhalation of Volatile	Inhalation of Particulate
<i>Construction in the contaminated area</i>		
MF <sub>e</sub>	4.08	373.3
MF <sub>d</sub>	35.93	35.93
MF <sub>a</sub>	chloroform: 18 dieldrin: 1 cadmium: 1	chloroform: 28 dieldrin: 28 cadmium: 36.68
MF	chloroform: 8.15 dieldrin: 146.8 cadmium: 146.8	chloroform: 479 dieldrin: 479 cadmium: 366
<i>Construction in the non-contaminated area</i>		
MF <sub>e</sub>	38.38	106.3
MF <sub>d</sub>	35.93	35.93
MF <sub>a</sub>	1.00	1.00
MF	1,379	3,819
<i>Operation</i>		
MF <sub>e</sub>	38.38	141.7
MF <sub>d</sub>	35.93	35.93
MF <sub>a</sub>	1.00	1.00
MF	1,379	5,092

**TABLE A-9 SFSCs (mg/kg) Based on Carcinogenic Risk Incurred by Workers**

Chemical	Exposure Pathway			
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption
<i>Construction in the contaminated area</i>				
Chloroform	1.74E+05	2.01E+00	NA <sup>a</sup>	NA
Dieldrin	3.41E+02	NA	2.83E+05	1.13E+03
Cadmium	NA	NA	5.58E+05	NA
<i>Construction in the non-contaminated area</i>				
Chloroform	NA	7.62E+03	NA	NA
Dieldrin	NA	NA	3.58E+07	NA
Cadmium	NA	NA	9.25E+07	NA
<i>Operation in the contaminated area</i>				
Chloroform	1.15E+06	5.63E+03	NA	NA
Dieldrin	2.25E+03	NA	9.11E+06	3.38E+03
Cadmium	NA	NA	2.35E+07	NA
<i>Operation in the non-contaminated area</i>				
Chloroform	NA	2.95E+04	NA	NA
Dieldrin	NA	NA	4.80E+07	NA
Cadmium	NA	NA	1.24E+08	NA

<sup>a</sup> NA = Not applicable; either potential exposure is negligible or RSL is not available.

**TABLE A-10 SFSCSLs (mg/kg) Based on Non-carcinogenic Risk Incurred by Workers**

Chemical	Exposure Pathway			
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption
<i>Construction in the contaminated area</i>				
Chloroform	7.58E+05	6.42E+01	NA <sup>a</sup>	NA
Dieldrin	3.86E+03	NA	NA	1.28E+04
Cadmium	7.58E+04	NA	1.44E+05	6.50E+05
<i>Construction in the non-contaminated area</i>				
Chloroform	NA	1.72E+05	NA	NA
Dieldrin	NA	NA	NA	NA
Cadmium	NA	NA	2.39E+07	NA
<i>Operation in the contaminated area</i>				
Chloroform	5.00E+06	3.29E+04	NA	NA
Dieldrin	2.55E+04	NA	NA	3.85E+04
Cadmium	5.00E+05	NA	6.07E+06	1.95E+06
<i>Operation in the non-contaminated area</i>				
Chloroform	NA	1.72E+05	NA	NA
Dieldrin	NA	NA	NA	NA
Cadmium	NA	NA	3.18E+07	NA

<sup>a</sup> NA = Not applicable; either potential exposure is negligible or RSL is not available.

**TABLE A-11 SFSCs (mg/kg) Based on Carcinogenic Risk Incurred by Offsite Residents**

Chemical	Exposure Pathway	
	Inhalation of Volatile	Inhalation of Particulate
<i>Construction in the contaminated area</i>		
Chloroform	7.34E+01	NA <sup>a</sup>
Dieldrin	NA	8.11E+09
Cadmium	NA	2.66E+10
<i>Construction in the non-contaminated area</i>		
Chloroform	1.76E+04	NA
Dieldrin	NA	8.25E+07
Cadmium	NA	2.06E+08
<i>Operation</i>		
Chloroform	6.80E+04	NA
Dieldrin	NA	1.10E+08
Cadmium	NA	2.75E+08

<sup>a</sup> NA = Not applicable; either potential exposure is negligible or RSL is not available.

**TABLE A-12 SFSCs (mg/kg) Based on Non-carcinogenic Risk Incurred by Offsite Residents**

Chemical	Exposure Pathway	
	Inhalation of Volatile	Inhalation of Particulate
<i>Construction in the contaminated area</i>		
Chloroform	2.36E+03	NA <sup>a</sup>
Dieldrin	NA	NA
Cadmium	NA	5.12E+06
<i>Construction in the non-contaminated area</i>		
Chloroform	4.00E+05	NA
Dieldrin	NA	NA
Cadmium	NA	5.35E+07
<i>Operation</i>		
Chloroform	4.00E+05	NA
Dieldrin	NA	NA
Cadmium	NA	7.13E+07

<sup>a</sup> NA = Not applicable; either potential exposure is negligible or RSL is not available.

## A.2.6 Convert SFSCs to Daily Risks

The SFSCs are soil concentration limits accounting for potential exposure to COCs in a single day and corresponding to a target cancer risk of  $1 \times 10^{-6}$  or a target hazard quotient of 1. Therefore, potential daily risks (risks incurred in a single day) associated with exposure to a COC in the contaminated area can be calculated by taking the ratio between the measured soil concentration of the COC and its SFSC, then multiplying the ratio with the target risk level. This conversion from an SFSC to a daily risk is described in Equations (1) and (2) in Section 4.1.4. The soil concentrations assumed in this example are 0.29 mg/kg for chloroform, 0.03 mg/kg for dieldrin, and 1,800 mg/kg for cadmium. Tables A.13–A.16 list the daily risks obtained from the conversions. Potential risks for all pathways are the sums of the risks from individual pathways.

**TABLE A-13 Carcinogenic Risks from One-day Exposure—Workers**

Chemical	Exposure Pathway				
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption	All Pathways
<i>Construction in the contaminated area</i>					
Chloroform	1.66E-12	1.45E-07	0.00E+00	0.00E+00	1.45E-07
Dieldrin	8.80E-11	0.00E+00	1.06E-13	2.67E-11	1.15E-10
Cadmium	0.00E+00	0.00E+00	3.23E-09	0.00E+00	3.23E-09
<i>Construction in the non-contaminated area</i>					
Chloroform	0.00E+00	3.81E-11	0.00E+00	0.00E+00	3.81E-11
Dieldrin	0.00E+00	0.00E+00	8.38E-16	0.00E+00	8.38E-16
Cadmium	0.00E+00	0.00E+00	1.95E-11	0.00E+00	1.95E-11
<i>Operation in the contaminated area</i>					
Chloroform	2.52E-13	5.15E-11	0.00E+00	0.00E+00	5.18E-11
Dieldrin	1.33E-11	0.00E+00	3.29E-15	8.89E-12	2.22E-11
Cadmium	0.00E+00	0.00E+00	7.65E-11	0.00E+00	7.65E-11
<i>Operation in the non-contaminated area</i>					
Chloroform	0.00E+00	9.83E-12	0.00E+00	0.00E+00	9.83E-12
Dieldrin	0.00E+00	0.00E+00	6.26E-16	0.00E+00	6.26E-16
Cadmium	0.00E+00	0.00E+00	1.45E-11	0.00E+00	1.45E-11

**TABLE A-14 Hazard Quotients from One-day Exposure—Workers**

Chemical	Exposure Pathway				
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption	All Pathways
<i>Construction in the contaminated area</i>					
Chloroform	3.83E-07	4.52E-03	0.00E+00	0.00E+00	4.52E-03
Dieldrin	7.76E-06	0.00E+00	0.00E+00	2.34E-06	1.01E-05
Cadmium	2.38E-02	0.00E+00	1.25E-02	2.77E-03	3.90E-02
<i>Construction in the non-contaminated area</i>					
Chloroform	0.00E+00	1.68E-06	0.00E+00	0.00E+00	1.68E-06
Dieldrin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	0.00E+00	7.54E-05	0.00E+00	7.54E-05
<i>Operation in the contaminated area</i>					
Chloroform	5.80E-08	8.81E-06	0.00E+00	0.00E+00	8.87E-06
Dieldrin	1.18E-06	0.00E+00	0.00E+00	7.79E-07	1.96E-06
Cadmium	3.60E-03	0.00E+00	2.96E-04	9.23E-04	4.82E-03
<i>Operation in the non-contaminated area</i>					
Chloroform	0.00E+00	1.68E-06	0.00E+00	0.00E+00	1.68E-06
Dieldrin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	0.00E+00	5.66E-05	0.00E+00	5.66E-05

**TABLE A-15 Carcinogenic Risks from One-day Exposure—Residents**

Chemical	Exposure Pathway		
	Inhalation of Volatile	Inhalation of Particulate	All Pathways
<i>Construction in the contaminated area</i>			
Chloroform	3.95E-09	0.00E+00	3.95E-09
Dieldrin	0.00E+00	3.70E-18	3.70E-18
Cadmium	0.00E+00	6.78E-14	6.78E-14
<i>Construction in the non-contaminated area</i>			
Chloroform	1.65E-11	0.00E+00	1.65E-11
Dieldrin	0.00E+00	3.64E-16	3.64E-16
Cadmium	0.00E+00	8.73E-12	8.73E-12
<i>Operation</i>			
Chloroform	4.27E-12	0.00E+00	4.27E-12
Dieldrin	0.00E+00	2.73E-16	2.73E-16
Cadmium	0.00E+00	6.55E-12	6.55E-12

**TABLE A-16 Hazard Quotients from One-day Exposure—Residents**

Chemical	Exposure Pathway		All Pathways
	Inhalation of Volatile	Inhalation of Particulate	
<i>Construction in the contaminated area</i>			
Chloroform	1.23E-04	0.00E+00	1.23E-04
Dieldrin	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	3.52E-04	3.52E-04
<i>Construction in the non-contaminated area</i>			
Chloroform	7.25E-07	0.00E+00	7.25E-07
Dieldrin	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	3.37E-05	3.37E-05
<i>Operation</i>			
Chloroform	7.25E-07	0.00E+00	7.25E-07
Dieldrin	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	2.52E-05	2.52E-05

### A.2.7 Determine the Exposure Durations in Days

The daily risks obtained in the previous step should be multiplied by the duration of activities to obtain the risks that could be incurred during the entire course of each activity. The duration of exposure during construction can be estimated using the sizes of the contaminated area and the entire solar energy facility, on the basis of the assumption that the average daily progress of construction is 4 acres per day. The durations used to estimate carcinogenic risk and non-carcinogenic risk associated with each activity could be different. For carcinogenic risk, all days of exposure should be counted, even though they may spread across multiple years; for non-carcinogenic risk, only the days of exposure during the first year should be counted. Table A.17 lists the exposure durations associated with different activities for use to estimate the risks to different receptors.

Because the contaminated area is about 10 acres, it would take about 2.5 days to finish construction in the contaminated area. The entire solar energy facility is about 2,000 acres, so it would take about 500 days to complete the entire construction. The entire duration of the construction phase, including weekends and holidays, would be about 730 days, which can be calculated as  $500/250 \times 365$ , where 250 (days/yr) is the assumed number of workdays in a year. The solar energy facility is planned for operation for 30 yr, which has 10,950 ( $365 \times 30$ ) days, including weekends and holidays.

**TABLE A-17 Exposure Durations for Different Activities and Receptors**

---

<i>Duration in days</i>	
Duration of construction (workday)	500
Duration of construction (including weekends and holidays)	730
Duration of operation (workday)	7,500
Duration of operation (including weekends and holidays)	10,950
<i>Number of days of exposure—carcinogenic risk</i>	
Construction worker in contaminated area	2.5
Construction worker in non-contaminated area	497.5
Operation worker in contaminated area	37.5
Operation worker in non-contaminated area	7,462.5
Resident—during construction in contaminated area	2.5
Resident—during construction (excluding construction in contaminated area)	727.5
Resident—during operation	1,095
<i>Number of days of exposure—non-carcinogenic risk</i>	
Construction worker in contaminated area	2.5
Construction worker in non-contaminated area	247.5
Operation worker in contaminated area	1.25
Operation worker in non-contaminated area	248.75
Resident—during construction in contaminated area	2.5
Resident—during construction (excluding construction in contaminated area)	362.5
Resident—during operation	365

---

To calculate carcinogenic risks, all the exposure days should be counted. Therefore, the exposure duration for a construction worker in the non-contaminated area is 497.5 (500 – 2.5) days. If an operation worker worked at the solar energy facility throughout the entire operation phase, the total number of days he would work would be 7,500 (250 × 30) days, out of which 37.5 (7,500 × 10 / 2,000) days would be spent in the contaminated area, and 7,462.5 (7,500 – 37.5) days would be spent in the non-contaminated area, assuming that the time spent in an area is proportional to the size of that area. If an offsite resident lives in the same house throughout the construction and operation of the solar energy facility, he could incur chemical exposure for 730 days during the construction phase (2.5 days when construction is conducted in the contaminated area and 727.5 days when construction is conducted in the non-contaminated area, including weekends and holidays) and 10,950 days during the operation phase.

To calculate non-carcinogenic risks, only the exposure days during the first year should be counted, assuming construction would start in the contaminated area so that potential exposures to COCs would be greater in the first year than in the subsequent year. Therefore, a construction worker would spend 2.5 days in the contaminated area and 247.5 (250 – 2.5) days in the non-contaminated area. An operation worker would spend 1.25 (250 × 10 / 2,000) days in the contaminated area and 248.75 (250 – 1.25) days in the non-contaminated area. The exposure duration for an offsite resident would be 365 days during both the construction and operation phases.

## A.2.8 Calculate Risks over the Entire Duration of Each Activity

The daily risks and the exposure duration obtained in the previous two steps can be multiplied together to get the risks over the course of each activity. Tables A-18 through A-21 list the multiplication results.

**TABLE A-18 Carcinogenic Risks over the Entire Duration of Activities—Exposures of Workers**

Chemical	Exposure Pathway				All Pathways
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption	
<i>Construction in the contaminated area</i>					
Chloroform	4.16E-12	3.62E-07	0.00E+00	0.00E+00	3.62E-07
Dieldrin	2.20E-10	0.00E+00	2.65E-13	6.67E-11	2.87E-10
Cadmium	0.00E+00	0.00E+00	8.07E-09	0.00E+00	8.07E-09
<i>Construction in the non-contaminated area</i>					
Chloroform	0.00E+00	1.89E-08	0.00E+00	0.00E+00	1.89E-08
Dieldrin	0.00E+00	0.00E+00	4.17E-13	0.00E+00	4.17E-13
Cadmium	0.00E+00	0.00E+00	9.68E-09	0.00E+00	9.68E-09
<i>Operation in the contaminated area</i>					
Chloroform	9.46E-12	1.93E-09	0.00E+00	0.00E+00	1.94E-09
Dieldrin	5.00E-10	0.00E+00	1.23E-13	3.33E-10	8.33E-10
Cadmium	0.00E+00	0.00E+00	2.87E-09	0.00E+00	2.87E-09
<i>Operation in the non-contaminated area</i>					
Chloroform	0.00E+00	7.34E-08	0.00E+00	0.00E+00	7.34E-08
Dieldrin	0.00E+00	0.00E+00	4.67E-12	0.00E+00	4.67E-12
Cadmium	0.00E+00	0.00E+00	1.08E-07	0.00E+00	1.08E-07

**TABLE A-19 Hazard Quotients over the Entire Duration of Activities—Exposures of Workers**

Chemical	Exposure Pathway				All Pathways
	Soil Ingestion	Inhalation of Volatile	Inhalation of Particulate	Dermal Absorption	
<i>Construction in the contaminated area</i>					
Chloroform	9.57E-07	1.13E-02	0.00E+00	0.00E+00	1.13E-02
Dieldrin	1.94E-05	0.00E+00	0.00E+00	5.84E-06	2.53E-05
Cadmium	5.94E-02	0.00E+00	3.13E-02	6.92E-03	9.76E-02
<i>Construction in the non-contaminated area</i>					
Chloroform	0.00E+00	4.16E-04	0.00E+00	0.00E+00	4.16E-04
Dieldrin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	0.00E+00	1.87E-02	0.00E+00	1.87E-02
<i>Operation in the contaminated area</i>					
Chloroform	7.25E-08	1.10E-05	0.00E+00	0.00E+00	1.11E-05
Dieldrin	1.47E-06	0.00E+00	0.00E+00	9.74E-07	2.44E-06
Cadmium	4.50E-03	0.00E+00	3.70E-04	1.15E-03	6.02E-03
<i>Operation in the non-contaminated area</i>					
Chloroform	0.00E+00	4.19E-04	0.00E+00	0.00E+00	4.19E-04
Dieldrin	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	0.00E+00	1.41E-02	0.00E+00	1.41E-02

**TABLE A-20 Carcinogenic Risks over the Entire Duration of Activities—Exposures of Residents**

Chemical	Exposure Pathway		All Pathways
	Inhalation of Volatile	Inhalation of Particulate	
<i>Construction in the contaminated area</i>			
Chloroform	9.88E-09	0.00E+00	9.88E-09
Dieldrin	0.00E+00	9.25E-18	9.25E-18
Cadmium	0.00E+00	1.69E-13	1.69E-13
<i>Construction in the non-contaminated area</i>			
Chloroform	1.20E-08	0.00E+00	1.20E-08
Dieldrin	0.00E+00	2.65E-13	2.65E-13
Cadmium	0.00E+00	6.35E-09	6.35E-09
<i>Operation</i>			
Chloroform	4.67E-08	0.00E+00	4.67E-08
Dieldrin	0.00E+00	2.99E-12	2.99E-12
Cadmium	0.00E+00	7.17E-08	7.17E-08

**TABLE A-21 Hazard Quotients over the Entire Duration of Activities—Exposures of Residents**

Chemical	Exposure Pathway		All Pathways
	Inhalation of Volatile	Inhalation of Particulate	
<i>Construction in the contaminated area</i>			
Chloroform	3.07E-04	0.00E+00	3.07E-04
Dieldrin	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	8.79E-04	8.79E-04
<i>Construction in the non-contaminated area</i>			
Chloroform	2.63E-04	0.00E+00	2.63E-04
Dieldrin	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	1.22E-02	1.22E-02
<i>Operation</i>			
Chloroform	2.65E-04	0.00E+00	2.65E-04
Dieldrin	0.00E+00	0.00E+00	0.00E+00
Cadmium	0.00E+00	9.22E-03	9.22E-03

### A.2.9 Calculate Total Risk to Each Receptor

The total risk to each receptor can be calculated by summing the risks from all pathways (listed in the final columns of Tables A.18–A.21) over the activities that the receptor would conduct or over the activities that would impact the receptor, and then summing the obtained risks over all the COCs. For example, for a construction worker, the total risk incurred would be the sum of the risk from constructing in the contaminated area and the risk from constructing in the non-contaminated area. For an offsite resident, the total risk incurred during the construction phase would be the sum of the risk associated with construction in the contaminated area and the risk associated with construction in the non-contaminated area. If the resident lived in the same location over the construction, operation, and decommissioning phases, the total lifetime cancer risk incurred would be the sum of the risks from all three phases. On the other hand, the non-carcinogenic risk is not cumulative (i.e., it is calculated by year). The hazard index is calculated by comparing the average daily exposure during a year with the toxicity value; therefore, the hazard index for different phases of solar energy development should not be added together; rather, they should be evaluated separately against the target risk level of 1.

Tables A.22 and A.23 show the total risk calculated for each receptor. In the previous sections, guidance was provided to estimate potential risks associated with only construction and operation phases of solar energy development, because potential risks associated with decommissioning would be similar to those associated with construction. The total cancer risk calculated for a resident scenario (listed in the last column of Table A.22) includes risks from all three phases, which was obtained on the basis of this assumption.

## A.2.10 Compare Total Risks with Target Risk Limits

Because the total cancer risks from all COCs calculated for a construction worker, an operation worker, or a resident (listed in the last row of Table A.22) are all less than  $1 \times 10^{-6}$ , and the hazard index from all COCs calculated for each of the receptors (listed in the last row of Table A.23) are all less than 1, it is concluded that the soil contamination would not pose unacceptable risks to human health if a utility-scale solar energy facility were developed at the hypothetical site considered in this example. Therefore, no remediation would be required for using the contaminated site for solar energy development, on the basis of the preliminary risk assessment results.

**TABLE A-22 Total Cancer Risk to Each Receptor**

Chemical	Receptor				
	Construction Worker	Operation Worker	Resident—Construction	Resident—Operation	Resident—Total <sup>a</sup>
Chloroform	3.80E-07	7.53E-08	2.19E-08	4.67E-08	6.86E-08
Dieldrin	2.87E-10	8.38E-10	2.65E-13	2.99E-12	3.25E-12
Cadmium	1.77E-08	1.11E-07	6.35E-09	7.17E-08	7.80E-08
All	3.97E-07	1.87E-07	2.83E-08	2.11E-07	1.46E-07

<sup>a</sup> The risks listed under “Resident—Total” are the sums of risks from the construction, operation, and decommissioning phases, assuming the risks from decommissioning would be the same as those from construction.

**TABLE A-23 Total Hazard Index to Each Receptor**

Chemical	Receptor			
	Construction Worker	Operation Worker	Resident—Construction	Resident—Operation
Chloroform	1.17E-02	4.30E-04	5.70E-04	2.65E-04
Dieldrin	2.53E-05	2.44E-06	0.00E+00	0.00E+00
Cadmium	1.16E-01	2.01E-02	1.31E-02	9.22E-03
All	1.28E-01	2.05E-02	1.37E-02	9.49E-03

### A.3 REFERENCES

EPA, 2013a, *Data Documentation for Mapping and Screening Criteria for Renewable Energy Potential on EPA and State Tracked Sites* RE-Powering America's Land Initiative, Updated July 2013, produced by Office of Solid Waste and Emergency Response, Center for Program Analysis. Available at [http://www.epa.gov/renewableenergyland/rd\\_mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm). Accessed Aug. 13, 2013.

EPA, 2013b, RE-Powering Screening Dataset. Available at [http://www.epa.gov/renewableenergyland/rd\\_mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm). Accessed Aug. 12, 2013.

EPA, 2013c, *Generic Tables*. Available at [http://www.epa.gov/reg3hwmd/risk/human/rb-concentration\\_table/Generic\\_Tables/index.htm](http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm). Accessed Aug. 9, 2013.



**APPENDIX B**  
**POTENTIAL CONTAMINANTS OF CONCERN**



## APPENDIX B

### POTENTIAL CONTAMINANTS OF CONCERN

As described in Chapter 3, a list of contaminants of concern (COCs) was compiled by reviewing contamination profiles for 80 contaminated sites located in six southwest states.<sup>1</sup> This list of COCs and the contaminated sites where they were identified is provided in the following table.

**TABLE B-1 List of Contaminants of Concern**

Contaminant	CAS Number	Contaminated Sites
1,1,1,2-tetrachloroethane	630-20-6	1. Fort Ord 2. Sharpe Army Depot 3. Indian Bend Wash Area
1,1,1-trichloroethane	71-55-6	1. Motorola, Inc. (52nd Street Plant) Indian Bend Wash Area 2. Tucson International Airport Area 3. Edwards Air Force Base 4. El Toro Marine Corps Air Station 5. Sharpe Army Depot Fort Ord 6. McClellan Air Force Base (groundwater contamination) 7. Operating Industries, Inc. Landfill 8. Intel Corp. (Mountain View Plant) 9. Fairchild Semiconductor Corp. (Mountain View Plant) 10. Raytheon Corp. 11. Aerojet General Corp. 12. Sacramento Army Depot 13. Firestone Tire & Rubber Co. (Salinas Plant) 14. Norton Air Force Base (Landfill #2) 15. Westinghouse Electric Corp. (Sunnyvale Plant) 16. Lowry Landfill 17. Rocky Mountain Arsenal—U.S. Army 18. Sand Creek Industrial 19. Hill Air Force Base 20. El Toro Marine Corps Air Station 21. Castle Air Force Base (6 areas) 22. Lawrence Livermore National Lab (Site 300) (U.S. DOE) 23. Travis Air Force Base

<sup>1</sup> The review of COCs and contaminated sites was conducted in the summer of 2012 using 2010 data, since then many more contaminated sites have been screened by EPA, and the database and mapping tool of contaminated sites with renewable energy development potential have been updated (EPA 2013, Mapping and Screening Tools, RE-Powering Mapper and *RE-Powering Screening Dataset*. Available at [http://www.epa.gov/renewableenergyland/rd\\_mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/rd_mapping_tool.htm)).

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
1,1,2,2-tetrachloroethane (1,1,2,2-PCA)	79-34-5	<ol style="list-style-type: none"> <li>1. Luke Air Force Base</li> <li>2. Phoenix-Goodyear Airport Area</li> <li>3. Edwards Air Force Base</li> <li>4. Aerojet General Corp.</li> <li>5. Lowry Landfill</li> <li>6. Rocky Mountain Arsenal—U.S. Army</li> <li>7. Ogden Defense Depot (Defense Logistics Agency)</li> <li>8. El Toro Marine Corps Air Station</li> </ol>
1,1,2-trichloro-1,2,2-trifluoroethane (freon 113)	76-13-1	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> <li>2. Hill Air Force Base</li> </ol>
1,1,2-trichloroethane	79-00-5	<ol style="list-style-type: none"> <li>1. Motorola, Inc. (52nd Street Plant) Edwards Air Force Base</li> <li>2. Sharpe Army Depot</li> <li>3. McClellan Air Force Base (groundwater contamination)</li> <li>4. Operating Industries, Inc. Landfill</li> <li>5. Aerojet General Corp.</li> <li>6. Lowry Landfill</li> <li>7. Rocky Mountain Arsenal—U.S. Army</li> <li>8. Sand Creek Industrial</li> <li>9. Travis Air Force Base</li> <li>10. Hill Air Force Base</li> <li>11. Indian Bend Wash Area</li> </ol>
1,12-benzoperylene	191-24-2	<ol style="list-style-type: none"> <li>1. Broderick Wood Products</li> </ol>
1,1-dichloroethane	75-34-3	<ol style="list-style-type: none"> <li>1. Motorola, Inc. (52nd Street Plant)</li> <li>2. Edwards Air Force Base</li> <li>3. Tucson International Airport Area</li> <li>4. Fresno Municipal Sanitary Landfill</li> <li>5. Sharpe Army Depot</li> <li>6. Fort Ord</li> <li>7. McClellan Air Force Base (groundwater contamination)</li> <li>8. Castle Air Force Base (6 areas)</li> <li>9. Operating Industries, Inc. Landfill</li> <li>10. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>11. Intel Corp. (Mountain View Plant)</li> <li>12. Raytheon Corp.</li> <li>13. Lowry Landfill</li> <li>14. Rocky Mountain Arsenal—U.S. Army</li> <li>15. El Toro Marine Corps Air Station</li> <li>16. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>17. Aerojet General Corp.</li> <li>18. Indian Bend Wash Area</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
1,1-dichloroethene	75-35-4	<ol style="list-style-type: none"> <li>1. Indian Bend Wash Area</li> <li>2. Yuma Marine Corps Air Station</li> <li>3. Barstow Marine Corps Logistics Base</li> <li>4. Edwards Air Force Base</li> <li>5. El Toro Marine Corps Air Station</li> <li>6. Fort Ord</li> <li>7. McClellan Air Force Base (groundwater contamination)</li> <li>8. Castle Air Force Base (6 areas)</li> <li>9. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>10. Intel Corp. (Mountain View Plant)</li> <li>11. Jet Propulsion Laboratory (NASA)</li> <li>12. Aerojet General Corp.</li> <li>13. Tracy Defense Depot (U.S. Army)</li> <li>14. Travis Air Force Base Hill Air Force Base</li> <li>15. Ogden Defense Depot (DLA)</li> <li>16. Tucson International Airport Area</li> <li>17. Motorola, Inc. (52nd Street Plant)</li> <li>18. Nineteenth Avenue Landfill</li> <li>19. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>20. Lawrence Livermore Nat'l Lab (Site 300) (U.S. DOE)</li> <li>21. Rocky Mountain Arsenal—U.S. Army</li> <li>22. Luke Air Force Base</li> <li>23. Phoenix-Goodyear Airport Area</li> <li>24. Sharpe Army Depot</li> <li>25. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>26. Operating Industries, Inc. Landfill</li> <li>27. Firestone Tire &amp; Rubber Co. (Salinas Plant)</li> <li>28. Lowry Landfill</li> <li>29. Marshall Landfill</li> <li>30. Sand Creek Industrial</li> <li>31. Hill Air Force Base</li> </ol>
1,2,2,2-tetrachloroethane	79-34-5	<ol style="list-style-type: none"> <li>1. Sharpe Army Depot</li> </ol>
1,2,3,6,7,8-hexachlorodibenzo-p-dioxin	67653-85-7	<ol style="list-style-type: none"> <li>1. Lawrence Livermore National Lab (Site 300) (U.S. DOE)</li> </ol>
1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin	35822-46-9	<ol style="list-style-type: none"> <li>1. Castle Air Force Base (6 areas)</li> <li>2. March Air Force Base</li> </ol>
1,2,3,7,8-pentachlorodibenzo-p-dioxin	67653-85-7	<ol style="list-style-type: none"> <li>1. Lawrence Livermore National Lab (Site 300) (U.S. DOE)</li> </ol>
1,2,3-trichloropropane	96-18-4	<ol style="list-style-type: none"> <li>1. Edwards Air Force Base</li> </ol>
1,2,4-TRICHLOROBENZENE	120-82-1	<ol style="list-style-type: none"> <li>1. Fort Ord</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Operating Industries, Inc. Landfill</li> <li>4. Norton Air Force Base (Landfill #2)</li> <li>5. Westinghouse Electric Corp. (Sunnyvale Plant)</li> <li>6. Lowry Landfill</li> <li>7. Indian Bend Wash Area</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
1,2,4-trimethyl benzene	95-63-6	1. McClellan Air Force Base (groundwater contamination) 2. Castle Air Force Base (6 areas)
1,2-DCE	540-59-0	1. El Toro Marine Corps Air Station 2. Fresno Municipal Sanitary Landfill 3. Fort Ord 4. Mather Air Force Base (AC&W Disposal Site) 5. Aerojet General Corp. 6. Rocky Mountain Arsenal—U.S. Army
1,2-DCA	107-06-2	1. Indian Bend Wash Area
1,2-dibromo-3-chloropropane	96-12-8	1. Castle Air Force Base (6 areas) 2. Hill Air Force Base
1,2-dibromoethane	106-93-4	1. Edwards Air Force Base 2. McClellan Air Force Base (groundwater contamination) 3. Indian Bend Wash Area
1,2-dichlorobenzene	95-50-1	1. Motorola, Inc. (52nd Street Plant) 2. Fresno Municipal Sanitary Landfill 3. Castle Air Force Base (6 areas) 4. Operating Industries, Inc., Landfill 5. Fairchild Semiconductor Corp. (Mountain View Plant) 6. Intel Corp. (Mountain View Plant) 7. Raytheon Corp. 8. Norton Air Force Base (Landfill #2) 9. Westinghouse Electric Corp. (Sunnyvale Plant) 10. Rocky Mountain Arsenal—U.S. Army 11. Hill Air Force Base 12. Indian Bend Wash Area
1,2-dichloroethane	107-06-2	1. Motorola, Inc. (52nd Street Plant) 2. Tucson International Airport Area 3. Barstow Marine Corps Logistics Base 4. Edwards Air Force Base 5. Pacific Coast Pipe Lines 6. Fresno Municipal Sanitary Landfill 7. Lawrence Livermore National Lab, Main Site (U.S. DOE) 8. Mather Air Force Base (AC&W Disposal Site) 9. McClellan Air Force Base (groundwater contamination) 10. Castle Air Force Base (6 areas) 11. Operating Industries, Inc., Landfill 12. Jet Propulsion Laboratory (NASA) 13. March Air Force Base 14. Sacramento Army Depot 15. Firestone Tire & Rubber Co. (Salinas Plant) 16. Norton Air Force Base (Landfill #2) 17. Westinghouse Electric Corp. (Sunnyvale Plant) 18. Lowry Landfill

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
1,2-dichloroethane ( <i>cont.</i> )		19. Sand Creek Industrial 20. Prewitt Abandoned Refinery 21. Hill Air Force Base 22. Midvale Slag 23. Camp Pendleton Marine Corps Base 24. El Toro Marine Corps Air Station 25. Fort Ord 26. Aerojet General Corp. 27. Lawrence Livermore National Lab (Site 300) 28. Travis Air Force Base 29. Rocky Mountain Arsenal—U.S. Army
1,2-dichloroethene	540-59-0	1. El Toro Marine Corps Air Station 2. Intel Corp. (Mountain View Plant) 3. Raytheon Corp. 4. Sacramento Army Depot 5. Tracy Defense Depot (U.S. Army) 6. Sand Creek Industrial 7. Fort Ord
1,2-dichloroethylene	540-59-0	1. Motorola, Inc. (52nd Street Plant) 2. Operating Industries, Inc. Landfill 3. Fairchild Semiconductor Corp. (Mountain View Plant) 4. Sacramento Army Depot 5. Norton Air Force Base (Landfill #2) 6. Lowry Landfill 7. Rocky Mountain Arsenal—U.S. Army 8. Sand Creek Industrial
1,2-dichloropropane	78-87-5	1. Tucson International Airport Area 2. Edwards Air Force Base 3. El Toro Marine Corps Air Station 4. Fresno Municipal Sanitary Landfill 5. Sharpe Army Depot 6. Fort Ord 7. Mather Air Force Base (AC&W Disposal Site) 8. Castle Air Force Base (6 areas) 9. Operating Industries, Inc., Landfill 10. Travis Air Force Base 11. Lowry Landfill 12. Sand Creek Industrial 13. Hill Air Force Base 14. Phoenix-Goodyear Airport Area 15. Indian Bend Wash Area
1,2-trans-dichloroethylene	156-60-5	1. Indian Bend Wash Area 2. Sacramento Army Depot 3. Sand Creek Industrial
1,3,5-TNB (1,3,5-Trinitrobenzene)	99-35-4	1. Fort Ord

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
1,3,5-trimethylbenzene	108-67-8	1. McClellan Air Force Base (groundwater contamination) 2. Castle Air Force Base (6 areas)
1,3-dichlorobenzene	541-73-1	1. Sharpe Army Depot 2. Castle Air Force Base (6 areas) 3. Westinghouse Electric Corp. (Sunnyvale Plant) 4. Lowry Landfill 5. Rocky Mountain Arsenal—U.S. Army 6. Indian Bend Wash Area
1,3-dichloropropene	542-75-6	1. Sharpe Army Depot 2. Fort Ord 3. Operating Industries, Inc., Landfill 4. Lowry Landfill
1,4-dichlorobenzene	106-46-7	1. Williams Air Force Base 2. Motorola, Inc. (52nd Street Plant) 3. Nineteenth Avenue Landfill 4. Fresno Municipal Sanitary Landfill 5. Mather Air Force Base (AC&W Disposal Site) 6. McClellan Air Force Base (groundwater contamination) 7. Castle Air Force Base (6 areas) 8. Operating Industries, Inc., Landfill 9. Westinghouse Electric Corp. (Sunnyvale Plant) 10. Travis Air Force Base Lowry Landfill 11. Rocky Mountain Arsenal—U.S. Army 12. Indian Bend Wash Area
1,4-dioxane	123-91-1	1. Edwards Air Force Base 2. McClellan Air Force Base (groundwater contamination) 3. Operating Industries, Inc., Landfill 4. Aerojet General Corp.
1,1,2-benzofluoranthene	207-08-9	1. Koppers Co., Inc. (Orville Plant)
2,2,4-trimethylpentane	540-84-1	1. McClellan Air Force Base (groundwater contamination)
2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalents (TEq)	1746-01-6	1. Camp Pendleton Marine Corps Base 2. McClellan Air Force Base (groundwater contamination) 3. Aerojet General Corp. 4. Lawrence Livermore National Lab (Site 300) 5. Tracy Defense Depot (U.S. Army) 6. Travis Air Force Base Lowry Landfill 7. Broderick Wood Products Rocky Flats Plant (U.S. DOE) 8. Ogden Defense Depot (DLA)
2,4,5-trichlorophenoxyacetic acid	93-76-5	1. Tracy Defense Depot (U.S. Army)
2,4,5-trichlorophenol	95-95-4	1. Broderick Wood Products
2,4,6-trichlorophenol	88-06-2	1. Tracy Defense Depot (U.S. Army)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
2,4-D [acetic acid (2,4-dichlorophenoxy)-]	94-75-7	1. Tracy Defense Depot (U.S. Army) 2. Sand Creek Industrial
2,4-DB; 2,4-dichloro-phenoxybutyric acid	94-82-6	1. McClellan Air Force Base (groundwater contamination)
2,4-dichlorophenol	120-83-2	1. Broderick Wood Products
2,4-dimethylphenol	105-67-9	1. Tracy Defense Depot (U.S. Army) 2. Lowry Landfill 3. Broderick Wood Products
2,4-dinitrophenol	51-28-5	1. McClellan Air Force Base (groundwater contamination) 2. Tracy Defense Depot (U.S. Army) 3. Lowry Landfill
2,4-dinitrotoluene (2,4-DNT)	121-14-2	1. Apache Powder Co. 2. Tracy Defense Depot (U.S. Army) 3. Hill Air Force Base 4. Fort Ord 5. Castle Air Force Base (6 areas) 6. Tooele Army Depot (North Area)
2,6-dinitrotoluene	606-20-2	1. McClellan Air Force Base (groundwater contamination) 2. Apache Powder Co.
2-chlorophenol	95-57-8	1. Lowry Landfill 2. Broderick Wood Products
2-hexanone	591-78-6	1. El Toro Marine Corps Air Station 2. Tracy Defense Depot (U.S. Army) 3. Lowry Landfill
2-methylnaphthalene	90-12-0	1. Pacific Coast Pipe Lines 2. Fort Ord 3. McClellan Air Force Base (groundwater contamination) 4. Tracy Defense Depot (U.S. Army) 5. Lowry Landfill 6. Broderick Wood Products 7. AT&SF (Albuquerque)
2-methylphenol	95-48-7	1. Lowry Landfill 2. Broderick Wood Products
3,4-benzofluoranthene	205-99-2	1. Koppers Co., Inc. (Orville Plant)
4,4-DDD	72-54-8	1. Camp Pendleton Marine Corps Base 2. Mather Air Force Base (AC&W Disposal Site) 3. Tracy Defense Depot (U.S. Army) 4. Lowry Landfill 5. Sand Creek Industrial

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
4,4-DDE	72-55-9	<ol style="list-style-type: none"> <li>1. Camp Pendleton Marine Corps Base</li> <li>2. Fort Ord</li> <li>3. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>4. March Air Force Base</li> <li>5. Tracy Defense Depot (U.S. Army)</li> <li>6. Lowry Landfill</li> <li>7. Sand Creek Industrial</li> <li>8. McClellan Air Force Base (groundwater contamination)</li> </ol>
4,4-DDT	50-29-3	<ol style="list-style-type: none"> <li>1. El Toro Marine Corps Air Station</li> <li>2. Fort Ord</li> <li>3. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>4. Castle Air Force Base (6 areas)</li> <li>5. March Air Force Base</li> <li>6. Tracy Defense Depot (U.S. Army)</li> <li>7. Lowry Landfill</li> <li>8. Sand Creek Industrial</li> </ol>
4,4-dichlorodiphenyldichloroethane	72-54-8	<ol style="list-style-type: none"> <li>1. El Toro Marine Corps Air Station</li> </ol>
4-amino-2,6-dinitrotoluene	19406-51-0	<ol style="list-style-type: none"> <li>1. Lawrence Livermore National Lab (Site 300)</li> </ol>
4-methylphenol	106-44-5	<ol style="list-style-type: none"> <li>1. Castle Air Force Base (6 areas)</li> <li>2. Tracy Defense Depot (U.S. Army)</li> <li>3. Broderick Wood Products</li> <li>4. McClellan Air Force Base (groundwater contamination)</li> </ol>
4-nitrophenol	100-02-7	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> </ol>
acenaphthene	83-32-9	<ol style="list-style-type: none"> <li>1. Fort Ord</li> <li>2. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>3. McClellan Air Force Base (groundwater contamination)</li> <li>4. Castle Air Force Base (6 areas)</li> <li>5. Koppers Co., Inc. (Oroville Plant)</li> <li>6. Travis Air Force Base</li> <li>7. Broderick Wood Products</li> </ol>
acenaphthylene	208-96-8	<ol style="list-style-type: none"> <li>1. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>2. Koppers Co., Inc. (Oroville Plant)</li> <li>3. Broderick Wood Products</li> </ol>
acetone	67-64-1	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Tucson International Airport Area</li> <li>3. Barstow Marine Corps Logistics Base</li> <li>4. El Toro Marine Corps Air Station</li> <li>5. Fort Ord</li> <li>6. McClellan Air Force Base (groundwater contamination)</li> <li>7. Operating Industries, Inc. Landfill</li> <li>8. Lawrence Livermore National Lab (Site 300)</li> <li>9. Tracy Defense Depot (U.S. Army)</li> <li>10. Travis Air Force Base Lowry Landfill</li> <li>11. Hill Air Force Base</li> <li>12. GBF, Inc., Dump</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
acetophenone	98-86-2	1. Midvale Slag
aldrin	309-00-2	1. Operating Industries, Inc., Landfill 2. Tracy Defense Depot (U.S. Army) 3. Travis Air Force Base 4. Lowry Landfill 5. Rocky Mountain Arsenal—U.S. Army 6. Sand Creek Industrial 7. Hill Air Force Base
alpha gross	12587-46-1	1. United Nuclear Corp. 2. Monticello Mill Tailings (U.S. DOE)
alpha-BHC (alpha-hexachlorocyclohexane)	319-84-6	1. Sand Creek Industrial
alpha-chlordane	57-74-9	1. Mather Air Force Base (AC&W Disposal Site) 2. McClellan Air Force Base (groundwater contamination) 3. Travis Air Force Base 4. Hill Air Force Base 5. Ogden Defense Depot (Defense Logistics Agency)
aluminum	7429-90-5	1. Phoenix-Goodyear Airport Area 2. Camp Pendleton Marine Corps Base 3. Edwards Air Force Base 4. El Toro Marine Corps Air Station 5. Sharpe Army Depot 6. Mather Air Force Base (AC&W Disposal Site) 7. McClellan Air Force Base (groundwater contamination) 8. Castle Air Force Base (6 areas) 9. Iron Mountain Mine 10. Tracy Defense Depot (U.S. Army) 11. Travis Air Force Base 12. Lowry Landfill 13. Central City, Clear Creek 14. United Nuclear Corp. 15. Hill Air Force Base 16. Midvale Slag 17. Murray Smelter
americium-241	7440-35-9	1. Rocky Flats Plant (U.S. DOE)
ammonia	7664-41-7	1. Operating Industries, Inc., Landfill
anthracene	120-12-7	1. Sharpe Army Depot 2. Mather Air Force Base (AC&W Disposal Site) 3. McClellan Air Force Base (groundwater contamination) 4. Castle Air Force Base (6 areas) 5. Koppers Co., Inc. (Oroville Plant) 6. Travis Air Force Base 7. Broderick Wood Products

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
antimony	7440-36-0	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Apache Powder Co.</li> <li>3. Barstow Marine Corps Logistics Base</li> <li>4. Camp Pendleton Marine Corps Base</li> <li>5. Edwards Air Force Base</li> <li>6. Sharpe Army Depot</li> <li>7. Fort Ord</li> <li>8. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>9. Castle Air Force Base (6 areas)</li> <li>10. Operating Industries, Inc., Landfill</li> <li>11. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>12. Intel Corp. (Mountain View Plant)</li> <li>13. Raytheon Corp.</li> <li>14. Aerojet General Corp.</li> <li>15. Iron Mountain Mine</li> <li>16. March Air Force Base</li> <li>17. Norton Air Force Base (Landfill #2)</li> <li>18. Travis Air Force Base</li> <li>19. George Air Force Base</li> <li>20. Lowry Landfill</li> <li>21. Sand Creek Industrial</li> <li>22. Denver Radium Site</li> <li>23. Midvale Slag</li> </ol>
aroclor-1232	11141-16-5	<ol style="list-style-type: none"> <li>1. Jet Propulsion Laboratory (NASA)</li> </ol>
aroclor-1242	53469-21-9	<ol style="list-style-type: none"> <li>1. Barstow Marine Corps Logistics Base</li> <li>2. Lawrence Livermore National Lab (Site 300)</li> </ol>
aroclor-1248	12672-29-6	<ol style="list-style-type: none"> <li>1. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>2. Lawrence Livermore National Lab (Site 300)</li> </ol>
aroclor-1254	11097-69-1	<ol style="list-style-type: none"> <li>1. El Toro Marine Corps Air Station</li> <li>2. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>3. Jet Propulsion Laboratory (NASA)</li> <li>4. Sacramento Army Depot</li> <li>5. Travis Air Force Base</li> </ol>
aroclor-1260	11097-69-1	<ol style="list-style-type: none"> <li>1. Barstow Marine Corps Logistics Base</li> <li>2. El Toro Marine Corps Air Station</li> <li>3. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>4. McClellan Air Force Base (groundwater contamination)</li> <li>5. Jet Propulsion Laboratory (NASA)</li> <li>6. March Air Force Base</li> <li>7. Sacramento Army Depot</li> <li>8. Tracy Defense Depot (U.S. Army)</li> <li>9. Travis Air Force Base</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
arsenic	7440-38-2	<ol style="list-style-type: none"> <li>1. Williams Air Force Base</li> <li>2. Phoenix-Goodyear Airport Area</li> <li>3. Iron King Mine—Humboldt Smelter</li> <li>4. Motorola, Inc. (52nd Street Plant)</li> <li>5. Apache Powder Co.</li> <li>6. Tucson International Airport Area</li> <li>7. Camp Pendleton Marine Corps Base</li> <li>8. El Toro Marine Corps Air Station</li> <li>9. Sharpe Army Depot</li> <li>10. Fort Ord</li> <li>11. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>12. McClellan Air Force Base (groundwater contamination)</li> <li>13. Castle Air Force Base (6 areas)</li> <li>14. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>15. Operating Industries, Inc., Landfill</li> <li>16. Intel Corp. (Mountain View Plant)</li> <li>17. Raytheon Corp.</li> <li>18. Koppers Co., Inc. (Oroville Plant)</li> <li>19. Louisiana-Pacific Corp.</li> <li>20. Western Pacific Railroad Co.</li> <li>21. Jet Propulsion Laboratory (NASA)</li> <li>22. Iron Mountain Mine</li> <li>23. Sacramento Army Depot</li> <li>24. Norton Air Force Base (Landfill #2)</li> <li>25. Tracy Defense Depot (U.S. Army)</li> <li>26. Travis Air Force Base</li> <li>27. Lowry Landfill</li> <li>28. Asarco, Inc. (Globe Plant)</li> <li>29. Lincoln Park</li> <li>30. Rocky Mountain Arsenal—U.S. Army</li> <li>31. Sand Creek Industrial</li> <li>32. Asarco, Inc. (Globe Plant)</li> <li>33. Broderick Wood Products</li> <li>34. Denver Radium Site</li> <li>35. Rocky Flats Plant (U.S. DOE)</li> <li>36. Central City, Clear Creek</li> <li>37. Eagle Mine</li> <li>38. Smelertown Site</li> <li>39. United Nuclear Corp.</li> <li>40. Kennecott (North Zone)</li> <li>41. Hill Air Force Base</li> <li>42. Midvale Slag</li> <li>43. Sharon Steel Corp. (Midvale Tailings)</li> <li>44. Monticello Mill Tailings (U.S. DOE)</li> <li>45. Murray Smelter</li> <li>46. Ogden Defense Depot (DLA)</li> <li>47. Davenport and Flagstaff</li> <li>48. Smelters International Smelting And Refining</li> <li>49. Jacobs Smelter</li> <li>50. Portland Cement (Kiln Dust 2 &amp; 3)</li> <li>51. Tooele Army Depot (North Area)</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
asbestos	1332-21-4	1. George Air Force Base 2. Prewitt Abandoned Refinery 3. GBF, Inc., Dump
atrazine	1912-24-9	1. Lowry Landfill 2. Rocky Mountain Arsenal—U.S. Army
azinphos-methyl	86-50-0	1. McClellan Air Force Base (groundwater contamination) 2. March Air Force Base
barium	7440-39-3	1. Phoenix-Goodyear Airport Area 2. Apache Powder Co. 3. Camp Pendleton Marine Corps Base 4. Fresno Municipal Sanitary Landfill 5. Sharpe Army Depot 6. Fort Ord 7. Mather Air Force Base (AC&W Disposal Site) 8. McClellan Air Force Base (groundwater contamination) 9. Castle Air Force Base (6 areas) 10. Operating Industries, Inc. Landfill 11. Koppers Co., Inc. (Oroville Plant) 12. Louisiana-Pacific Corp. 13. Tracy Defense Depot (U.S. Army) 14. George Air Force Base 15. Lowry Landfill 16. Sand Creek Industrial 17. Hill Air Force Base 18. Midvale Slag 19. Ogden Defense Depot (DLA) 20. Tooele Army Depot (North Area)
benzene	71-43-2	1. Williams Air Force Base 2. Luke Air Force Base 3. Motorola, Inc. (52nd Street Plant) 4. Indian Bend Wash Area 5. Tucson International Airport Area 6. Barstow Marine Corps Logistics Base 7. Edwards Air Force Base 8. El Toro Marine Corps Air Station 9. Pacific Coast Pipe Lines 10. Fresno Municipal Sanitary Landfill 11. Sharpe Army Depot 12. Lawrence Livermore National Lab, Main Site (U.S. DOE) 13. Fort Ord

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
benzene ( <i>cont.</i> )		14. Mather Air Force Base (AC&W Disposal Site) 15. McClellan Air Force Base (groundwater contamination) 16. Castle Air Force Base (6 areas) 17. Operating Industries, Inc., Landfill 18. Koppers Co., Inc. (Oroville Plant) 19. March Air Force Base 20. Crazy Horse Sanitary Landfill 21. Norton Air Force Base (Landfill #2) 22. firestone tire & rubber co. (Salinas Plant) 23. Westinghouse Electric Corp. (Sunnyvale Plant) 24. Lawrence Livermore National Lab (Site 300) 25. Travis Air Force Base 26. George Air Force Base 27. Lowry Landfill 28. Marshall Landfill 29. Rocky Mountain Arsenal—U.S. Army 30. Sand Creek Industrial 31. Broderick Wood Products 32. AT&SF (Albuquerque) 33. Prewitt Abandoned Refinery 34. Hill Air Force Base 35. Midvale Slag 36. Ogden Defense Depot (DLA) 37. GBF, Inc., Dump
benzo(GHI)perylene	191-24-2	1. Mather Air Force Base (AC&W Disposal Site) 2. McClellan Air Force Base (groundwater contamination) 3. Castle Air Force Base (6 areas) 4. Travis Air Force Base
benzo(GHI)perylene	191-24-2	1. Mather Air Force Base (AC&W Disposal Site) 2. McClellan Air Force Base (groundwater contamination) 3. Castle Air Force Base (6 areas) 4. Travis Air Force Base
benzo(K)fluoranthene	207-08-9	1. Edwards Air Force Base 2. El Toro Marine Corps Air Station 3. Pacific Coast Pipe Lines 4. Sharpe Army Depot 5. Mather Air Force Base (AC&W Disposal Site) 6. McClellan Air Force Base (groundwater contamination) 7. Castle Air Force Base (6 areas) 8. March Air Force Base 9. Norton Air Force Base (Landfill #2) 10. Travis Air Force Base 11. AT&SF (Albuquerque) 12. Prewitt Abandoned Refinery

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
benzo[A]anthracene	56-55-3	<ol style="list-style-type: none"> <li>1. Edwards Air Force Base</li> <li>2. El Toro Marine Corps Air Station</li> <li>3. Pacific Coast Pipe Lines</li> <li>4. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>5. McClellan Air Force Base (groundwater contamination)</li> <li>6. Castle Air Force Base (6 areas)</li> <li>7. March Air Force Base</li> <li>8. Norton Air Force Base (Landfill #2)</li> <li>9. Tracy Defense Depot (U.S. Army)</li> <li>10. Travis Air Force Base</li> <li>11. Lowry Landfill</li> <li>12. Broderick Wood Products</li> <li>13. AT&amp;SF (Albuquerque)</li> <li>14. Prewitt Abandoned Refinery</li> <li>15. Tooele Army Depot (North Area)</li> <li>16. Koppers Co., Inc. (Oroville Plant)</li> </ol>
benzo[A]pyrene	50-32-8	<ol style="list-style-type: none"> <li>1. Luke Air Force Base</li> <li>2. Edwards Air Force Base</li> <li>3. El Toro Marine Corps Air Station</li> <li>4. Pacific Coast Pipe Lines</li> <li>5. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>6. McClellan Air Force Base (groundwater contamination)</li> <li>7. Castle Air Force Base (6 areas)</li> <li>8. March Air Force Base</li> <li>9. Norton Air Force Base (Landfill #2)</li> <li>10. Tracy Defense Depot (U.S. Army)</li> <li>11. Travis Air Force Base</li> <li>12. Lowry Landfill</li> <li>13. Broderick Wood Products</li> <li>14. Rocky Flats Plant (U.S. DOE)</li> <li>15. Smelertown Site</li> <li>16. AT&amp;SF (Albuquerque)</li> <li>17. Prewitt Abandoned Refinery</li> <li>18. Midvale Slag</li> <li>19. Ogden Defense Depot (DLA)</li> <li>20. Tooele Army Depot (North Area)</li> <li>21. Koppers Co., Inc. (Oroville Plant)</li> </ol>
benzoic acid	65-85-0	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> <li>2. Lowry Landfill</li> </ol>
benzyl alcohol	100-51-6	<ol style="list-style-type: none"> <li>1. Tracy Defense Depot (U.S. Army)</li> <li>2. Lowry Landfill</li> </ol>
benzyl chloride	100-44-7	<ol style="list-style-type: none"> <li>1. Indian Bend Wash Area</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
beryllium	7440-41-7	<ol style="list-style-type: none"> <li>1. Williams Air Force Base</li> <li>2. Phoenix-Goodyear Airport Area</li> <li>3. Apache Powder Co.</li> <li>4. Camp Pendleton Marine Corps Base</li> <li>5. El Toro Marine Corps Air Station</li> <li>6. Sharpe Army Depot</li> <li>7. McClellan Air Force Base (groundwater contamination)</li> <li>8. Castle Air Force Base (6 areas)</li> <li>9. Operating Industries, Inc., Landfill</li> <li>10. March Air Force Base</li> <li>11. Norton Air Force Base (Landfill #2)</li> <li>12. Lawrence Livermore National Lab (Site 300)</li> <li>13. Tracy Defense Depot (U.S. Army)</li> <li>14. Lowry Landfill</li> <li>15. Hill Air Force Base</li> <li>16. Tooele Army Depot (North Area)</li> </ol>
beta gross	12587-47-2	<ol style="list-style-type: none"> <li>1. Monticello Mill Tailings (U.S. DOE)</li> </ol>
beta-BHC (beta-Hexachlorocyclohexane)	319-85-7	<ol style="list-style-type: none"> <li>1. Sharpe Army Depot</li> <li>2. Operating Industries, Inc., Landfill</li> <li>3. Lowry Landfill</li> <li>4. Sand Creek Industrial</li> <li>5. Hill Air Force Base</li> </ol>
bicycloheptadiene	84680-95-6	<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> </ol>
bis(2-chloroethyl)ether	111-44-4	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> <li>2. Lowry Landfill</li> <li>3. Midvale Slag</li> </ol>
bis(2-ethylhexyl)phthalate	117-81-7	<ol style="list-style-type: none"> <li>1. Tucson International Airport Area</li> <li>2. Camp Pendleton Marine Corps Base</li> <li>3. Sharpe Army Depot</li> <li>4. Fort Ord</li> <li>5. McClellan Air Force Base (groundwater contamination)</li> <li>6. Castle Air Force Base (6 areas)</li> <li>7. Operating Industries, Inc., Landfill</li> <li>8. Jet Propulsion Laboratory (NASA)</li> <li>9. Aerojet General Corp.</li> <li>10. March Air Force Base</li> <li>11. Tracy Defense Depot (U.S. Army)</li> <li>12. Travis Air Force Base</li> <li>13. Lowry Landfill</li> <li>14. AT&amp;SF (Albuquerque)</li> <li>15. Hill Air Force Base</li> <li>16. Midvale Slag</li> </ol>
boron	7440-42-8	<ol style="list-style-type: none"> <li>1. Camp Pendleton Marine Corps Base</li> <li>2. Tracy Defense Depot (U.S. Army)</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
boron oxide	1303-86-2	1. Koppers Co., Inc. (Oroville Plant) 2. Louisiana-Pacific Corp.
bromacil	314-40-9	1. Sharpe Army Depot 2. Ogden Defense Depot (DLA)
bromodichloromethane	75-27-4	1. Motorola, Inc. (52nd Street Plant) 2. Barstow Marine Corps Logistics Base 3. El Toro Marine Corps Air Station 4. Sharpe Army Depot 5. Castle Air Force Base (6 areas) 6. Jet Propulsion Laboratory (NASA) 7. Aerojet General Corp. 8. Travis Air Force Base 9. Hill Air Force Base
bromoform	75-25-2	1. Barstow Marine Corps Logistics Base 2. El Toro Marine Corps Air Station 3. Sharpe Army Depot 4. Lowry Landfill
bromomethane	74-83-9	1. Indian Bend Wash Area
butyl benzyl phthalate	85-68-7	1. Castle Air Force Base (6 areas) 2. Operating Industries, Inc., Landfill 3. Jet Propulsion Laboratory (NASA) 4. Lowry Landfill
cadmium	7440-43-9	1. Phoenix-Goodyear Airport Area 2. Motorola, Inc. (52nd Street Plant) 3. Tucson International Airport Area 4. Barstow Marine Corps Logistics Base 5. Camp Pendleton Marine Corps Base 6. Edwards Air Force Base 7. Sharpe Army Depot 8. Fort Ord 9. Mather Air Force Base (AC&W Disposal Site) 10. McClellan Air Force Base (groundwater contamination) 11. Castle Air Force Base (6 areas) 12. Operating Industries, Inc., Landfill 13. Fairchild Semiconductor Corp. (Mountain View Plant) 14. Intel Corp. (Mountain View Plant) 15. Raytheon Corp. 16. Aerojet General Corp. 17. Iron Mountain Mine 18. Sacramento Army Depot

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
cadmium ( <i>cont.</i> )		19. Norton Air Force Base (Landfill #2) 20. Lawrence Livermore National Lab (Site 300) 21. Travis Air Force Base 22. George Air Force Base 23. Smuggler Mountain 24. Lowry Landfill 25. Marshall Landfill 26. Asarco, Inc. (Globe Plant) 27. Lincoln Park 28. Rocky Mountain Arsenal—U.S. Army 29. Sand Creek Industrial 30. Broderick Wood Products 31. Central City, Clear Creek 32. Eagle Mine 33. United Nuclear Corp. 34. Hill Air Force Base 35. Midvale Slag 36. Murray Smelter 37. Sharon Steel Corp. (Midvale Tailings) 38. Ogden Defense Depot (DLA) 39. Portland Cement (Kiln Dust 2 & 3) 40. Tooele Army Depot (North Area)
calcium	7440-70-2	1. Sharpe Army Depot
calcium carbonate	471-34-1	1. Rocky Mountain Arsenal—U.S. Army
calcium oxide	1305-78-8	1. Rocky Mountain Arsenal—U.S. Army
camphechlor	8001-35-2	1. Sand Creek Industrial
carbaryl	63-25-2	1. Tracy Defense Depot (U.S. Army)
carbazole	86-74-8	1. Lowry Landfill 2. Broderick Wood Products 3. AT&SF (Albuquerque)
carbofuran	1563-66-2	1. Tracy Defense Depot (U.S. Army)
carbon disulfide	75-15-0	1. El Toro Marine Corps Air Station 2. Fort Ord 3. Lowry Landfill
carbon tetrachloride	56-23-5	1. Phoenix-Goodyear Airport Area 2. Motorola, Inc. (52nd Street Plant) 3. Tucson International Airport Area 4. Edwards Air Force Base 5. El Toro Marine Corps Air Station 6. Sharpe Army Depot 7. Lawrence Livermore National Lab, Main Site (U.S. DOE)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
carbon tetrachloride ( <i>cont.</i> )		<ol style="list-style-type: none"> <li>8. Fort Ord</li> <li>9. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>10. McClellan Air Force Base (groundwater contamination)</li> <li>11. Castle Air Force Base (6 areas)</li> <li>12. Operating Industries, Inc., Landfill</li> <li>13. Jet Propulsion Laboratory (NASA)</li> <li>14. Aerojet General Corp.</li> <li>15. March Air Force Base</li> <li>16. Sacramento Army Depot</li> <li>17. Tracy Defense Depot (U.S. Army)</li> <li>18. Travis Air Force Base</li> <li>19. Lowry Landfill</li> <li>20. Rocky Mountain Arsenal—U.S. Army</li> <li>21. Hill Air Force Base</li> <li>22. Indian Bend Wash Area</li> </ol>
chlordane	57-74-9	<ol style="list-style-type: none"> <li>1. Sharpe Army Depot</li> <li>2. Fort Ord</li> <li>3. Operating Industries, Inc., Landfill</li> <li>4. Norton Air Force Base (Landfill #2)</li> <li>5. Tracy Defense Depot (U.S. Army)</li> <li>6. Lowry Landfill</li> <li>7. Travis Air Force Base</li> <li>8. Rocky Mountain Arsenal—U.S. Army</li> <li>9. Ogden Defense Depot (DLA)</li> <li>10. Tooele Army Depot (North Area)</li> </ol>
chloride	68188-88-5	<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> <li>2. Homestake Mining Co.</li> </ol>
chlorinated fluorocarbon (freon 113)	76-13-1	<ol style="list-style-type: none"> <li>1. Hill Air Force Base</li> </ol>
chloroacetic acid	79-11-8	<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> </ol>
chlorobenzene	108-90-7	<ol style="list-style-type: none"> <li>1. Motorola, Inc. (52nd Street Plant)</li> <li>2. Indian Bend Wash Area</li> <li>3. Tucson International Airport Area</li> <li>4. El Toro Marine Corps Air Station</li> <li>5. Fresno Municipal Sanitary Landfill</li> <li>6. Sharpe Army Depot</li> <li>7. Castle Air Force Base (6 areas)</li> <li>8. Operating Industries, Inc., Landfill</li> <li>9. Norton Air Force Base (Landfill #2)</li> <li>10. Westinghouse Electric Corp. (Sunnyvale Plant)</li> <li>11. Travis Air Force Base</li> <li>12. Rocky Mountain Arsenal—U.S. Army</li> <li>13. Hill Air Force Base</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
chloroform	67-66-3	<ol style="list-style-type: none"> <li>1. Williams Air Force Base</li> <li>2. Phoenix-Goodyear Airport Area</li> <li>3. Motorola, Inc. (52nd Street Plant)</li> <li>4. Indian Bend Wash Area</li> <li>5. Tucson International Airport Area</li> <li>6. Barstow Marine Corps Logistics Base</li> <li>7. Edwards Air Force Base</li> <li>8. El Toro Marine Corps Air Station</li> <li>9. Fresno Municipal Sanitary Landfill</li> <li>10. Sharpe Army Depot</li> <li>11. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>12. Fort Ord</li> <li>13. McClellan Air Force Base (groundwater contamination)</li> <li>14. Castle Air Force Base (6 areas)</li> <li>15. Operating Industries, Inc., Landfill</li> <li>16. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>17. Intel Corp. (Mountain View Plant)</li> <li>18. Raytheon Corp.</li> <li>19. Jet Propulsion Laboratory (NASA)</li> <li>20. Aerojet General Corp.</li> <li>21. Sacramento Army Depot</li> <li>22. Lawrence Livermore National Lab (Site 300)</li> <li>23. Tracy Defense Depot (U.S. ARMY)</li> <li>24. Travis Air Force Base</li> <li>25. Rocky Mountain Arsenal—U.S. Army</li> <li>26. Sand Creek Industrial</li> <li>27. Hill Air Force Base</li> <li>28. Ogden Defense Depot (DLA)</li> </ol>
chloromethane	74-87-3	<ol style="list-style-type: none"> <li>1. Motorola, Inc. (52nd Street Plant)</li> <li>2. Tucson International Airport Area</li> <li>3. El Toro Marine Corps Air Station</li> <li>4. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>5. Castle Air Force Base (6 areas)</li> <li>6. Travis Air Force Base</li> <li>7. Indian Bend Wash Area</li> </ol>
chlorophenoxy herbicides		<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> </ol>
chloropicrin	76-06-2	<ol style="list-style-type: none"> <li>1. Ogden Defense Depot (DLA)</li> </ol>
chromium	7440-47-3	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Motorola, Inc. (52nd Street Plant)</li> <li>3. Apache Powder Co.</li> <li>4. Tucson International Airport Area</li> <li>5. Camp Pendleton Marine Corps Base</li> <li>6. Sharpe Army Depot</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
chromium ( <i>cont.</i> )		<ol style="list-style-type: none"> <li>7. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>8. Fort Ord</li> <li>9. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>10. McClellan Air Force Base (groundwater contamination)</li> <li>11. Castle Air Force Base (6 areas)</li> <li>12. Operating Industries, Inc., Landfill</li> <li>13. Koppers Co., Inc. (Oroville Plant)</li> <li>14. Western Pacific Railroad Co.</li> <li>15. Riverbank Army Ammunition Plant</li> <li>16. Sacramento Army Depot</li> <li>17. Norton Air Force Base (Landfill #2)</li> <li>18. Tracy Defense Depot (U.S. Army)</li> <li>19. Travis Air Force Base</li> <li>20. Lowry Landfill</li> <li>21. Marshall Landfill</li> <li>22. Rocky Mountain Arsenal—U.S. Army</li> <li>23. Sand Creek Industrial</li> <li>24. Central City, Clear Creek</li> <li>25. Homestake Mining Co.</li> <li>26. Hill Air Force Base</li> <li>27. Midvale Slag</li> <li>28. Portland Cement (Kiln Dust 2 &amp; 3)</li> <li>29. Tooele Army Depot (North Area)</li> </ol>
chromium hexavalent (VI)	18540-29-9	<ol style="list-style-type: none"> <li>1. Tucson International Airport Area</li> <li>2. Edwards Air Force Base</li> <li>3. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>4. Fort Ord</li> <li>5. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>6. McClellan Air Force Base (groundwater contamination)</li> <li>7. Operating Industries, Inc., Landfill</li> <li>8. Jet Propulsion Laboratory (NASA)</li> <li>9. Aerojet General Corp.</li> <li>10. Sacramento Army Depot</li> <li>11. Central City, Clear Creek</li> <li>12. Hill Air Force Base</li> <li>13. GBF, Inc., Dump</li> </ol>
chrysene	218-01-9	<ol style="list-style-type: none"> <li>1. Edwards Air Force Base</li> <li>2. El Toro Marine Corps Air Station</li> <li>3. Pacific Coast Pipe Lines</li> <li>4. Sharpe Army Depot</li> <li>5. Fort Ord</li> <li>6. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>7. McClellan Air Force Base (groundwater contamination)</li> <li>8. Castle Air Force Base (6 areas)</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
chrysene ( <i>cont.</i> )		<ol style="list-style-type: none"> <li>9. Koppers Co., Inc. (Oroville Plant)</li> <li>10. Norton Air Force Base (Landfill #2)</li> <li>11. Travis Air Force Base</li> <li>12. Broderick Wood Products</li> <li>13. AT&amp;SF (Albuquerque)</li> <li>14. Prewitt Abandoned Refinery</li> </ol>
cis-1,2-DCE	156-59-2	<ol style="list-style-type: none"> <li>1. El Toro Marine Corps Air Station</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Castle Air Force Base (6 areas)</li> <li>4. Aerojet General Corp.</li> <li>5. Travis Air Force Base</li> <li>6. Ogden Defense Depot (DLA)</li> <li>7. Indian Bend Wash Area</li> </ol>
cis-1,2-dichloroethene	156-59-2	<ol style="list-style-type: none"> <li>1. Tucson International Airport Area</li> <li>2. Edwards Air Force Base</li> <li>3. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>4. Fort Ord</li> <li>5. McClellan Air Force Base (groundwater contamination)</li> <li>6. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>7. Intel Corp. (Mountain View Plant)</li> <li>8. Aerojet General Corp.</li> <li>9. Westinghouse Electric Corp. (Sunnyvale Plant)</li> <li>10. Lee Acres Landfill (U.S. DOI)</li> <li>11. Hill Air Force Base</li> <li>12. Ogden Defense Depot (DLA)</li> </ol>
cis-1,3-dichloropropene	10061-01-5	<ol style="list-style-type: none"> <li>1. Indian Bend Wash Area</li> </ol>
cis-1,2-dichloroethylene	156-59-2	<ol style="list-style-type: none"> <li>1. Fresno Municipal Sanitary Landfill</li> <li>2. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>3. McClellan Air Force Base (groundwater contamination)</li> <li>4. Raytheon Corp.</li> <li>5. Sacramento Army Depot</li> <li>6. Norton Air Force Base (Landfill #2)</li> <li>7. Lawrence Livermore National Lab (Site 300)</li> <li>8. Hill Air Force Base</li> <li>9. Ogden Defense Depot (DLA)</li> <li>10. Fort Ord</li> </ol>
cobalt	7440-48-4	<ol style="list-style-type: none"> <li>1. Camp Pendleton Marine Corps Base</li> <li>2. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>3. McClellan Air Force Base (groundwater contamination)</li> <li>4. Lowry Landfill</li> <li>5. United Nuclear Corp.</li> </ol>
copper	7440-50-8	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Barstow Marine Corps Logistics Base</li> <li>3. Camp Pendleton Marine Corps Base</li> <li>4. McClellan Air Force Base (groundwater contamination)</li> <li>5. Fort Ord</li> <li>6. Mather Air Force Base (AC&amp;W Disposal Site)</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
copper ( <i>cont.</i> )		<ol style="list-style-type: none"> <li>7. Castle Air Force Base (6 areas)</li> <li>8. Operating Industries, Inc., Landfill</li> <li>9. Koppers Co., Inc. (Oroville Plant)</li> <li>10. Iron Mountain Mine</li> <li>11. Sacramento Army Depot</li> <li>12. Norton Air Force Base (Landfill #2)</li> <li>13. Lawrence Livermore National Lab (Site 300)</li> <li>14. Travis Air Force Base</li> <li>15. George Air Force Base</li> <li>16. Lowry Landfill</li> <li>17. Rocky Mountain Arsenal—U.S. Army</li> <li>18. Broderick Wood Products</li> <li>19. Central City, Clear Creek</li> <li>20. Eagle Mine</li> <li>21. Kennecott (North Zone)</li> <li>22. Midvale Slag</li> <li>23. Monticello Mill Tailings (U.S. DOE)</li> <li>24. Murray Smelter</li> </ol>
cyanide	57-12-5	<ol style="list-style-type: none"> <li>1. Tucson International Airport Area</li> <li>2. Casmalia Resources</li> <li>3. Operating Industries, Inc., Landfill</li> <li>4. Riverbank Army Ammunition Plant</li> <li>5. Norton Air Force Base (Landfill #2)</li> <li>6. Lowry Landfill</li> <li>7. GBF, Inc., Dump</li> </ol>
cyclohexane	110-82-7	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> </ol>
DBCP (1,2-dibromo-3-chloropropane)	96-12-8	<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> </ol>
DDD (dichlorodiphenyldichloroethane)	72-54-8	<ol style="list-style-type: none"> <li>1. Sharpe Army Depot</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Tracy Defense Depot (U.S. ARMY)</li> <li>4. Ogden Defense Depot (DLA)</li> <li>5. Rocky Mountain Arsenal—U.S. Army</li> </ol>
diazinon		<ol style="list-style-type: none"> <li>1. GBF, Inc., Dump</li> </ol>
DDE	72-55-9	<ol style="list-style-type: none"> <li>1. Sharpe Army Depot</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Tracy Defense Depot (U.S. Army)</li> <li>4. Travis Air Force Base</li> <li>5. Rocky Mountain Arsenal—U.S. Army</li> <li>6. Ogden Defense Depot (DLA)</li> </ol>
DDT (dichlorodiphenyltrichloroethane)	50-29-3	<ol style="list-style-type: none"> <li>1. Sharpe Army Depot</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Castle Air Force Base (6 areas)</li> <li>4. Tracy Defense Depot (U.S. Army)</li> <li>5. Travis Air Force Base</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
DDT (dichlorodiphenyltrichloroethane) (cont.)		6. Lowry Landfill 7. Rocky Mountain Arsenal—U.S. Army 8. Ogden Defense Depot (DLA) 9. GBF, Inc., Dump
delta-benzene hexachloride	319-86-8	1. Tooele Army Depot (North Area) 2. McClellan Air Force Base (groundwater contamination) 3. Ogden Defense Depot (DLA)
di(2-ethylhexyl)phthalate	117-81-7	1. Castle Air Force Base (6 areas)
dibenzo(A,H)anthracene	53-70-3	1. Edwards Air Force Base 2. El Toro Marine Corps Air Station 3. Pacific Coast Pipe Lines 4. Mather Air Force Base (AC&W Disposal Site) 5. McClellan Air Force Base (groundwater contamination) 6. Travis Air Force 7. Base Broderick Wood Products 8. Smelertown Site 9. AT&SF (Albuquerque) 10. Tooele Army Depot (North Area)
dibenzofuran	132-64-9	1. Koppers Co., Inc. (Oroville Plant) 2. Lowry Landfill
dibromochloromethane	124-48-1	1. Motorola, Inc. (52nd Street Plant) 2. Barstow Marine Corps Logistics Base 3. El Toro Marine Corps Air Station 4. Sharpe Army Depot 5. Operating Industries, Inc., Landfill 6. Aerojet General Corp. 7. Travis Air Force Base 8. Hill Air Force Base
dicamba	1918-00-9	1. Tracy Defense Depot (U.S. Army)
dichlorobenzene (mixed isomers)	25321-22-6	1. Sharpe Army Depot 2. Norton Air Force Base (Landfill #2)
dichlorodifluoromethane	75-71-8	1. Tucson International Airport Area 2. Fresno Municipal Sanitary Landfill 3. Sharpe Army Depot 4. McClellan Air Force Base (groundwater contamination) 5. Castle Air Force Base (6 areas)
dichloromethane	75-09-2	1. Motorola, Inc. (52nd Street Plant) 2. Fort Ord 3. Koppers Co., Inc. (Oroville Plant) 4. Broderick Wood Products 5. Indian Bend Wash Area
dichloropropane	26638-19-7	1. Lawrence Livermore National Lab (Site 300)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
dicyclopentadiene	77-73-6	1. Rocky Mountain Arsenal—U.S. Army
dieldrin	60-57-1	1. Williams Air Force Base 2. El Toro Marine Corps Air Station 3. Sharpe Army Depot 4. Fort Ord 5. Mather Air Force Base (AC&W Disposal Site) 6. McClellan Air Force Base (groundwater contamination) 7. Castle Air Force Base (6 areas) 8. Tracy Defense Depot (U.S. Army) 9. Travis Air Force Base 10. Lowry Landfill 11. Rocky Mountain Arsenal—U.S. Army 12. Sand Creek Industrial 13. Hill Air Force Base 14. Ogden Defense Depot (DLA)
diesel fuel	68334-30-5	1. Mather Air Force Base (AC&W Disposal Site) 2. Castle Air Force Base (6 areas) 3. Tracy Defense Depot (U.S. Army)
diethyl phthalate	84-66-2	1. McClellan Air Force Base (groundwater contamination) 2. Aerojet General Corp. 3. Tracy Defense Depot (U.S. Army)
diethylene glycol	111-46-6	1. Apache Powder Co.
di-n-butyl phthalate	84-74-2	1. McClellan Air Force Base (groundwater contamination) 2. Castle Air Force Base (6 areas) 3. Jet Propulsion Laboratory (NASA) 4. Tracy Defense Depot (U.S. Army)
di-n-octyl phthalate	117-84-0	1. Sharpe Army Depot 2. McClellan Air Force Base (groundwater contamination) 3. Castle Air Force Base (6 areas) 4. Operating Industries, Inc., Landfill 5. Lowry Landfill 6. Hill Air Force Base
dinoseb	88-85-7	1. McClellan Air Force Base (groundwater contamination)
dioxins (chlorinated dibenzodioxins)	9014-42-0	1. Koppers Co., Inc. (Orville Plant) 2. Tracy Defense Depot (U.S. Army) 3. Travis Air Force Base 4. George Air Force Base 5. Smelertown Site
furans	110-00-9	1. Norton Air Force Base (Landfill #2) 2. Broderick Wood Products

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
dioxins/dibenzofurans		1. Fort Ord 2. McClellan Air Force Base (groundwater contamination) 3. Koppers Co., Inc. (Oroville Plant) 4. Broderick Wood Products
diphenylaminechloroarsine	578-94-9	1. Ogden Defense Depot (DLA)
diuron	330-54-1	1. Tracy Defense Depot (U.S. Army)
endosulfan	115-29-7	1. Travis Air Force Base
endrin	72-20-8	1. Operating Industries, Inc. Landfill 2. Tracy Defense Depot (U.S. Army) 3. Lowry Landfill 4. Rocky Mountain Arsenal—U.S. Army
endrin ketone	53494-70-5	1. Lowry Landfill
EPN (ethyl-p-nitrophenyl phosphonate)	2104-64-5	1. March Air Force Base
ethylbenzene	100-41-4	1. Phoenix-Goodyear Airport Area 2. Motorola, Inc. (52nd Street Plant) 3. Nineteenth Avenue Landfill 4. Indian Bend Wash Area 5. Tucson International Airport Area 6. Edwards Air Force Base 7. El Toro Marine Corps Air Station 8. Pacific Coast Pipe Lines 9. Sharpe Army Depot 10. Fort Ord 11. Mather Air Force Base (AC&W Disposal Site) 12. McClellan Air Force Base (groundwater contamination) 13. Castle Air Force Base (6 areas) 14. Operating Industries, Inc., Landfill 15. Koppers Co., Inc. (Oroville Plant) 16. March Air Force Base 17. Sacramento Army Depot 18. Firestone Tire & Rubber Co. (Salinas Plant) 19. Norton Air Force Base (Landfill #2) 20. Westinghouse Electric Corp. (Sunnyvale Plant) 21. Lawrence Livermore National Lab (Site 300) 22. Tracy Defense Depot (U.S. Army) 23. George Air Force Base 24. Lowry Landfill 25. Rocky Mountain Arsenal—U.S. Army 26. Prewitt Abandoned Refinery 27. Hill Air Force Base
ethyl toluene		1. Indian Bend Wash Area
ethylene dibromide	106-93-4	1. Lawrence Livermore National Lab, Main Site (U.S. DOE) 2. Castle Air Force Base (6 areas) 3. Lowry Landfill

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
fensulfothion	115-90-2	1. McClellan Air Force Base (groundwater contamination)
fluoranthene	206-44-0	1. Sharpe Army Depot 2. Mather Air Force Base (AC&W Disposal Site) 3. McClellan Air Force Base (groundwater contamination) 4. Castle Air Force Base (6 areas) 5. Koppers Co., Inc. (Oroville Plant) 6. Tracy Defense Depot (U.S. Army) 7. Travis Air Force Base 8. Lowry Landfill 9. Broderick Wood Products
fluorene	86-73-7	1. Fort Ord 2. Mather Air Force Base (AC&W Disposal Site) 3. McClellan Air Force Base (groundwater contamination) 4. Castle Air Force Base (6 areas) 5. Koppers Co., Inc. (Oroville Plant) 6. Broderick Wood Products
fluoride	16984-48-8	1. Apache Powder Co. 2. Operating Industries, Inc., Landfill 3. Lowry Landfill 4. Rocky Mountain Arsenal—U.S. Army 5. Sand Creek Industrial 6. Central City, Clear Creek 7. Hill Air Force Base
fluoroacetic acid	144-49-0	1. Rocky Mountain Arsenal—U.S. Army
formaldehyde	50-00-0	1. Louisiana-Pacific Corp. 2. GBF, Inc., Dump
freon-11 (trichlorofluoromethane)	75-69-4	1. Castle Air Force Base (6 areas) 2. Lawrence Livermore National Lab (Site 300)
freon-112	76-12-0	1. Fresno Municipal Sanitary Landfill 2. Lawrence Livermore National Lab (Site 300)
freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane)	76-13-1	1. Fairchild Semiconductor Corp. (Mountain View Plant) 2. Intel Corp. (Mountain View Plant) 3. Raytheon Corp. 4. Jet Propulsion Laboratory (NASA) 5. Aerojet General Corp. 6. Lawrence Livermore National Lab (Site 300) 7. Tucson International Airport Area 8. Indian Bend Wash Area
freon-114	76-14-2	1. Indian Bend Wash Area
furan	110-00-9	1. Tracy Defense Depot (U.S. Army)
gamma radioactivity emitters		1. Denver Radium Site 2. Monticello Mill Tailings (U.S. DOE)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
gamma-BHC (gamma-hexachlorocyclohexane, (lindane))	58-89-9	1. McClellan Air Force Base (groundwater contamination) 2. Operating Industries, Inc., Landfill 3. Lowry Landfill 4. Sand Creek Industrial 5. Denver Radium Site 6. Hill Air Force Base 7. Sharpe Army Depot 8. Tracy Defense Depot (U.S. Army) 9. Sand Creek Industrial
gamma-chlordane	57-74-9	1. Mather Air Force Base (AC&W Disposal Site) 2. McClellan Air Force Base (groundwater contamination) 3. Lowry Landfill 4. Hill Air Force Base
gasoline	8006-61-9	1. Mather Air Force Base (AC&W Disposal Site) 2. Castle Air Force Base (6 areas) 3. Tracy Defense Depot (U.S. Army) 4. Travis Air Force Base
heptachlor	76-44-8	1. Fort Ord 2. Operating Industries, Inc., Landfill 3. Tracy Defense Depot (U.S. Army) 4. Travis Air Force Base 5. Lowry Landfill 6. Sand Creek Industrial
heptachlor epoxide	1024-57-3	1. Fort Ord 2. McClellan Air Force Base (groundwater contamination) 3. Operating Industries, Inc., Landfill 4. Tracy Defense Depot (U.S. Army) 5. Travis Air Force Base 6. Lowry Landfill 7. Sand Creek Industrial
hexachlorobenzene	118-74-1	1. Lowry Landfill
hexachlorobutadiene	87-68-3	1. Castle Air Force Base (6 areas) 2. Lowry Landfill 3. Hill Air Force Base 4. Indian Bend Wash Area
hexachlorocyclopentadiene	77-47-4	1. Lowry Landfill 2. Rocky Mountain Arsenal—U.S. Army
hexachlorocyclohexane (gamma isomer)	58-89-9	1. Lowry Landfill
hexane	110-54-3	1. McClellan Air Force Base (groundwater contamination)
HMX octahydro-1,3,5,7-tetranitro-1,3,5,7-tetra	2691-41-0	1. Fort Ord 2. Lawrence Livermore National Lab (Site 300)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
indeno(1,2,3-cd)pyrene	193-39-5	<ol style="list-style-type: none"> <li>1. Luke Air Force Base</li> <li>2. Edwards Air Force Base</li> <li>3. El Toro Marine Corps Air Station</li> <li>4. Pacific Coast Pipe Lines</li> <li>5. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>6. McClellan Air Force Base (Groundwater Contamination)</li> <li>7. Castle Air Force Base (6 areas)</li> <li>8. Koppers Co., Inc. (Oroville Plant)</li> <li>9. March Air Force Base</li> <li>10. Norton Air Force Base (Landfill #2)</li> <li>11. Travis Air Force Base</li> <li>12. AT&amp;SF (Albuquerque)</li> </ol>
inorganic lead	7439-92-1	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Fairchild Semiconductor Corp. (Mountain View Plant)</li> <li>4. Intel Corp. (Mountain View Plant)</li> <li>5. Raytheon Corp.</li> <li>6. Louisiana-Pacific Corp.</li> <li>7. Tracy Defense Depot (U.S. Army)</li> <li>8. Marshall Landfill</li> <li>9. Broderick Wood Products</li> <li>10. Denver Radium Site</li> <li>11. Prewitt Abandoned Refinery</li> <li>12. Sharon Steel Corp. (Midvale Tailings)</li> </ol>
iron	7439-89-6	<ol style="list-style-type: none"> <li>1. Camp Pendleton Marine Corps Base</li> <li>2. Edwards Air Force Base</li> <li>3. Sharpe Army Depot</li> <li>4. McClellan Air Force Base (groundwater contamination)</li> <li>5. Iron Mountain Mine</li> <li>6. Marshall Landfill</li> <li>7. Central City, Clear Creek</li> <li>8. Midvale Slag</li> </ol>
isodrin	465-73-6	<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> </ol>
isophorone	78-59-1	<ol style="list-style-type: none"> <li>1. Lowry Landfill</li> </ol>
isopropyl ether	108-20-3	<ol style="list-style-type: none"> <li>1. Koppers Co., Inc. (Oroville Plant)</li> <li>2. Louisiana-Pacific Corp.</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
lead	7439-92-1	<ol style="list-style-type: none"> <li>1. Williams Air Force Base</li> <li>2. Phoenix-Goodyear Airport Area</li> <li>3. Iron King Mine—Humboldt Smelter</li> <li>4. Motorola, Inc. (52nd Street Plant)</li> <li>5. Apache Powder Co.</li> <li>6. Tucson International Airport Area</li> <li>7. Barstow Marine Corps Logistics Base</li> <li>8. Camp Pendleton Marine Corps Base</li> <li>9. Pacific Coast Pipe Lines</li> <li>10. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>11. Fort Ord</li> <li>12. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>13. McClellan Air Force Base (groundwater contamination)</li> <li>14. Castle Air Force Base (6 areas)</li> <li>15. Operating Industries, Inc., Landfill</li> <li>16. Western Pacific Railroad Co.</li> <li>17. Aerojet General Corp.</li> <li>18. Iron Mountain Mine</li> <li>19. March Air Force Base</li> <li>20. Sacramento Army Depot</li> <li>21. Norton Air Force Base (Landfill #2)</li> <li>22. Lawrence Livermore National Lab (Site 300)</li> <li>23. Tracy Defense Depot (U.S. Army)</li> <li>24. Travis Air Force Base</li> <li>25. George Air Force Base</li> <li>26. Smuggler Mountain</li> <li>27. Lowry Landfill</li> <li>28. Asarco, Inc. (Globe Plant)</li> <li>29. Lincoln Park</li> <li>30. Rocky Mountain Arsenal—U.S. Army</li> <li>31. Sand Creek Industrial</li> <li>32. Asarco, Inc. (Globe Plant)</li> <li>33. Broderick Wood Products</li> <li>34. Denver Radium Site</li> <li>35. Central City, Clear Creek</li> <li>36. Eagle Mine</li> <li>37. Prewitt Abandoned Refinery</li> <li>38. Kennecott (North Zone)</li> <li>39. Midvale Slag</li> <li>40. Sharon Steel Corp. (Midvale Tailings)</li> <li>41. Monticello Mill Tailings (U.S. DOE)</li> <li>42. Murray Smelter</li> <li>43. Ogden Defense Depot (DLA)</li> <li>44. GBF, Inc., Dump</li> <li>45. Jacobs Smelter</li> <li>46. International Smelting and Refining</li> <li>47. Davenport and Flagstaff Smelters</li> <li>48. Portland Cement (Kiln Dust 2 &amp; 3)</li> <li>49. Tooele Army Depot (North Area)</li> </ol>
lead-210	14255-04-0	<ol style="list-style-type: none"> <li>1. Denver Radium Site</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
lewisite	541-25-3	1. Rocky Mountain Arsenal—U.S. Army
linuron	330-55-2	1. Tracy Defense Depot (U.S. Army)
m,p-xylene	179601-23-1	1. McClellan Air Force Base (groundwater contamination) 2. Edwards Air Force Base
magnesium	7439-95-4	1. Sharpe Army Depot 2. Lawrence Livermore National Lab, Main Site (U.S. DOE)
malathion	121-75-5	1. Lowry Landfill 2. Rocky Mountain Arsenal—U.S. Army
manganese	7439-96-5	1. Apache Powder Co. 2. Camp Pendleton Marine Corps Base 3. Edwards Air Force Base 4. El Toro Marine Corps Air Station 5. Fresno Municipal Sanitary Landfill 6. Sharpe Army Depot 7. Mather Air Force Base (AC&W Disposal Site) 8. Castle Air Force Base (6 areas) 9. Operating Industries, Inc., Landfill 10. Louisiana-Pacific Corp. 11. March Air Force Base 12. Tracy Defense Depot (U.S. Army) 13. George Air Force Base 14. Lowry Landfill 15. Rocky Mountain Arsenal—U.S. Army 16. Sand Creek Industrial 17. Central City, Clear Creek 18. United Nuclear Corp. 19. Lee Acres Landfill (U.S. DOI) 20. Hill Air Force Base 21. Midvale Slag 22. Monticello Mill Tailings (U.S. DOE) 23. Portland Cement (Kiln Dust 2 & 3)
MCPA; 2-methyl-4-chlorophenoxyacetic acid	94-74-6	1. McClellan Air Force Base (groundwater contamination) 2. March Air Force Base 3. Tracy Defense Depot (U.S. Army)
mcpp	93-65-2	1. El Toro Marine Corps Air Station
mecoprop	93-65-2	1. McClellan Air Force Base (groundwater contamination)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
mercury	7439-97-6	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Camp Pendleton Marine Corps Base</li> <li>3. Fort Ord</li> <li>4. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>5. McClellan Air Force Base (groundwater contamination)</li> <li>6. Castle Air Force Base (6 areas)</li> <li>7. Operating Industries, Inc., Landfill</li> <li>8. Aerojet General Corp.</li> <li>9. Iron Mountain Mine</li> <li>10. Sacramento Army Depot</li> <li>11. Norton Air Force Base (Landfill #2)</li> <li>12. Tracy Defense Depot (U.S. Army)</li> <li>13. Travis Air Force Base</li> <li>14. George Air Force Base</li> <li>15. Lowry Landfill</li> <li>16. Marshall Landfill</li> <li>17. Rocky Mountain Arsenal—U.S. Army</li> <li>18. Sand Creek Industrial</li> <li>19. Central City, Clear Creek</li> <li>20. Hill Air Force Base</li> <li>21. Midvale Slag</li> <li>22. Murray Smelter</li> <li>23. Ogden Defense Depot (DLA)</li> <li>24. Tooele Army Depot (North Area)</li> </ol>
metals		<ol style="list-style-type: none"> <li>1. Norton Air Force Base (Landfill #2)</li> </ol>
methane	74-82-8	<ol style="list-style-type: none"> <li>1. Fresno Municipal Sanitary Landfill</li> </ol>
methiocarb	2032-65-7	<ol style="list-style-type: none"> <li>1. Tracy Defense Depot (U.S. Army)</li> </ol>
methoxychlor	72-43-5	<ol style="list-style-type: none"> <li>1. Operating Industries, Inc., Landfill</li> <li>2. Travis Air Force Base</li> </ol>
methyl chloride (chloromethane)	74-87-3	<ol style="list-style-type: none"> <li>1. Mather Air Force Base (AC&amp;W Disposal Site)</li> </ol>
methyl ethyl ketone (2 butanone)	78-93-3	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Tucson International Airport Area</li> <li>3. Fort Ord</li> <li>4. McClellan Air Force Base (groundwater contamination)</li> <li>5. Hill Air Force Base</li> <li>6. El Toro Marine Corps Air Station</li> <li>7. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>8. Operating Industries, Inc., Landfill</li> <li>9. Sacramento Army Depot</li> <li>10. Tracy Defense Depot (U.S. Army)</li> <li>11. Lowry Landfill</li> <li>12. Indian Bend Wash Area</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
methyl isobutyl ketone (4-methyl-2-pentanone)	108-10-1	1. McClellan Air Force Base (groundwater contamination) 2. Lowry Landfill 3. Rocky Mountain Arsenal—U.S. Army 4. El Toro Marine Corps Air Station 5. Operating Industries, Inc., Landfill 6. Tracy Defense Depot (U.S. Army)
methyl tert-butyl ether	1634-04-4	1. Edwards Air Force Base 2. McClellan Air Force Base (groundwater contamination)
methylene chloride	75-09-2	1. Phoenix-Goodyear Airport Area 2. Tucson International Airport Area 3. Barstow Marine Corps Logistics Base 4. Edwards Air Force Base 5. El Toro Marine Corps Air Station 6. Pacific Coast Pipe Lines 7. Fresno Municipal Sanitary Landfill 8. Sharpe Army Depot 9. Mather Air Force Base (AC&W Disposal Site) 10. McClellan Air Force Base (groundwater contamination) 11. Castle Air Force Base (6 areas) 12. Operating Industries, Inc., Landfill 13. Aerojet General Corp. 14. March Air Force Base 15. Lawrence Livermore National Lab (Site 300) 16. Travis Air Force Base 17. Lowry Landfill 18. Rocky Mountain Arsenal—U.S. Army 19. Sand Creek Industrial 20. Hill Air Force Base
methylphosphonic acid	993-13-5	1. Rocky Mountain Arsenal—U.S. Army
mevinphos	7786-34-7	1. March Air Force Base
mirex	2385-85-5	1. McClellan Air Force Base (groundwater contamination)
molybdenum	7439-98-7	1. Camp Pendleton Marine Corps Base 2. Edwards Air Force Base 3. Sharpe Army Depot 4. McClellan Air Force Base (groundwater contamination) 5. Castle Air Force Base (6 areas) 6. Lincoln Park 7. Denver Radium Site 8. United Nuclear Corp.  9. Homestake Mining Co. 10. Monticello Mill Tailings (U.S. DOE) 11. Portland Cement (Kiln Dust 2 & 3)
monuron	150-68-5	1. Sharpe Army Depot 2. Tracy Defense Depot (U.S. Army)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
mustard gas	505-60-2	1. Rocky Mountain Arsenal—U.S. Army
M-xylene	108-38-3	1. Rocky Mountain Arsenal—U.S. Army
naphthalene	91-20-3	1. Williams Air Force Base 2. Apache Powder Co. 3. Edwards Air Force Base 4. Pacific Coast Pipe Lines 5. Fort Ord 6. Mather Air Force Base (AC&W Disposal Site) 7. McClellan Air Force Base (groundwater contamination) 8. Castle Air Force Base (6 areas) 9. Koppers Co., Inc. (Oroville Plant) 10. Norton Air Force Base (Landfill #2) 11. Tracy Defense Depot (U.S. Army) 12. Travis Air Force Base 13. Lowry Landfill 14. Sand Creek Industrial 15. Broderick Wood Products 16. AT&SF (Albuquerque)
N-butyl benzene	104-51-8	1. McClellan Air Force Base (groundwater contamination)
nickel	7440-02-0	1. Phoenix-Goodyear Airport Area 2. Tucson International Airport Area 3. Sharpe Army Depot 4. Fort Ord 5. Mather Air Force Base (AC&W Disposal Site) 6. McClellan Air Force Base (groundwater contamination) 7. Castle Air Force Base (6 areas) 8. Operating Industries, Inc., Landfill 9. Koppers Co., Inc. (Oroville Plant) 10. Iron Mountain Mine Norton 11. Norton Air Force Base (Landfill #2) 12. Tracy Defense Depot (U.S. Army) 13. Travis Air Force Base 14. Lowry Landfill 15. Lincoln Park 16. Sand Creek Industrial 17. Central City, Clear Creek 18. United Nuclear Corp.  19. Lee Acres Landfill (U.S. DOI) 20. Hill Air Force Base 21. Murray Smelter 22. Ogden Defense Depot (DLA) 23. Tooele Army Depot (North Area)
nitrate	14797-55-8	1. Apache Powder Co. 2. Tucson International Airport Area 3. Edwards Air Force Base 4. Lawrence Livermore National Lab, Main Site (U.S. DOE)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
nitrate ( <i>cont.</i> )		5. Operating Industries, Inc., Landfill 6. Jet Propulsion Laboratory (NASA) 7. Aerojet General Corp. 8. Lawrence Livermore National Lab (Site 300) 9. Tracy Defense Depot (U.S. Army) 10. United Nuclear Corp. 11. Homestake Mining Co. 12. Monticello Mill Tailings (U.S. DOE)
nitrate/nitrite		1. Operating Industries, Inc., Landfill 2. Aerojet General Corp. 3. Rocky Mountain Arsenal—U.S. Army
nitrobenzene	98-95-3	1. Fort Ord 2. Lowry Landfill
nitroglycerin	55-63-0	1. Fort Ord
N-nitrosodimethylamine	62-75-9	1. Edwards Air Force Base
N-nitrosodiphenylamine	86-30-6	1. McClellan Air Force Base (groundwater contamination) 2. Aerojet General Corp. 3. Ogden Defense Depot (DLA)
N-Propyl Benzene	103-65-1	1. McClellan Air Force Base (groundwater contamination)
octachlorodibenzo-p-dioxin (OCDD)	3268-87-9	1. Castle Air Force Base (6 areas)
oxamyl	23135-22-0	1. Tracy Defense Depot (U.S. Army)
O-xylene	95-47-6	1. Edwards Air Force Base 2. McClellan Air Force Base (groundwater contamination) 3. Rocky Mountain Arsenal—U.S. Army
P,P-DDD	72-54-8	1. Camp Pendleton Marine Corps Base 2. McClellan Air Force Base (groundwater contamination)
P,P-DDE	72-55-9	1. Camp Pendleton Marine Corps Base 2. McClellan Air Force Base (groundwater contamination)
P,P-DDT	50-29-3	1. Camp Pendleton Marine Corps Base 2. McClellan Air Force Base (groundwater contamination)
parathion	56-38-2	1. Rocky Mountain Arsenal—U.S. Army
PCB-1248	12672-29-6	1. Lawrence Livermore National Lab (Site 300) 2. Travis Air Force Base
PCB-1248 (aroclor-1248)	12672-29-6	1. Travis Air Force Base

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
PCB-1254	11097-69-1	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> <li>2. Aerojet General Corp.</li> <li>3. Lawrence Livermore National Lab (Site 300)</li> <li>4. Travis Air Force Base</li> <li>5. Hill Air Force Base</li> </ol>
PCB-1260	11096-82-5	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> <li>2. Aerojet General Corp.</li> <li>3. Lowry Landfill</li> <li>4. Hill Air Force Base</li> </ol>
PCBs	1336-36-3	<ol style="list-style-type: none"> <li>1. Nineteenth Avenue Landfill</li> <li>2. Tucson International Airport Area</li> <li>3. Casmalia Resources</li> <li>4. McClellan Air Force Base (groundwater contamination)</li> <li>5. Castle Air Force Base (6 areas)</li> <li>6. March Air Force Base</li> <li>7. Norton Air Force Base (Landfill #2)</li> <li>8. Westinghouse Electric Corp. (Sunnyvale Plant)</li> <li>9. Lawrence Livermore National Lab (Site 300)</li> <li>10. Tracy Defense Depot (U.S. Army)</li> <li>11. Travis Air Force Base</li> <li>12. Lowry Landfill</li> <li>13. Rocky Mountain Arsenal—U.S. Army</li> <li>14. Air Force Plant PJKS</li> <li>15. Ogden Defense Depot (DLA)</li> </ol>
PCE	127-18-4	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Motorola, Inc. (52nd Street Plant)</li> <li>3. Indian Bend Wash Area</li> <li>4. Barstow Marine Corps Logistics Base</li> <li>5. El Toro Marine Corps Air Station</li> <li>6. Fresno Municipal Sanitary Landfill</li> <li>7. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>8. Fort Ord</li> <li>9. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>10. McClellan Air Force Base (groundwater contamination)</li> <li>11. Castle Air Force Base (6 areas)</li> <li>12. Aerojet General Corp.</li> <li>13. Lawrence Livermore National Lab (Site 300)</li> <li>14. Travis Air Force Base</li> <li>15. George Air Force Base</li> <li>16. Hill Air Force Base</li> </ol>
pentachlorobenzene	608-93-5	<ol style="list-style-type: none"> <li>1. Lowry Landfill</li> </ol>
pentachlorophenol	87-86-5	<ol style="list-style-type: none"> <li>1. Barstow Marine Corps Logistics Base</li> <li>2. Operating Industries, Inc., Landfill</li> <li>3. Koppers Co., Inc. (Oroville Plant)</li> <li>4. Louisiana-Pacific Corp.</li> <li>5. Tracy Defense Depot (U.S. Army)</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
pentachlorophenol ( <i>cont.</i> )		6. Travis Air Force Base 7. Lowry Landfill 8. Broderick Wood Products
perchlorate	14797-73-0	1. Apache Powder Co. 2. Edwards Air Force Base 3. El Toro Marine Corps Air Station 4. McClellan Air Force Base (groundwater contamination) 5. Jet Propulsion Laboratory (NASA) 6. Aerojet General Corp. 7. Lawrence Livermore National Lab (Site 300)
perchloroethene	127-18-4	1. Indian Bend Wash Area 2. Edwards Air Force Base
perchloroethylene (tetrachloroethylene)	127-18-4	1. Motorola, Inc. (52nd Street Plant) 2. McClellan Air Force Base (groundwater contamination) 3. Sand Creek Industrial 4. Broderick Wood Products
phenanthrene	85-01-8	1. Sharpe Army Depot 2. Fort Ord 3. Mather Air Force Base (AC&W Disposal Site) 4. McClellan Air Force Base (groundwater contamination) 5. Castle Air Force Base (6 areas) 6. Koppers Co., Inc. (Oroville Plant) 7. Tracy Defense Depot (U.S. Army) 8. Travis Air Force Base 9. Lowry Landfill 10. Broderick Wood Products
phenol	108-95-2	1. Fairchild Semiconductor Corp. (Mountain View Plant) 2. Intel Corp. (Mountain View Plant) 3. Raytheon Corp. 4. March Air Force Base 5. Tracy Defense Depot (U.S. Army) 6. Lowry Landfill 7. Marshall Landfill 8. Broderick Wood Products 9. GBF, Inc., Dump
phorate	298-02-2	1. Tracy Defense Depot (U.S. Army)
phosgene	75-44-5	1. Ogden Defense Depot (DLA)
plutonium-239	15117-48-3	1. Rocky Flats Plant (U.S. DOE)
plutonium-239/240		1. Rocky Flats Plant (U.S. DOE)
plutonium-240	14119-33-6	1. Rocky Flats Plant (U.S. DOE)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
polychlorinated biphenyls	1336-36-3	1. Edwards Air Force Base 2. Norton Air Force Base (Landfill #2) 3. Westinghouse Electric Corp. (Sunnyvale Plant) 4. Hill Air Force Base 5. Ogden Defense Depot (DLA)
potassium	7440-09-7	1. Sharpe Army Depot
propene	115-07-1	1. McClellan Air Force Base (groundwater contamination)
P-xylene	106-42-3	1. Rocky Mountain Arsenal—U.S. Army
pyrene	129-00-0	1. Sharpe Army Depot 2. Fort Ord 3. Mather Air Force Base (AC&W Disposal Site) 4. McClellan Air Force Base (groundwater contamination) 5. Castle Air Force Base (6 areas) 6. Koppers Co., Inc. (Orville Plant) 7. Tracy Defense Depot (U.S. Army) 8. Travis Air Force Base 9. Lowry Landfill 10. Broderick Wood Products 11. Tooele Army Depot (North Area)
radium	7440-14-4	1. Denver Radium Site
radium-226	13982-63-3	1. Norton Air Force Base (Landfill #2) 2. Lincoln Park 3. Denver Radium Site 4. United Nuclear Corp. 5. Homestake Mining Co. 6. Monticello Mill Tailings (U.S. DOE) 7. Monticello Radioactively Contaminated Properties
radium-228	15262-20-1	1. United Nuclear Corp. 2. Homestake Mining Co.
radon	10043-92-2	1. Denver Radium Site 2. Homestake Mining Co. 3. Monticello Mill Tailings (U.S. DOE)
radon-222	14859-67-7	1. Monticello Radioactively Contaminated Properties
RDX (hexahydro-1,3,5-trinitro-1,3,5-triazine)	121-82-4	1. Fort Ord 2. Castle Air Force Base (6 areas) 3. Lawrence Livermore National Lab (Site 300) 4. Tooele Army Depot (North Area)
ronnell	299-84-3	1. Tracy Defense Depot (U.S. Army)
sarin	107-44-8	1. Rocky Mountain Arsenal—U.S. Army

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
SEC-butyl benzene	135-98-9	1. McClellan Air Force Base (groundwater contamination)
selenium	7782-49-2	1. Phoenix-Goodyear Airport Area 2. Fresno Municipal Sanitary Landfill 3. Fort Ord 4. McClellan Air Force Base (groundwater contamination) 5. Castle Air Force Base (6 areas) 6. Operating Industries, Inc. Landfill 7. Norton Air Force Base (Landfill #2) 8. Tracy Defense Depot (U.S. Army) 9. Travis Air Force Base 10. Lincoln Park 11. Sand Creek Industrial 12. Denver Radium Site 13. United Nuclear Corp. 14. Homestake Mining Co. 15. Kennecott (North Zone) 16. Midvale Slag 17. Monticello Mill Tailings (U.S. DOE) 18. Murray Smelter
silver	7440-22-4	1. Phoenix-Goodyear Airport Area 2. Camp Pendleton Marine Corps Base 3. Sharpe Army Depot 4. Fort Ord 5. Mather Air Force Base (AC&W Disposal Site) 6. McClellan Air Force Base (groundwater contamination) 7. Louisiana-Pacific Corp. 8. Aerojet General Corp. 9. Iron Mountain Mine 10. Sacramento Army Depot 11. Norton Air Force Base (Landfill #2) 12. Travis Air Force Base 13. Lowry Landfill 14. Central City, Clear Creek 15. Hill Air Force Base 16. Midvale Slag 17. Murray Smelter 18. Tooele Army Depot (North Area)
simazine	122-34-9	1. Tracy Defense Depot (U.S. Army)
sodium	7440-23-5	1. Sharpe Army Depot 2. Monticello Mill Tailings (U.S. DOE)
sodium hydroxide	1310-73-2	1. Hill Air Force Base
styrene	100-42-5	1. El Toro Marine Corps Air Station 2. McClellan Air Force Base (groundwater contamination) 3. Castle Air Force Base (6 areas) 4. Operating Industries, Inc., Landfill 5. Lowry Landfill

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
styrene ( <i>cont.</i> )		6. Sand Creek Industrial 7. Indian Bend Wash Area
sulfate		1. Iron King Mine—Humboldt Smelter 2. Lawrence Livermore National Lab, Main Site (U.S. DOE) 3. Rocky Mountain Arsenal—U.S. Army 4. Homestake Mining Co. 5. Kennecott (North Zone) 6. Monticello Mill Tailings (U.S. DOE)
TBOS	4766-57-8	1. Lawrence Livermore National Lab (Site 300)
TCA	71-55-6	1. Indian Bend Wash Area 2. El Toro Marine Corps Air Station
TCE	79-01-6	1. Phoenix-Goodyear Airport Area 2. Indian Bend Wash Area 3. Tucson International Airport Area 4. El Toro Marine Corps Air Station 5. Fresno Municipal Sanitary Landfill 6. Lawrence Livermore National Lab, Main Site (U.S. DOE) 7. Fort Ord 8. Mather Air Force Base (AC&W Disposal Site) 9. McClellan Air Force Base (groundwater contamination) 10. Castle Air Force Base (6 areas) 11. Jet Propulsion Laboratory (NASA) 12. Aerojet General Corp. 13. Lawrence Livermore National Lab (Site 300) 14. Tracy Defense Depot (U.S. Army) 15. Travis Air Force Base 16. George Air Force Base 17. Rocky Mountain Arsenal—U.S. Army 18. Air Force Plant PJKS 19. Hill Air Force Base 20. Ogden Defense Depot (DLA)
tetrachloroethane	79-34-5	1. Sharpe Army Depot
tetrachloroethene	127-18-4	1. Phoenix-Goodyear Airport Area 2. Indian Bend Wash Area 3. Tucson International Airport Area 4. Yuma Marine Corps Air Station 5. Barstow Marine Corps Logistics Base 6. Camp Pendleton Marine Corps Base 7. Edwards Air Force Base 8. El Toro Marine Corps Air Station 9. Fort Ord 10. McClellan Air Force Base (groundwater contamination) 11. Castle Air Force Base (6 areas)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
tetrachloroethene ( <i>cont.</i> )		12. Fairchild Semiconductor Corp. (Mountain View Plant) 13. Intel Corp. (Mountain View Plant) 14. Raytheon Corp. 15. Jet Propulsion Laboratory (NASA) 16. Aerojet General Corp. 17. Sacramento Army Depot 18. Tracy Defense Depot (U.S. Army) 19. Sand Creek Industrial 20. Hill Air Force Base 21. Midvale Slag 22. Ogden Defense Depot (DLA)
tetrachloroethylene	127-18-4	1. Motorola, Inc. (52nd Street Plant) 2. Camp Pendleton Marine Corps Base 3. Fresno Municipal Sanitary Landfill 4. Sharpe Army Depot 5. Fort Ord 6. Mather Air Force Base (AC&W Disposal Site) 7. McClellan Air Force Base (groundwater contamination) 8. Castle Air Force Base (6 areas) 9. Operating Industries, Inc., Landfill 10. Raytheon Corp. 11. Sacramento Army Depot 12. Norton Air Force Base (Landfill #2) 13. Lawrence Livermore National Lab (Site 300) 14. Lowry Landfill 15. Rocky Mountain Arsenal—U.S. Army 16. Broderick Wood Products 17. Lee Acres Landfill (U.S. DOI) 18. Hill Air Force Base 19. GBF, Inc., Dump
tetryl	479-45-8	1. Fort Ord
thallium	7440-28-0	1. Camp Pendleton Marine Corps Base 2. Edwards Air Force Base 3. Sharpe Army Depot 4. Fort Ord 5. McClellan Air Force Base (groundwater contamination) 6. Castle Air Force Base (6 areas) 7. Operating Industries, Inc., Landfill 8. Iron Mountain Mine 9. March Air Force Base 10. Midvale Slag 11. Murray Smelter
thorium-230	14269-63-7	1. Denver Radium Site 2. Monticello Radioactively Contaminated Properties
tin	7440-31-5	1. Mather Air Force Base (AC&W Disposal Site)
TNT	118-96-7	1. Fort Ord

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
toluene	108-88-3	<ol style="list-style-type: none"> <li>1. Williams Air Force Base</li> <li>2. Nineteenth Avenue Landfill</li> <li>3. Indian Bend Wash Area</li> <li>4. Tucson International Airport Area</li> <li>5. Camp Pendleton Marine Corps Base</li> <li>6. Edwards Air Force Base</li> <li>7. El Toro Marine Corps Air Station</li> <li>8. Pacific Coast Pipe Lines</li> <li>9. Sharpe Army Depot</li> <li>10. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>11. Fort Ord</li> <li>12. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>13. McClellan Air Force Base (groundwater contamination)</li> <li>14. Castle Air Force Base (6 areas)</li> <li>15. Operating Industries, Inc., Landfill</li> <li>16. Koppers Co., Inc. (Oroville Plant)</li> <li>17. March Air Force Base</li> <li>18. Crazy Horse Sanitary Landfill</li> <li>19. Firestone Tire &amp; Rubber Co. (Salinas Plant)</li> <li>20. Westinghouse Electric Corp. (Sunnyvale Plant)</li> <li>21. Lawrence Livermore National Lab (Site 300)</li> <li>22. Tracy Defense Depot (U.S. Army)</li> <li>23. George Air Force Base</li> <li>24. Rocky Mountain Arsenal—U.S. Army</li> <li>25. Sand Creek Industrial</li> <li>26. Broderick Wood Products</li> <li>27. Prewitt Abandoned Refinery</li> <li>28. Hill Air Force Base</li> </ol>
total chromium	7440-47-3	<ol style="list-style-type: none"> <li>1. Tucson International Airport Area</li> <li>2. McClellan Air Force Base (groundwater contamination)</li> <li>3. Sacramento Army Depot</li> <li>4. Hill Air Force Base</li> </ol>
total extractable petroleum hydrocarbons (TEPH)	11270043	<ol style="list-style-type: none"> <li>1. Castle Air Force Base (6 areas)</li> </ol>
total PCBs	1336-36-3	<ol style="list-style-type: none"> <li>1. Edwards Air Force Base</li> <li>2. Tooele Army Depot (North Area)</li> </ol>
total xylenes	1330-20-7	<ol style="list-style-type: none"> <li>1. Edwards Air Force Base</li> <li>2. Sacramento Army Depot</li> <li>3. Broderick Wood Products</li> </ol>
toxaphene	8001-35-2	<ol style="list-style-type: none"> <li>1. Travis Air Force Base</li> <li>2. Sand Creek Industrial</li> </ol>
TPH-D(diesel)	68334-30-5	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> </ol>
TPH-G(gasoline)	8006-61-9	<ol style="list-style-type: none"> <li>1. McClellan Air Force Base (groundwater contamination)</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
trans-1,2-DCE	156-60-5	1. Lawrence Livermore National Lab (Site 300) 2. Rocky Mountain Arsenal—U.S. Army
trans-1,2-dichloroethene	156-60-5	1. Motorola, Inc. (52nd Street Plant) 2. Tucson International Airport Area 3. Edwards Air Force Base 4. Intel Corp. (Mountain View Plant) 5. Aerojet General Corp. 6. Lee Acres Landfill (U.S. DOI)
trans-1,2-dichloroethylene	156-60-5	1. Sharpe Army Depot 2. Raytheon Corp. 3. Rocky Mountain Arsenal—U.S. Army 4. Sand Creek Industrial 5. Hill Air Force Base 6. Tucson International Airport Area 7. Indian Bend Wash Area
trans-1,3-dichloropropene	10061-02-6	1. Indian Bend Wash Area
trichloroethane	74552-83-3	1. Indian Bend Wash Area 2. Lawrence Livermore National Lab, Main Site (U.S. DOE)
trichloroethylene	79-01-6	1. Motorola, Inc. (52nd Street Plant) 2. Tucson International Airport Area 3. El Toro Marine Corps Air Station 4. Sharpe Army Depot 5. Mather Air Force Base (AC&W Disposal Site) 6. McClellan Air Force Base (groundwater contamination) 7. Castle Air Force Base (6 areas) 8. Operating Industries, Inc. Landfill 9. Raytheon Corp. 10. Sacramento Army Depot 11. Lawrence Livermore National Lab (Site 300) 12. George Air Force Base 13. Rocky Mountain Arsenal—U.S. Army 14. Sand Creek Industrial 15. Broderick Wood Products 16. Lee Acres Landfill (U.S. DOI) 17. Hill Air Force Base 18. Ogden Defense Depot (DLA) 19. Phoenix-Goodyear Airport Area 20. GBF, Inc., Dump
trichlorofluoromethane	75-69-4	1. Phoenix-Goodyear Airport Area 2. Edwards Air Force Base 3. El Toro Marine Corps Air Station 4. Fresno Municipal Sanitary Landfill 5. McClellan Air Force Base (groundwater contamination) 6. Operating Industries, Inc., Landfill 7. Lawrence Livermore National Lab (Site 300) 8. Indian Bend Wash Area

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
triphenyl phosphate	115-86-6	1. McClellan Air Force Base (groundwater contamination)
tritium	10028-17-8	1. Lawrence Livermore National Lab, Main Site (U.S. DOE) 2. Lawrence Livermore National Lab (Site 300)
unexploded ordnance (UXO)	11270046	1. Fort Ord
uranium	7440-61-1	1. Lawrence Livermore National Lab (Site 300) 2. Lincoln Park Denver Radium Site 3. Homestake Mining Co. 4. Monticello Mill Tailings (U.S. DOE)
uranium-234	13966-29-5	1. Travis Air Force Base 2. Monticello Mill Tailings (U.S. DOE)
uranium-235	7440-61-1	1. Travis Air Force Base 2. Monticello Mill Tailings (U.S. DOE)
uranium-238	7440-61-1	1. Lawrence Livermore National Lab (Site 300) 2. Monticello Mill Tailings (U.S. DOE)
vanadium	7440-62-2	1. Apache Powder Co. 2. Sharpe Army Depot 3. Mather Air Force Base (AC&W Disposal Site) 4. McClellan Air Force Base (groundwater contamination) 5. Tracy Defense Depot (U.S. Army) 6. Lowry Landfill 7. Sand Creek Industrial 8. Rocky Flats Plant (U.S. DOE) 9. Homestake Mining Co. 10. Hill Air Force Base 11. Monticello Mill Tailings (U.S. DOE)
vanadium metal and or alloy	7440-62-2	1. Rocky Flats Plant (U.S. DOE)
vanadium pentoxide	1314-62-1	1. Apache Powder Co.
vinyl chloride	75-01-4	1. Motorola, Inc. (52nd Street Plant) 2. Indian Bend Wash Area 3. Tucson International Airport Area 4. Edwards Air Force Base 5. El Toro Marine Corps Air Station 6. Fresno Municipal Sanitary Landfill 7. Sharpe Army Depot 8. Fort Ord 9. Mather Air Force Base (AC&W Disposal Site) 10. McClellan Air Force Base (groundwater contamination) 11. Castle Air Force Base (6 areas) 12. Operating Industries, Inc., Landfill 13. Fairchild Semiconductor Corp. (Mountain View Plant) 14. Intel Corp. (Mountain View Plant)

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
vinyl chloride ( <i>cont.</i> )		<ol style="list-style-type: none"> <li>15. Raytheon Corp.</li> <li>16. Aerojet General Corp.</li> <li>17. March Air Force Base</li> <li>18. Norton Air Force Base (Landfill #2)</li> <li>19. Lawrence Livermore National Lab (Site 300)</li> <li>20. Travis Air Force Base</li> <li>21. Lowry Landfill</li> <li>22. Sand Creek Industrial</li> <li>23. Lee Acres Landfill (U.S. DOI)</li> <li>24. Hill Air Force Base</li> <li>25. Ogden Defense Depot (DLA)</li> </ol>
VX (O-ethyl S-[2-(diisopropylamino)ethyl] methylphosphonothioate)	50782-69-9	<ol style="list-style-type: none"> <li>1. Rocky Mountain Arsenal—U.S. Army</li> </ol>
xylene	1330-20-7	<ol style="list-style-type: none"> <li>1. Indian Bend Wash Area</li> <li>2. Pacific Coast Pipe Lines</li> <li>3. Sharpe Army Depot</li> <li>4. Lawrence Livermore National Lab, Main Site (U.S. DOE)</li> <li>5. Fort Ord</li> <li>6. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>7. Koppers Co., Inc. (Orville Plant)</li> <li>8. Firestone Tire &amp; Rubber Co. (Salinas Plant)</li> <li>9. Norton Air Force Base (Landfill #2)</li> <li>10. Lowry Landfill</li> <li>11. Rocky Mountain Arsenal—U.S. Army</li> <li>12. Broderick Wood Products</li> <li>13. Prewitt Abandoned Refinery</li> <li>14. Hill Air Force Base</li> </ol>
xylenes	1330-20-7	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Nineteenth Avenue Landfill</li> <li>3. Tucson International Airport Area</li> <li>4. Edwards Air Force Base</li> <li>5. El Toro Marine Corps Air Station</li> <li>6. Mather Air Force Base (AC&amp;W Disposal Site)</li> <li>7. McClellan Air Force Base (groundwater contamination)</li> <li>8. Castle Air Force Base (6 areas)</li> <li>9. Operating Industries, Inc., Landfill</li> <li>10. March Air Force Base</li> <li>11. Westinghouse Electric Corp. (Sunnyvale Plant)</li> <li>12. Lawrence Livermore National Lab (Site 300)</li> <li>13. Tracy Defense Depot (U.S. Army)</li> <li>14. Travis Air Force Base</li> <li>15. George Air Force Base</li> <li>16. Broderick Wood Products</li> </ol>
zinc	7440-66-6	<ol style="list-style-type: none"> <li>1. Phoenix-Goodyear Airport Area</li> <li>2. Edwards Air Force Base</li> <li>3. Sharpe Army Depot</li> <li>4. Fort Ord</li> </ol>

**TABLE B-1 (Cont.)**

Contaminant	CAS Number	Contaminated Sites
zinc ( <i>cont.</i> )		<ol style="list-style-type: none"><li>5. Mather Air Force Base (AC&amp;W Disposal Site)</li><li>6. McClellan Air Force Base (groundwater contamination)</li><li>7. Castle Air Force Base (6 areas)</li><li>8. Operating Industries, Inc., Landfill</li><li>9. Louisiana-Pacific Corp.</li><li>10. Aerojet General Corp.</li><li>11. Iron Mountain Mine</li><li>12. Sacramento Army Depot</li><li>13. Norton Air Force Base (Landfill #2)</li><li>14. Travis Air Force Base</li><li>15. Lawrence Livermore National Lab (Site 300)</li><li>16. George Air Force Base</li><li>17. Lowry Landfill</li><li>18. Lincoln Park</li><li>19. Rocky Mountain Arsenal—U.S. Army</li><li>20. Denver Radium Site</li><li>21. Central City, Clear Creek</li><li>22. Eagle Mine</li><li>23. AT&amp;SF (Albuquerque)</li><li>24. Midvale Slag</li><li>25. Murray Smelter</li><li>26. Ogden Defense Depot (DLA)</li></ol>

Source: EPA 2010, *Renewable Energy Interactive Mapping Tool*. Available at [http://www.epa.gov/renewableenergyland/mapping\\_tool.htm](http://www.epa.gov/renewableenergyland/mapping_tool.htm). Accessed Summer 2012.