

CONTENTS

ENVIRONMENTAL HEALTH CRITERIA FOR THALLIUM

PREAMBLE	9
1. SUMMARY	19
1.1 Identity, physical and chemical properties, and analytical methods	19
1.2 Sources of human and environmental exposure	19
1.3 Environmental transport, distribution and transformation	21
1.4 Environmental levels and human exposure	21
1.5 Kinetics and metabolism in laboratory animals and humans	22
1.6 Effects on laboratory mammals and <i>in vitro</i> test systems	23
1.7 Effects on humans	24
1.8 Human dose-response relationship	27
1.9 Effects on other organisms in the laboratory and field	27
2. IDENTITY, PHYSICAL AND CHEMICAL PROPERTIES, AND ANALYTICAL METHODS	29
2.1 Identity	29
2.2 Physical and chemical properties	29
2.3 Conversion factor	33
2.4 Analytical methods	33
2.4.1 Sampling and sample preparation	33
2.4.2 Methods of determination	35
2.4.2.1 Atomic absorption spectrometry	35
2.4.2.2 Inductively coupled plasma - mass spectrometry	40
2.4.2.3 Other methods	41
2.4.3 Quality control and quality assurance	42
2.4.4 Conclusions	43
3. SOURCES OF HUMAN AND ENVIRONMENTAL EXPOSURE	45
3.1 Natural occurrence	45
3.2 Anthropogenic sources	45
3.2.1 Production levels and processes	45

3.2.2	Uses	45
3.2.3	Emissions from industrial sources	47
3.2.3.1	Metal production industries	49
3.2.3.2	Power-generating plants	49
3.2.3.3	Brickworks and cement plants	50
3.2.3.4	Sulfuric acid plants	51
4.	ENVIRONMENTAL TRANSPORT, DISTRIBUTION AND TRANSFORMATION	52
4.1	Transport and distribution between media	52
4.1.1	Transport and distribution in air, water and soil	52
4.1.2	Soil-vegetation transfer	54
4.1.2.1	Factors affecting soil-vegetation transfer	54
4.1.2.2	Absorption by plants	55
4.1.2.3	Distribution in plants	57
4.2	Biotransformation	59
4.3	Interaction with other physical, chemical, or biological factors	59
5.	ENVIRONMENTAL LEVELS AND HUMAN EXPOSURE	60
5.1	Environmental levels	60
5.1.1	Air	60
5.1.2	Water	61
5.1.2.1	Areas not contaminated by thallium	61
5.1.2.2	Areas contaminated by thallium from industrial sources	61
5.1.3	Rocks, soil and sediment	64
5.1.3.1	Areas not contaminated by thallium	64
5.1.3.2	Areas contaminated by thallium from industrial sources	66
5.1.4	Plants and animals	68
5.1.4.1	Plants	69
5.1.4.2	Animals	77
5.2	General population exposure	87
5.3	Occupational exposure during manufacture, formulation or use	89
6.	KINETICS AND METABOLISM	90
6.1	Absorption	90
6.1.1	Animals	90

6.1.1.1	Aquatic animals	90
6.1.1.2	Terrestrial animals	90
6.1.2	Humans	91
6.2	Distribution	92
6.2.1	Animals	92
6.2.1.1	Distribution after administration of a single dose	93
6.2.1.2	Distribution after long-term sublethal administration	98
6.2.1.3	Transplacental transfer of thallium	99
6.2.2	Humans	101
6.2.2.1	Increased concentrations after lethal poisoning	101
6.2.2.2	Increased concentrations after long-term sublethal poisoning	110
6.2.2.3	Transplacental transfer of thallium	113
6.3	Metabolic transformation	114
6.4	Elimination and excretion	114
6.4.1	Animals	114
6.4.2	Humans	115
6.4.3	Methods to estimate daily intake of thallium	116
6.5	Retention and turnover (Biological half-life)	116
6.5.1	Animals	116
6.5.2	Humans	117
6.6	Kinetics at the cellular level	118
7.	EFFECTS ON LABORATORY MAMMALS AND <i>IN VITRO</i> TEST SYSTEMS	119
7.1	Single exposure	119
7.1.1	Toxicity and symptoms	119
7.1.2	Effects on various organs	124
7.2	Short-term exposure	125
7.2.1	Toxicity and symptoms	125
7.2.2	Effects on various organs	126
7.3	Long-term exposure: chronic toxicity	126
7.3.1	Toxicity and symptoms	126
7.3.2	Effects on various organs	129
7.4	Skin and eye irritation	129
7.4.1	Skin and hair	129
7.4.2	Eye	131
7.5	Reproductive toxicity, embryotoxicity and teratogenicity	131
7.5.1	Gonadotoxic effects	131
7.5.2	Embryotoxicity and teratogenicity	132

7.5.2.1	Chickens	132
7.5.2.2	Mammals	133
7.5.2.3	Delayed effects on development of offspring	135
7.6	Mutagenicity and related end-points	136
7.7	Carcinogenicity	137
7.8	Neurotoxicity	137
7.8.1	Central nervous system	137
7.8.1.1	Histology and ultrastructure	137
7.8.1.2	Electrophysiological and biochemical investigations	138
7.8.1.3	Behavioural toxicology	139
7.8.2	Peripheral nervous system	139
7.8.2.1	Histology and ultrastructure	140
7.8.2.2	Electrophysiological and biochemical investigations	141
7.9	<i>In vitro</i> test systems: cell lines	142
7.10	Factors modifying toxicity	142
7.10.1	Enhancement of elimination	142
7.10.2	Selenium	143
7.11	Mechanisms of toxicity - mode of action	143
8.	EFFECTS ON HUMANS	147
8.1	General population exposure	147
8.1.1	Acute toxicity	147
8.1.2	Effects of long-term exposure: chronic toxicity	152
8.2	Occupational exposure	153
8.3	Subpopulations at special risk	154
8.4	Target organs in intoxicated humans: pathomorphology and pathophysiology	155
8.4.1	Gastrointestinal tract and renal system	155
8.4.2	Cardiovascular system	156
8.4.3	Skin and hair	157
8.4.4	Nervous system	158
8.4.4.1	Central nervous system	158
8.4.4.2	Peripheral nervous system	159
8.4.5	Other organs	162
8.5	Special effects	162
8.5.1	Reproduction and developmental effects	162
8.5.2	Carcinogenicity	164
8.5.3	Immunotoxicological effects	164
8.6	Factors modifying toxicity: enhancement of elimination	164

8.7	Protective measures against excessive occupational exposure	166
9.	EFFECTS ON OTHER ORGANISMS IN THE LABORATORY AND FIELD	169
9.1	Microorganisms	169
9.2	Aquatic organisms	171
9.2.1	Plants	172
9.2.2	Animals	177
9.3	Terrestrial organisms	182
9.3.1	Plants	182
9.3.1.1	Plant photosynthesis	182
9.3.1.2	Cytotoxic effects	189
9.3.1.3	Growth of plants	189
9.3.1.4	Different sensitivities to thallium(I) and thallium (III)	191
9.3.1.5	Concentration of trace elements	191
9.3.1.6	Sensitivity of plants	195
9.3.2	Wild animals	196
9.3.3	Household pets and farm animals	197
10.	EVALUATION	201
10.1	Evaluation of human health risks	201
10.1.1	Exposure levels	201
10.1.2	Kinetics	202
10.1.3	Toxic effects	203
10.1.4	Dose-response relationship (animals)	204
10.1.5	Dose-response relationship (humans)	205
10.2	Evaluation of the effects of thallium on the environment	207
11.	CONCLUSIONS AND RECOMMENDATIONS	209
12.	FURTHER RESEARCH	211
	REFERENCES	213
	RESUME	249
	RESUMEN	263