Contents

Foreword by C.R. Krishna Murti xiii

Foreword by Michel J. Mercier xiv

Preface by Norton Nelson xv

Acknowledgements xvii

Scientific Group on Methodologies for the Safety Evaluation of Chemicals xviii

Participants of the Workshop xxi

PART A JOINT REPORT

1 Introduction, General Conclusions, and Recommendations 3
- 1.1 Introduction 3
- 1.2 General Conclusions 4
- 1.3 General Recommendations 6
- 1.4 Reference 7

2 Exposure Measurements 9
- 2.1 Definition of Exposure 10
- 2.2 Objectives of Exposure Assessment 12
- 2.3 Approaches for Determining Exposures 13
  - 2.3.1 Direct Approach 14
  - 2.3.2 Indirect Approach 14
- 2.4 Study Designs 15
  - 2.4.1 Direct Approach 15
    - 2.4.1.1 *Improvement of Survey Response Rate in the Direct Approach* 16
  - 2.4.2 Study Design: Indirect Approach for Human Exposure 17
    - 2.4.2.1 *Human Exposure to Air Pollution* 18
- 2.6 Human Gastro-intestinal and Skin Exposure 21
  - 2.6.1 Multimedia Exposure 22
- 2.7 Non-human Exposure 22

2.8 Uses of Existing Data 23
2.9 Recommendations 25
2.10 References 27

3 Modeling of Transport and Alteration of Chemicals 29
3.1 The Use of Models in Exposure Assessment 29
3.2 Stages of Modeling Processes 30
3.3 Summary of Models 31
3.3.1 Geographical 32
3.3.2 Atmosphere 32
3.3.3 Hydrosphere 33
3.3.4 Compartmental Models 33
3.3.5 Terminology 34
3.4 When are Simple Models Applicable? 35
3.5 The Limitations of Modeling of Transport and Fate 36
3.5.1 Basic Adequacy of the Models 36
3.5.2 Coefficient Estimation and Field Measurements 37
3.5.3 Mathematical and Numerical Problems 38
3.5.4 Importance of Chemical Speciation 38
3.6 Estimation Methods 39
3.7 Laboratory/Field Consistency of Coefficients 40
3.8 Uncertainty of Transfer Coefficients 41
3.9 Alternative Approaches to Validation 42
3.10 Examples of Exposure Calculation 43
3.11 Conclusions 45
3.12 Recommendations 46
3.13 References 47

4 Biological Monitoring of Exposure to Chemicals 49
4.1 Toxicokinetics 52
4.1.1 Kinetic Considerations 53
4.1.2 Toxicokinetics and Exposure Assessment 56
4.1.3 Development of General Strategies 57
4.1.4 Quality Assurance 58
4.1.5 Conclusions 59
4.1.6 Recommendations 59
4.2 Determination of Internal Dose 59
4.2.1 Analysis of Elements 59
4.2.2 Analysis of Biological Materials for Parent Chemicals and their Metabolites 60
4.2.3 Recommendations 61
4.3 Biological Exposure Markers 62
4.3.1 Biological Markers as Indicators of Exposure to Carcinogens and Mutagens 64

4.3.2 Blood Analysis for Biological Effects of Mutagens and Carcinogens 66
4.3.2.1 *Non-specific Biological Exposure Markers* 67
4.3.2.2 *Specific Methods of Macromolecular Adduct Determination* 68
4.4.2.3 *Urine and Faecal Analysis for Biological Effects of Mutagens and Carcinogens* 71
4.3.3 Biological Markers as Indicators of Exposure in Non-human Targets 72
4.3.3.1 *In Animals* 72
4.3.3.2 *In Terrestrial Plants* 72
4.4 Advantages and Limitations of Biological Markers 73
4.4.1 Epidemiology 74
4.4.2 Animal Toxicology 75
4.4.3 Clinical, Preventive, Occupational Medicine 76
4.4.4 Limitations of Biological Markers 77
4.4.5 Criteria for Biological Markers 77
4.4.6 Relative Value of Chemical Analysis and Biological Responses for Ecological Monitoring 78
4.5 Ecological Responses as Indicators of Exposure 80
4.6 Conclusions 83
4.7 Recommendations 84
4.8 References 86

5 Analytical Methods 89
5.1 Air 89
5.1.1 Personal Exposure Monitors 89
5.1.1.1 *Gases* 91
5.1.1.2 *Particles* 94
5.1.1.3 *Filter Media* 100
5.1.2 Analysis of the Collected Atmospheric Aerosols 100
5.1.2.1 *Mass Analysis* 100
5.1.2.2 *Elemental Analysis* 101
5.1.2.3 *Energy Dispersive X-Ray Fluorescence Analysis* 101
5.1.2.4 *Proton Induced X-Ray Emission Analysis (PIXE)* 102
5.1.2.5 *Instrumental Neutron Activation Analysis* 102
5.1.2.6 *Atomic Absorption Spectrometry Analysis* 103
5.1.2.7 *Acidity Measurements* 104
5.1.2.8 *Analysis of Soluble Ionic Species* 104
5.1.2.9 *Carbon Analysis* 104
5.1.3 Conclusions 107
5.1.4 Recommendations 107
5.1.5 References 110

PART B CONTRIBUTED CHAPTERS

Techniques to Estimate Potential Exposures to Chemicals in the Environment 115
John D. Spengler and Lance A. Wallace

Geographically Based Models for Surface and Estuarine Waters and River/Aquifer Interfaces 131
Jean J. Fried

Time Integrated Compartment Models 151
Helge Gydesen

Modeling Chemical Transport in the Unsaturated Zone of the Subsurface 163
Warren T. Piver

Geographically-based Atmospheric Models 175
D. M. Whelpdale

Some Specifications of Multimedia Exposure Monitoring Assessment 195
K. A. Bustueva

Comparative Analysis of Indoor and Outdoor TSP Concentrations in Bombay, Toronto, and Zagreb 199
M. Fugas and H. W. de Koning

Micro-environment versus Personal Monitoring: Estimation of Exposure to Carbon Monoxide 205
Naihua Duan, Harold Sauls, and David Holland

Sampling and Analysis of Water to Assess Exposure 219
A. J. Dobbs and D. T. E. Hunt

Monitoring Systems for the Assessment of Dietary Intakes of Contaminants 233
G. K. Gheorghiev

Methods for Assessing Exposure of Insects 249
Vladimir Landa, Jan Sula, Frantisek Marec, Vladimir Metha, and Tomas Soldan

Biological Markers in Environmental Epidemiology: Constraints and Opportunities 267
Peter H. Gann, Devra L. Davis and Frederica Perera

Biological Monitoring in the Epidemiology of Chronic Effects of Cadmium in Workers 287
Janusz A. Indulski and Marek Jakubowski

Measurement of Macromolecular Adducts as Indicators of Carcinogen Exposure 297
R. Colin Garner

Role of Cytogenetic Surveillance To Assess Exposure to Carcinogens 309
Harri Vainio and Marja Sorsa

Measurement of Metabolites as Indicators of Exposure to Chemicals 323
Stuart A. Slorach

Direct Indicators of Exposure: Monitoring Chemicals in Tissues, Body Fluids, Urine and Exhaled Air 331
R. L. Zielhuis

Statistical Methods to Estimate Human Exposure to Environmental Pollutants 347
Mel Kollander

Demographic Patterns and Human Responses to Environmental Contaminants 357
Anatoli I. Yashin, Alan J. Bernstein and James W. Vaupel

Systemic Responses to Exposure to Chemicals and Their Responses as Indicators 371
C. R. Krishna Murti

Toxic Effects on Individuals, Populations and Aquatic Ecosystems and Indicators of Exposures to Chemicals 393
Thomas W. Duke and Donald I. Mount

Index 405

Tables

Table 2.1	Objectives of exposure assessment	13
Table 4.1	Illustrations of biological materials and analytical methods to monitor exposure to inorganic elements	60
Table 4.2	Illustrations of biological materials and analytical methods that can be used for monitoring exposure to chemicals	61
Table 4.3	Illustrations of biological materials and analytical methods that can be used for monitoring exposure to chemicals by investigating their metabolites	62
Table 4.4	Biological markers used to measure exposure in non-human targets	65
Table 4.5	Summary comparisons between chemical and biological monitoring for ecological systems	79
Table 5.1	16 PAHs in the Paris aerosol	106

Figures

Figure 2.1	Graphical representation of the exposure and dosage received by organism i at location (x,y,z) and time t to a pollutant in a carrier medium with concentration c (x,y,z,t)	11
Figure 2.2	Hypothetical frequency distribution of the exposures of a population over space and time	14
Figure 3.1	Flowchart of the modeling process	31
Figure 4.1	Classes of toxic effects in humans and non-human targets with indices of measures of impairment of function and of disease	50
Figure 4.2	Decision-tree model to ascertain the relevance of biological markers of injury	51
Figure 4.3	Relationship between exposure and toxicokinetic behaviour in organisms	53
Figure 5.1	Size distributions and origins of particles in ambient air	95