

**TOXICOLOGICAL PROFILE FOR
TOTAL PETROLEUM HYDROCARBONS (TPH)**

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry

September 1999

DISCLAIMER

The use of company or product name(s) is for identification only and does not imply endorsement by the Agency for Toxic Substances and Disease Registry.

UPDATE STATEMENT

A Toxicological Profile for Total Petroleum Hydrocarbons (TPH) was released in September 1998. This edition supersedes any previously released draft or final profile.

Toxicological profiles are revised and republished as necessary, but no less than once every three years. For information regarding the update status of previously released profiles, contact ATSDR at:

Agency for Toxic Substances and Disease Registry
Division of Toxicology/Toxicology Information Branch
1600 Clifton Road NE, E-29
Atlanta, Georgia 30333

FOREWORD

This toxicological profile is prepared in accordance with guidelines developed by the Agency for Toxic Substances and Disease Registry (ATSDR) and the Environmental Protection Agency (EPA). The original guidelines were published in the *Federal Register* on April 17, 1987. Each profile will be revised and republished as necessary.

The ATSDR toxicological profile succinctly characterizes the toxicologic and adverse health effects information for the hazardous substance described therein. Each peer-reviewed profile identifies and reviews the key literature that describes a hazardous substance's toxicologic properties. Other pertinent literature is also presented, but is described in less detail than the key studies. The profile is not intended to be an exhaustive document; however, more comprehensive sources of specialty information are referenced.

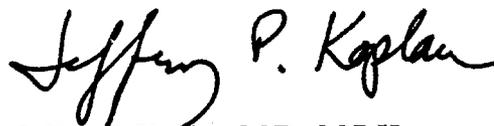
The focus of the profiles is on health and toxicologic information; therefore, each toxicological profile begins with a public health statement that describes, in nontechnical language, a substance's relevant toxicological properties. Following the public health statement is information concerning levels of significant human exposure and, where known, significant health effects. The adequacy of information to determine a substance's health effects is described in a health effects summary. Data needs that are of significance to protection of public health are identified by ATSDR and EPA.

Each profile includes the following:

- (A) The examination, summary, and interpretation of available toxicologic information and epidemiologic evaluations on a hazardous substance to ascertain the levels of significant human exposure for the substance and the associated acute, subacute, and chronic health effects;
- (B) A determination of whether adequate information on the health effects of each substance is available or in the process of development to determine levels of exposure that present a significant risk to human health of acute, subacute, and chronic health effects; and
- (C) Where appropriate, identification of toxicologic testing needed to identify the types or levels of exposure that may present significant risk of adverse health effects in humans.

The principal audiences for the toxicological profiles are health professionals at the Federal, State, and local levels; interested private sector organizations and groups; and members of the public.

This profile reflects ATSDR's assessment of all relevant toxicologic testing and information that has been peer-reviewed. Staff of the Centers for Disease Control and Prevention and other Federal scientists have also reviewed the profile. In addition, this profile has been peer-reviewed by a nongovernmental panel and is being made available for public review. Final responsibility for the contents and views expressed in this toxicological profile resides with ATSDR.



Jeffrey P. Koplan, M.D., M.P.H.
Administrator
Agency for Toxic Substances and
Disease Registry

*Legislative Background

The toxicological profiles are developed in response to the Superfund Amendments and Reauthorization Act (SARA) of 1986 (Public Law 99-499) which amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund). Section 211 of SARA also amended Title 10 of the U. S. Code, creating the Defense Environmental Restoration Program. Section 2704(a) of Title 10 of the U. S. Code directs the Secretary of Defense to notify the Secretary of Health and Human Services of not less than 25 of the most commonly found unregulated hazardous substances at defense facilities. Section 2704(b) of Title 10 of the U. S. Code directs the Administrator of the Agency for Toxic Substances and Disease Registry (ATSDR) to prepare a toxicological profile for each substance on the list provided by the Secretary of Defense under subsection (b).

CONTRIBUTORS

CHEMICAL MANAGER(S)/AUTHORS(S):

G. Daniel Todd, Ph.D.
ATSDR, Division of Toxicology, Atlanta, GA

Robert L. Chessin, M.S.P.H.
Research Triangle Institute, Research Triangle Park, NC

Joan Colman, Ph.D.
Syracuse Research Corporation, Syracuse, NY

THE PROFILE HAS UNDERGONE THE FOLLOWING ATSDR INTERNAL REVIEWS:

1. Health Effects Review. The Health Effects Review Committee examines the health effects chapter of each profile for consistency and accuracy in interpreting health effects and classifying end points.
3. Minimal Risk Level Review. The Minimal Risk Level Workgroup considers issues relevant to substance-specific minimal risk levels (MRLs), reviews the health effects database of each profile, and makes recommendations for derivation of MRLs.
4. Science Policy Oversight Committee. The SPOC reviews documents for consistency with ATSDR policy.
4. Data Needs Review. The Research Implementation Branch reviews data needs sections to assure consistency across profiles and adherence to instructions in the Guidance.

PEER REVIEW

A peer review panel was assembled for total petroleum hydrocarbons. The panel consisted of the following members:

1. Barbara Callahan, Ph.D., Director of Risk Assessment Services, Fluor Daniel GTI, Norwood, Massachusetts;
2. Michael Hutcheson, Ph.D, MPH, Deputy Director, Air and Water Toxics, Office of Research and Standards, Massachusetts Department of Environmental Protection, Boston, Massachusetts; and
3. Paul Kostecki, Ph.D., Professor, University of Massachusetts, School of Public Health, Amherst, Massachusetts.

These experts collectively have knowledge of total petroleum hydrocarbons' physical and chemical properties, toxicokinetics, key health end points, mechanisms of action, human and animal exposure, and quantification of risk to humans. All reviewers were selected in conformity with the conditions for peer review specified in Section 104(i)(13) of the Comprehensive Environmental Response, Compensation, and Liability Act, as amended.

Scientists from the Agency for Toxic Substances and Disease Registry (ATSDR) have reviewed the peer reviewers' comments and determined which comments will be included in the profile. A listing of the peer reviewers' comments not incorporated in the profile, with a brief explanation of the rationale for their exclusion, exists as part of the administrative record for this compound. A list of databases reviewed and a list of unpublished documents cited are also included in the administrative record.

The citation of the peer review panel should not be understood to imply its approval of the profile's final content. The responsibility for the content of this profile lies with the ATSDR.

CONTENTS

FOREWORD	v
CONTRIBUTORS	vii
PEER REVIEW	ix
LIST OF FIGURES	xv
LIST OF TABLES	xvii
1. PUBLIC HEALTH STATEMENT	1
1.1 WHAT ARE TOTAL PETROLEUM HYDROCARBONS?	1
1.2 WHAT HAPPENS TO TPH WHEN IT ENTERS THE ENVIRONMENT?	2
1.3 HOW MIGHT I BE EXPOSED TO TPH?	3
1.4 HOW CAN TPH ENTER AND LEAVE MY BODY?	3
1.5 HOW CAN TPH AFFECT MY BODY?	4
1.6 IS THERE A MEDICAL TEST TO DETERMINE IF I HAVE BEEN EXPOSED TO TPH?	5
1.7 WHAT RECOMMENDATIONS HAS THE FEDERAL GOVERNMENT MADE TO PROTECT HUMAN HEALTH?	6
1.8 WHERE CAN I GET MORE INFORMATION?	7
2. OVERVIEW OF TOTAL PETROLEUM HYDROCARBONS (TPH)	9
2.1 DEFINITION OF TOTAL PETROLEUM HYDROCARBONS	9
2.2 TOTAL PETROLEUM HYDROCARBONS ANALYSIS OVERVIEW	11
2.3 TPH FRACTIONS AND THE ATSDR APPROACH TO EVALUATING THE PUBLIC HEALTH IMPLICATIONS OF EXPOSURE TO TPH	12
3. IDENTITY AND ANALYSIS OF TOTAL PETROLEUM HYDROCARBONS	17
3.1 INTRODUCTION	17
3.2 CHEMICAL AND PHYSICAL INFORMATION	18
3.3 ANALYTICAL METHODS	24
3.3.1 Environmental Samples.	24
3.3.1.1 Soils and Sediments	33
3.3.1.2 Water and Waste Water	33
3.3.1.3 Air	34
3.3.2 Biological Samples	35
3.3.3 Adequacy of the Database	35
3.3.4 Ongoing Studies	37
4. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL	39

5. POTENTIAL FOR HUMAN EXPOSURE	57
5.1 OVERVIEW	57
5.2 RELEASES TO THE ENVIRONMENT	57
5.3 FATE AND TRANSPORT	68
5.3.1 Overview	68
5.3.2 Fate and Transport Processes	69
5.3.2.1 Bulk Oil Migration	69
5.3.2.2 Compound Migration	70
5.3.2.3 Biodegradation	73
5.3.3 Models	76
5.3.3.1 Transport Equations	78
5.3.3.2 Estimating Physical and Chemical Properties	79
5.3.3.3 Transport Models	80
5.4 LEVELS IN THE ENVIRONMENT	81
5.5 ADEQUACY OF THE DATABASE	88
5.5.1 Identification of Data Needs	88
5.5.2 Ongoing Studies	91
6. HEALTH EFFECTS	93
6.1 INTRODUCTION	93
6.1.1 TPH Definition and Issues	93
6.1.2 Existing Risk-Based Methods for TPH Health Assessment	96
6.1.3 Overview of the ATSDR Approach	99
6.2 DISCUSSION OF HEALTH EFFECTS BY FRACTION AND ROUTE OF EXPOSURE	102
6.2.1 Aromatic EC ₅ -EC ₉ Indicator Compounds	104
6.2.1.1 Inhalation Exposure	104
6.2.1.2 Oral Exposure	105
6.2.1.3 Dermal Exposure	110
6.2.2 Aromatic EC ₉ -EC ₁₆ Combined Fractions	110
6.2.2.1 Inhalation Exposure	114
6.2.2.2 Oral Exposure	115
6.2.2.3 Dermal Exposure	119
6.2.3 Aromatic EC ₁₆ -EC ₃₅ Combined Fractions	119
6.2.3.1 Inhalation Exposure	119
6.2.3.2 Oral Exposure	120
6.2.3.3 Dermal Exposure	122
6.2.4 Aliphatic EC ₅ -EC ₈ Combined Fractions	122
6.2.4.1 Inhalation Exposure	124
6.2.4.2 Oral Exposure	127
6.2.4.3 Dermal Exposure	127
6.2.5 Aliphatic EC ₈ -EC ₁₆ Combined Fractions	129
6.2.5.1 Inhalation Exposure	130
6.2.5.2 Oral Exposure	130
6.2.5.3 Dermal Exposure	132

6.2.6	Aliphatic EC _{>16} -EC ₃₅ Combined Fractions	132
6.2.6.1	Inhalation Exposure	134
6.2.6.2	Oral Exposure	134
6.2.6.3	Dermal Exposure	135
6.3	DISCUSSION OF HEALTH EFFECTS FOR WHOLE PETROLEUM PRODUCTS	135
6.3.1	Jet Fuels	135
6.3.2	Fuel Oils	139
6.3.3	Automotive Gasoline	141
6.3.4	Various Petroleum Refinery Streams	143
6.3.5	Stoddard Solvent	143
6.3.6	Mineral-Based Crankcase Oil	143
6.3.7	Mineral Oil Hydraulic Fluids	145
6.3.8	Asphalt	145
6.3.9	Crude Oil	146
6.4	TOXICOKINETICS	146
6.4.1	Absorption	149
6.4.1.1	Inhalation Exposure	149
6.4.1.2	Oral Exposure	151
6.4.1.3	Dermal Exposure	151
6.4.2	Distribution	152
6.4.3	Metabolism	155
6.4.4	Elimination and Excretion	157
6.4.5	Physiologically Based Pharmacokinetic (PBPK)/Pharmacodynamic (PD) Models	158
6.5	MECHANISM OF ACTION	159
6.5.1	Pharmacokinetics Mechanisms	159
6.5.2	Mechanisms of Toxicity	160
6.5.3	Animal-to-Human Extrapolations	161
6.6	SELECTION OF FRACTION-SPECIFIC HEALTH EFFECTS CRITERIA	162
6.6.1	Overview	162
6.6.2	Minimal Risk Levels, Critical Effects, and Cancer Assessments for Fractions of TPH	165
6.7	RELEVANCE TO PUBLIC HEALTH	178
6.8	BIOMARKERS OF EXPOSURE AND EFFECT	182
6.8.1	Biomarkers Used to Identify or Quantify Exposure to TPH	183
6.8.2	Biomarkers Used to Characterize Effects Caused by TPH	184
6.9	INTERACTIONS WITH OTHER SUBSTANCES	185
6.10	POPULATIONS THAT ARE UNUSUALLY SUSCEPTIBLE	186
6.11	METHODS FOR REDUCING TOXIC EFFECTS	188
6.11.1	Reducing Peak Absorption Following Exposure	189
6.11.2	Reducing Body Burden	189
6.11.3	Interfering with the Mechanism of Action for Toxic Effects	189
6.12	ADEQUACY OF THE DATABASE	190
7.	REGULATIONS AND ADVISORIES	193
8.	REFERENCES	201
9.	GLOSSARY	225

APPENDICES

A. MRLS AND CANCER CLASSIFICATION FOR TPH COMPONENTS AND
WHOLE PRODUCTS A-1

B USER'S GUIDE B-1

C ACRONYMS, ABBREVIATIONS, AND SYMBOLS C-1

D PETROLEUM PRODUCT COMPOSITION D-1

E IDENTITY, COMPONENTS, AND CHEMICAL/PHYSICAL PROPERTIES OF
SELECTED PETROLEUM PRODUCTS E-1

INDEX I-1

LIST OF FIGURES

5-1	State Density of NPL Sites with TPH Contamination	58
5-2	Risk Based Corrective Action Process Flow Chart	83
6-1	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Benzene—Inhalation	106
6-2	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Toluene—Inhalation	107
6-3	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Ethylbenzene—Inhalation	108
6-4	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Mixed Xylene—Inhalation	109
6-5	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Benzene—Oral	111
6-6	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Toluene and Ethylbenzene—Oral	112
6-7	Aromatic EC ₅ -EC ₉ Exposures Associated with Health Effects - Xylenes—Oral	113
6-8	Aromatic EC _{>9} -EC ₁₆ Exposures Associated with Health Effects—Inhalation	116
6-9	Aromatic EC _{>8} -EC ₁₆ Exposures Associated with Health Effects—Oral	118
6-10	Aromatic EC _{>16} -EC ₃₅ Exposures Associated with Health Effects—Inhalation	121
6-11	Aromatic EC _{>16} -EC ₃₅ Exposures Associated with Health Effects—Oral	123
6-12	Aliphatic EC ₅ -EC ₈ Exposures Associated with Health Effects—Inhalation	126
6-13	Aliphatic EC ₅ -EC ₈ Exposures Associated with Health Effects—Oral	128
6-14	Aliphatic EC _{>8} -EC ₁₆ Exposures Associated with Health Effects—Inhalation	131
6-15	Aliphatic EC _{>8} -EC ₁₆ Exposures Associated with Health Effects—Oral	133
6-16	Aliphatic EC _{>16} -EC ₃₅ Exposures Associated with Health Effects—Oral	136

LIST OF TABLES

2-1	Representative Physical Parameters for TPH Analytical Fractions Based on Correlation to Relative Boiling Point Index	14
2-2	ATSDR TPH Fractions and Representative Compounds	15
3-1	ATSDR Profiles with Information on Analytical Methods Relevant to Petroleum Products	19
3-2	Summary of Conventional TPH Methods	26
3-3	Analytical Methods for Determining Total Petroleum Hydrocarbons in Environmental Samples	28
3-4	Summary of Gas Chromatographic TPH Methods	31
3-5	Analytical Methods for Determining Total Petroleum Hydrocarbons in Biological Samples	36
4-1	U.S. Annual Refinery Output	43
4-2	Crude Oil Production Trends by State	44
4-3	Barrel Oil Equivalents of Petroleum Liquid Fuels	45
4-4	1997 U.S. Refinery Output of Major Products as Percentages of Total Refinery Output	46
4-5	U.S. Petroleum Imports for 1978 and 1998	48
4-6	U.S. Petroleum Exports for 1978 and 1998	49
4-7	U.S. Petroleum Demand for 1978 and 1998	50
4-8	Petroleum Use Patterns by Sectors for 1995	51
5-1	Total Number of Oil Spills by Size: 1984–1996	61
5-2	Total Number of Oil Spills from Vessels: 1984–1996	62
5-3	Total Number of Oil Spills from Facilities: 1984–1996	63
5-4	Nature of Oil Spill by Material or Product: 1984–1996	64
5-5	Estimated Releases from Components of the Oil System	66
5-6	Selected Soil and Groundwater Models	77
5-7	Representative Physical Parameters for TPH Fractions, Based on Correlation to Relative Boiling Point Index	82
5-8	Comparison of Select Hydrocarbon Solubilities for JP-4	86
5-9	Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX) Concentrations in Water Equilibrated with Various Petroleum Products	87
6-1	Fraction-Specific Provisional Inhalation MRLs and Critical Effects	163
6-2	Fraction-Specific Provisional Oral MRLs and Critical Effects	164
6-3	Inhalation MRLs, Critical Effects, and EPA Cancer Assessments for Aromatic EC ₅ –EC ₉ Fraction	166
6-4	Oral MRLs, Critical Effects, and EPA Cancer Assessments for Aromatic EC ₅ –EC ₉ Fraction	167
6-5	Inhalation MRLs, Critical Effects, and EPA Cancer Assessments for Aromatic EC ₉ –EC ₁₆ Fraction	169
6-6	Oral MRLs, Critical Effects, and EPA Cancer Assessments for Aromatic EC ₉ –EC ₁₆ Fraction	170

6-7	Oral MRLs, Critical Effects, and EPA Cancer Assessments for Aromatic EC _{>16} -EC ₃₅ Fraction	172
6-8	Inhalation, Critical Effects, MRLs and EPA Cancer Assessments for Aromatic EC ₅ -EC ₈ Fraction	174
6-9	Inhalation, Critical Effects, MRLs and EPA Cancer Assessments for Aliphatic EC _{>8} -EC ₁₆ Fraction	176
6-10	Oral MRLs, Critical Effects, and EPA Cancer Assessments for Aliphatic EC _{>8} -EC ₁₆ Fraction	177
6-11	Oral MRLs, Critical Effects, and EPA Cancer Assessments of Aliphatic EC _{>16} -EC ₃₅ Fraction	179
7-1	Regulations and Guidelines Applicable to Total Petroleum Hydrocarbons	195
A-1	Minimal Risk Levels and Cancer Classification for TPH Constituents, Compounds and Whole Products	A-1
D-1	Petroleum Product Composition	D-2
E-1.a	Chemical Identity of Gasoline	E-2
E-1.b	Major Hydrocarbon Components of Gasoline	E-3
E-1.c	Physical and Chemical Properties of Gasoline	E-8
E-2.a	Chemical Identity of Stoddard Solvent	E-9
E-2.b	Possible Formulations of Stoddard Solvent (Percent)	E-10
E-2.c	Physical and Chemical Properties of Stoddard Solvent	E-12
E-3.a	Chemical Identity, Composition and Chemical/Physical Properties of JP-4	E-13
E-3.b	Typical Hydrocarbon Composition of JP-4 Jet Fuel	E-14
E-3.c	Physical and Chemical Properties of JP-4	E-18
E-4.a	Chemical Identity of Fuel Oils	E-19
E-4.b	Analysis of Fuel Oils	E-20
E-4.c	Physical and Chemical Properties of Fuel Oils	E-21
E-5.a	Chemical Identity of Mineral-Based Crankcase Oil	E-22
E-5.b	Concentration of Components in Used Mineral-Based Crankcase Oil	E-23
E-5.c	Physical and Chemical Properties of Mineral-based Crankcase Oils	E-24
E-6.a	Chemical Identity of Mineral Oil	E-25
E-6.b	Physical and Chemical Properties of Mineral Oil	E-26