Monitoring for Health Hazards at Work

Fourth Edition

John W. Cherrie, BSc, PhD, FFOH
Institute of Occupational Medicine, Edinburgh, UK

Robin M. Howie, Grad Inst P, Dip Occ Hyg
Independent Consultant, Edinburgh, UK

Sean Semple, BSc, MSc, PhD
University of Aberdeen, UK

With contributions from Adrian Watson

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Contents

List of Illustrations, ix
List of Instruction Sheets, xiv
Preface, xvi
Acknowledgements, xviii
Units and Abbreviations, xix

Part 1 Introduction

Chapter 1 Occupational Hygiene and Risk Assessment, 3
  1.1 Introduction, 3
  1.2 Hazard and risk, 7
  1.3 Risk assessment, 7
  1.4 The stages of a risk assessment, 8
  1.5 Who should carry out risk assessment, 12

Chapter 2 Identifying Hazards, 13
  2.1 Introduction, 13
  2.2 Identifying hazards, 13
  2.3 Example of hazard identification, 15
  2.4 Conclusions arising from a hazard assessment, 16

Chapter 3 Exposure, Exposure Routes and Biological Monitoring, 18
  3.1 Introduction, 18
  3.2 Measuring exposure, 21
  3.3 Biological monitoring, 22
  3.4 Exposure assessment: what the legislation requires, 22
  3.5 Conclusions, 23

Chapter 4 The Exposure Context, 25
  4.1 Context for measurement, 25
  4.2 Sources of hazardous substances, 25
Contents

4.3 Dispersion through the workroom, 27
4.4 Receptor, 29
4.5 Jobs and tasks, 29

Chapter 5 Why Measure?, 31
5.1 Introduction, 31
5.2 Reasons for undertaking monitoring, 31

Chapter 6 How to Carry Out a Survey, 34
6.1 Introduction, 34
6.2 Planning the survey, 34
6.3 Workplace monitoring, 35
6.4 Monitoring strategies, 37
6.5 Quality assurance and quality control, 39
6.6 Survey checklists, 41

Chapter 7 Analysis of Measurement Results, 48
7.1 Introduction, 48
7.2 Dealing with variability in measurement results, 48
7.3 Summary statistics and data presentation, 50

Chapter 8 Hygiene Reports and Records, 53
8.1 Measurement records, 53
8.2 Survey reports, 55

Part 2 Inhalation Exposure

Chapter 9 Dust and Fibrous Aerosols, 63
9.1 Introduction, 63
9.2 Airborne dust, 63
9.3 Fibres, 65
9.4 Measurement of airborne dust levels, 66
9.5 Measurement of flow rate, 73
9.6 Pumps, 74
9.7 Direct-reading aerosol monitors, 75
9.8 Calibration of a rotameter or electronic flow calibrator by using the soap-bubble method, 76
9.9 The measurement of inhalable airborne dust, 80
9.10 The measurement of airborne respirable dust by using a cyclone sampler, 83
9.11 The sampling and counting of airborne asbestos fibres, 84
9.12 The choice of filter and filter holder to suit a specific dust, fume or mist, 88
9.13 To trace the behaviour of a dust cloud by using a Tyndall beam, 89
Chapter 10 Gases and Vapours, 92
10.1 Introduction, 92
10.2 Collection devices, 94
10.3 Containers, 100
10.4 Direct-reading instruments, 101
10.5 To measure personal exposure to solvent vapours using an adsorbent tube, 102
10.6 Sampling for gases by using a bubbler, 104
10.7 To measure the short-term airborne concentration of a gas by using a colorimetric detector tube, 106
10.8 To measure a vapour concentration using a diffusive sampler, 108

Chapter 11 Bioaerosols, 111
11.1 Introduction, 111
11.2 Classification of microorganisms, 112
11.3 Viruses, 112
11.4 Bacteria, 113
11.5 Moulds and yeasts, 114
11.6 Allergens, 115
11.7 Principles of containment, 115
11.8 Handling microorganisms, 116
11.9 Monitoring bioaerosols, 117
11.10 Measurement of endotoxins and allergens, 120
11.11 Interpretation of sample results, 121

Part 3 Dermal and Ingestion Exposure

Chapter 12 Dermal and Ingestion Exposure Measurement, 125
12.1 Introduction, 125
12.2 Occupations where dermal exposure is important, 125
12.3 Local and systemic effects, 126
12.4 How do we know if dermal exposure is an issue?, 127
12.5 What do we measure?, 128
12.6 Methods for dermal exposure measurement, 129
12.7 Sampling strategy, 132
12.8 Liquids and solids, 132
12.9 Biomonitoring and modelling of dermal exposure, 134
12.10 From exposure to uptake, 135
12.11 Controlling dermal exposure, 136
12.12 Inadvertent ingestion exposure, 136

Part 4 Physical Agents

Chapter 13 Noise, 143
13.1 Introduction, 143
Contents

13.2 Pressure and magnitude of pressure variation, 143
13.3 Frequency, 144
13.4 Duration, 147
13.5 Occupational exposure limits, 147
13.6 Equipment available, 148
13.7 Sound level meters and personal noise dosimeters, 148
13.8 Personal noise dosimeters, 151
13.9 Calibration, 152
13.10 To measure workplace noise using a SLM, 153
13.11 To measure workplace noise using a PND, 155
13.12 To measure the spectrum of a continuous noise by octave band analysis, 157
13.13 To determine the degree of noise exposure and the actions to take, 159

Chapter 14 Vibration, 161
14.1 Introduction, 161
14.2 Vibration, 163
14.3 Occupational exposure limits, 165
14.4 Risk assessment, 165
14.5 Measurements and measurement equipment, 166
14.6 To measure hand–arm vibration, 167
14.7 Control of vibration, 171

Chapter 15 Heat and Cold, 173
15.1 Introduction, 173
15.2 Heat stress, 175
15.3 Measurement equipment, 176
15.4 Personal monitoring, 181
15.5 Measurement of the thermal environment, 182
15.6 Predicted Heat Strain Index, 185
15.7 Risk assessment strategy, 186
15.8 Cold, 188
15.9 To calculate the wind chill factor, 189

Chapter 16 Lighting, 191
16.1 Introduction, 191
16.2 Lighting Standards, 192
16.3 Equipment available, 193
16.4 Calibration, 193
16.5 To measure lighting, 194
16.6 Control, 197

Chapter 17 Ionising Radiation, 199
17.1 Introduction, 199
17.2 Ionising radiation, 200
17.3 Background radiation, 201
17.4 Basic concepts and quantities, 201
17.5 Types of radiation, 202
17.6 Energy, 204
17.7 Activity, 204
17.8 Radiation dose units, 205
17.9 Dose limits, 206
17.10 Derived limits, 207
17.11 Procedures to minimise occupational dose, 207
17.12 Personal dosimetry and medical surveillance, 209

Chapter 18 Non-Ionising Radiation, 216
18.1 Introduction, 216
18.2 Ultraviolet radiation, 218
18.3 Infrared radiation, 220
18.4 Microwaves and radiowaves, 220
18.5 Lasers, 222

Part 5 Assessing the Effectiveness of Control

Chapter 19 Introduction to Control, 227
19.1 Introduction, 227
19.2 Specific control measures, 228
19.3 The effectiveness of control measures, 231

Chapter 20 Ventilation, 233
20.1 Introduction, 233
20.2 Air pressure, 234
20.3 Measurement equipment, 235
20.4 Ventilation measurement records, 242
20.5 Measurement of air flow in ducts, 246
20.6 Measurement of pressure in ventilation systems, 252
20.7 To measure the face velocity on a booth or hood, 254
20.8 To measure the face velocity on a fume cupboard, 255
20.9 To measure the performance of a suction inlet, 257

Chapter 21 Personal Protective Equipment, 260
21.1 Introduction, 260
21.2 Components of an effective PPE programme, 260
21.3 Face-fit testing using a particle counter, 269

Part 6 Risk Assessment and Risk Communication

Chapter 22 Risk Assessment, 275
22.1 Introduction, 275
22.2 Identify all hazardous substances or agents, 276
22.3 Identify the likely levels of exposure, 276
22.4 Identify all persons likely to be exposed, 278
22.5 Assess whether the exposures are likely to cause harm, 279
22.6 Consider elimination or substitution, 279
22.7 Define additional control measures necessary to reduce the harm to acceptable levels, 280

Chapter 23 Risk Communication, 282
   23.1 Introduction, 282
   23.2 Risk perception, 282
   23.3 Trust, 283
   23.4 Communication, 284
   23.5 An example of quantitative risk assessment to aid risk communication, 285

Equipment Suppliers, 288
Chemical Analytical Services, 290
Index, 291
List of Illustrations

1.1 An idealized exposure–response relationship.
3.1 A simple conceptual model of exposure to hazardous substances: (a) inhalation; (b) dermal; (c) ingestion; (d) injection.
4.1 The ratio of near- (NF) to far-field (FF) exposure levels in different conditions.
4.2 Exposure over a working shift.
7.1 Results from ten measurements of inhalable dust in a packing plant.
7.2 Results from 100 measurements of inhalable dust in a packing plant.
7.3 A log–probability plot showing data from ten measurements of exposure during bag filling.
9.2 Dust sampling equipment worn by operator, with IOM inhalable sampler in blown-up inset. (Reproduced with permission from SKC Ltd.)
9.6 The MRE 113 respirable dust sampler (Reproduced with permission Monitoring for Health Hazards at Work, 3rd edition, by Indira Ashton and Frank S. Gill, Blackwell Publishers Ltd., 2000, p. 9.)
9.7 The cowl sampler used for asbestos and other fibrous dusts. (Reproduced with permission from Occupational Hygiene, 3rd edition, edited by Kerry
List of Illustrations


9.9 An electronic flow calibrator. (Reproduced with permission from Casella Measurement Ltd.)

9.10 Apparatus used to calibrate a rotameter. (Reproduced with permission Monitoring for Health Hazards at Work, 3rd edition, by Indira Ashton and Frank S. Gill, Blackwell Publishers Ltd., 2000, p. 16.)

9.11 Typical rotameter calibration chart.


9.13 Acetone vapouriser used to prepare samples for microscopic analysis. (Reproduced with permission from JS Holdings.)


10.1 A single-gas detector with optional datalogger. (Reproduced with permission from Draeger Safety UK Ltd.)

10.2 Typical impinger samplers (SKC Ltd). (Reproduced with permission Monitoring for Health Hazards at Work, 3rd edition, by Indira Ashton and Frank S. Gill, Blackwell Publishers Ltd., 2000, p. 54.)

10.3 Adsorbent tubes. (Reproduced with permission from SKC Ltd.)

10.4 Badge type diffusive sampler. (Reproduced with permission from 3M United Kingdom PLC.)

10.5 Tube-type diffusive sampler. (Reproduced with permission from Draeger Safety UK Ltd.)

10.6 Colorimetric detector tube sampler and a range of tubes. (Reproduced with permission from Draeger Safety UK Ltd.)

10.7 Gas-tight sampling bags. (Reproduced with permission from SKC Ltd.)

10.8 A portable Fourier-transform infrared analyser. (Reproduced with permission from Quantitech Ltd.)

10.9 A MultiRAE photo-ionisation monitor. (Reproduced with permission from RAE Systems UK)

11.1 A multi-stage liquid impinger. (Reproduced with permission from Burkard Manufacturing Co. Limited)
List of Illustrations

11.2 Cascade impactor for bioaerosols. (Reproduced with permission from Casella Measurement Ltd.)


13.1 Change in acoustic pressure with time for a pure tone. (Reproduced with permission from Occupational Hygiene, 3rd edition, edited by Kerry Gardiner and J. Malcolm Harrington, Blackwell Publishing Ltd., 2005, Figure 17.1).

13.2 Change in acoustic pressure with distance for a pure tone. (Reproduced with permission from Occupational Hygiene, 3rd edition, edited by Kerry Gardiner and J. Malcolm Harrington, Blackwell Publishing Ltd., 2005, Figure 17.2).

13.3 The weighting curves used in noise measurement. (Reproduced with permission from Occupational Hygiene, 3rd edition, edited by Kerry Gardiner and J. Malcolm Harrington, Blackwell Publishing Ltd., 2005, Figure 17.8).

13.4 Simple sound level meters. (Reproduced with permission from Casella Measurement Ltd.)

13.5 Octave band monitoring with a sound level meter. (Reproduced with permission from Casella Measurement Ltd.)

13.6 A noise dosemeter. (Reproduced with permission from Casella Measurement Ltd.)

13.7 A selection of hearing protection devices (muffs, reusable inserts and disposable inserts). (Reproduced with permission from Moldex-Metric AG & Co. KG)


14.2 The relationship between displacement, velocity and acceleration for a simple mass and spring system.

14.3 Vibration measurements in practice. (Reproduced with permission from Bruel & Kjaer UK Ltd.)

15.1 Kata thermometer. (Reproduced with permission from Ashton and Gill)

15.2 Globe thermometer with glass thermometer. (Reproduced with permission from Ashton and Gill)

15.3 Integrating heat stress monitor. (Reproduced with permission from Quest Technologies)

15.4 Portable heat strain monitor. (a) monitor on belt (b) schematic arrangement of sensors (Reproduced with permission from Quest Technologies)

15.5 Arrangement of thermometers on a stand. (Reproduced with permission from Ashton and Gill)

16.1 The light meter. (Reproduced with permission from Castle Group)
xii  List of Illustrations

17.1  The electromagnetic spectrum.

17.2  Decay of an unstable nuclide to a stable one. (Reproduced with permission Monitoring for Health Hazards at Work, 3rd edition, by Indira Ashton and Frank S. Gill, Blackwell Publishers Ltd., 2000. pp. 165.)


17.4  An example of decay in stages: lead to bismuth to polonium to lead. (Reproduced with permission Monitoring for Health Hazards at Work, 3rd edition, by Indira Ashton and Frank S. Gill, Blackwell Publishers Ltd., 2000. pp. 166.)

17.5  A Geiger–Muller counter. (Reproduced with permission from Thermo Fisher Scientific.)

17.6  A scintillation detector. (Reproduced with permission from Berthold Technologies (UK) Ltd.)

17.7  Two thermoluminescent detectors (TLDs). (Reproduced with permission from Mirion Technologies, Inc.)

17.8  Two film badges. (Reproduced with permission from Loxford Equipment Company Ltd.)

18.1  A broad-spectrum UV monitor along with the weighting. (Reproduced with permission from LOT-Oriel Ltd (for International Light))

18.2  A hand-held monitor for IRA and part of IRB. (Reproduced with permission from LOT-Oriel Ltd (for International Light))

18.3  A leak monitor for microwave ovens. (Reproduced with permission from ETS-Lindgren)

19.1  Diagram showing the incorrect placement of a hood while welding, i.e. too far from the source.

19.2  Operators placing their head between the emission source and the extraction hood.

20.1  Portable inclined manometer.


20.3  Digital micromanometer. (Reproduced with permission from TSI Instruments Ltd.)

20.4  Electronic vane anemometer.

20.5  Heated sensor anemometer. (Reproduced with permission from TSI Instruments Ltd.)

20.6  Pitot-static tube. (Reproduced with permission from JS Holdings.)


20.8  Measuring positions for placing pitot-static tubes in circular ducting. (Reproduced with permission from Gardiner and Harrington.)
List of Illustrations

20.9  Log-Tchebycheff rule for traverse points in a rectangular duct. (Reproduced with permission from Gardiner and Harrington.)


20.11 Extract slot showing measured air speed results and plotted contours. (Reproduced with permission Monitoring for Health Hazards at Work, 3rd edition, by Indira Ashton and Frank S. Gill, Blackwell Publishers Ltd., 2000. p. 110.)

21.1  A selection of respiratory protection: (a) disposable respirator FFP1; (b) half-mask respirator; (c) powered hood TH2; (d) full facepiece respirator; (e) full masks breathing apparatus. (Reproduced with permission from Draeger Safety UK Ltd.)

21.2  Face-fit testing kit – PortaCount. (Reproduced with permission from TSI Instruments Ltd.)
List of Instruction Sheets

Chapter 9
9.8 Calibration of a rotameter or electronic flow calibrator by using the soap-bubble method, 76
9.9 The measurement of inhalable airborne dust, 80
9.10 The measurement of airborne respirable dust by using a cyclone sampler, 83
9.11 The sampling and counting of airborne asbestos fibres, 84
9.13 To trace the behaviour of a dust cloud by using a Tyndall beam, 89

Chapter 10
10.5 To measure personal exposure to solvent vapours using an adsorbent tube, 102
10.6 Sampling for gases by using a bubbler, 104
10.7 To measure the short-term airborne concentration of a gas by using a colorimetric detector tube, 106
10.8 To measure a vapour concentration using a diffusive sampler, 108

Chapter 13
13.10 To measure workplace noise using a SLM, 153
13.11 To measure workplace noise using a PND, 155
13.12 To measure the spectrum of a continuous noise by octave band analysis, 157

Chapter 14
14.6 To measure hand–arm vibration, 167

Chapter 15
15.5 Measurement of the thermal environment, 182
15.9 To calculate the wind chill factor, 189
List of Instruction Sheets

Chapter 16
16.5 To measure lighting, 194

Chapter 20
20.5 Measurement of air flow in ducts, 246
20.6 Measurement of pressure in ventilation systems, 252
20.7 To measure the face velocity on a booth or hood, 254
20.8 To measure the face velocity on a fume cupboard, 255
20.9 To measure the performance of a suction inlet, 257

Chapter 21
21.3 Face-fit testing using a particle counter, 269
Preface

The methods for measuring exposure to hazards in the workplace have progressively developed over the last 50 or more years. A major impetus for improving ways of assessing workers’ exposure to chemical, biological and physical hazards in the UK was the introduction of the Health and Safety at Work (etc.) Act in 1974, which required employers to ensure that tasks and work environments were ‘safe and without risks to health…’. Subsequent regulations made under the Act have strengthened the role for measurement as part of a modern approach to health and safety at work. Recent developments have seen greater standardisation of approaches to measurement and an increasing understanding of the role of exposure measurement in the context of assessing risks to health. Over the last 10 years there has been increasing interest in how best to quantify dermal exposure to chemicals and in the future we expect to see more interest in measurement of chemicals inadvertently ingested from contaminated hands or objects. Today, methods for measuring hazards at work are being applied throughout the world, and in the future the process of globalisation and standardisation will ensure greater uniformity in approaches to measurement.

The earlier editions of this book provided a very practical introduction to the topic, with helpful practical advice about how to undertake specific measurements of everything from hazardous airborne dusts to hot stressful environments. We had used the book in teaching occupational hygiene students and to help support other health and safety professionals develop their skills and had found it invaluable. When we were asked to take on the job of revising and updating the text for the fourth edition, we took the opportunity to think carefully about the changes in practice that had taken place and to reflect these in the text while retaining the practical ‘how to do it’ approach that had made the book unique.

The text of this fourth edition has been completely reorganised into 6 separate sections and 25 chapters. The sections cover background material necessary to understand the context within which measurements are made, and then we deal with measurement of exposure to inhalation hazards, dermal
and ingestion hazards and physical agents such as noise, heat and radiation. The final sections deal with measurements to assess the effectiveness of risk management measures such as local ventilation or personal protection, and risk assessment/risk communication. We believe that these provide a comprehensive introduction to the topic that will help the reader understand how measurements should be made and their results communicated to the workforce.

We hope that the book will be a useful source for students interested in learning about the practical aspects of occupational hygiene measurements. However, we have also included information on many new techniques and emerging areas of occupational hygiene practice and hope that there is also much that will be useful to established professionals who perhaps relied on previous editions of the book in the earlier part of their career. As with the earlier editions we have tried to ensure that the text is accessible to a wide range of health and safety professionals, including safety advisors, occupational health nurses, ergonomists, occupational physicians and occupational hygienists.

It is important to realise that the measurement methods we describe in this book are tools that can be used to assess the degree of risk and guide further preventative actions where necessary. In doing this the readers will need to use a wider knowledge base encompassing the underpinning legislation, toxicology, other sciences, engineering and management techniques. These topics are beyond the scope of the present work. In addition, there is a need to apply sound professional judgment in deciding what type of measurements will be helpful and in interpreting the results that are obtained. There is no substitute for good academic or professional education or training. In the UK, the British Occupational Hygiene Society (www.BOHS.org) regulates a system of qualifications that covers most of the techniques described in this book. Internationally, the Occupational Hygiene Training Association (OHTA) provides a similar role. There are also relevant postgraduate courses available in universities in the UK and throughout the world.

We are interested to receive feedback from readers about the book and to continue to support those interested in measurement of health hazards and other aspects of occupational hygiene. Visit www.OH-world.org for more information.

John W. Cherrie
Robin M. Howie
Sean Semple
January 2010
Acknowledgements

We owe a great deal to the authors of the earlier edition of this book – Frank Gill and Indira Ashton. They recognised the need for a simple practical introduction to monitoring for health hazards at work, and their text provided a wealth of material that we have reused and recycled in this edition. We are also grateful to the many colleagues and friends who have offered advice and provided comments on earlier drafts of the text. In particular, we wish to thank Finlay Dick, Alastair Robertson, Adrian Watson, Adrian Hirst, Richard Graveling, Andy Gillies, Bob Rajan and Brian Crook. Adrian Watson also provided initial draft material for the chapters on lighting and vibration, which was invaluable in revising these sections of the book.

The authors would also like to thank the many companies who have provided information and photographs of measurement equipment to illustrate the book.

Of course, the book would have never been finished without the support of our wives and families, for which we are most grateful.
## Units and Abbreviations

The more common units used in workplace environmental measurement

<table>
<thead>
<tr>
<th>Unit</th>
<th>Dimension</th>
<th>SI</th>
<th>Imperial</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>$L$</td>
<td>m</td>
<td>ft</td>
<td>$ft \times 0.3048 = m$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mm</td>
<td>in</td>
<td>$in \times 25.4 = mm$</td>
</tr>
<tr>
<td>Area</td>
<td>$L^2$</td>
<td>m$^2$</td>
<td>ft$^2$</td>
<td>$ft^2 \times 9.29 \times 10^{-2} = m^2$</td>
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<td></td>
<td></td>
<td>mm$^2$</td>
<td>in$^2$</td>
<td>$in^2 \times 645.2 = mm^2$</td>
</tr>
<tr>
<td>Volume</td>
<td>$L^3$</td>
<td>m$^3$</td>
<td>1 litre</td>
<td>$ft^3 \times 2.832 \times 10^{-2} = m^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mm$^3$</td>
<td>gallon</td>
<td>gallon $\times 4.546 = litre$</td>
</tr>
<tr>
<td>Mass</td>
<td>$M$</td>
<td>kg</td>
<td>lb</td>
<td>$lb \times 0.4536 = kg$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>g (gram)</td>
<td>oz</td>
<td>$oz \times 28.35 = g$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mg</td>
<td>grain</td>
<td>$gr \times 64.79 = mg$</td>
</tr>
</tbody>
</table>

Airborne concentration of substance

- (Mass) $\frac{M}{L^3}$ mg m$^{-3}$ grain ft $ft^3 \times 2288 = mg m^{-3}$
- (Volume) $-\frac{M}{T}$ parts per million (ppm)
- (Particle) $\frac{L}{T^2}$ mp cm$^{-3}$ mp ft$^{-3}$ (millions of particles per cm$^3$ (ft$^3$))

Acceleration $\frac{L}{T^2}$ m s$^{-2}$ ft sec$^{-2}$ $ft^2 s^{-2} \times 0.305 = m s^{-2}$

Density $\frac{M}{L^3}$ kg m$^{-3}$ (g l$^{-1}$) lb ft$^{-3}$ $lb ft^{-3} \times 16.02 = kg m^{-3}$

Flow rate

- (Mass) $\frac{M}{T}$ kg s$^{-1}$ lb hr$^{-1}$ $lb hr^{-1} \times 1.26 \times 10^{-4} = kg s^{-1}$
- (Volume) $\frac{L^3}{T}$ m$^3$ s$^{-1}$ ft$^{-3}$ min$^{-1}$ $ft^3 min^{-1} \times 4.719 \times 10^{-4} = m^3 s^{-1}$

Force $\frac{ML}{T^2}$ N (Newton) lb, $lb \times 4.448 = N$

*In this book SI units are used throughout; however, conversions from Imperial to SI are given in the list of common units. Also, we use the form mg m$^{-3}$ when presenting units rather than mg/m$^3$; although both are acceptable in practice.*
**Units and Abbreviations**

<table>
<thead>
<tr>
<th>Unit</th>
<th>Dimension</th>
<th>SI</th>
<th>Imperial</th>
<th>Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>–</td>
<td>K (Kelvin) °C (degree Celsius)</td>
<td>°F</td>
<td>(°F-32) x 0.5555 = °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Fahrenheit)</td>
<td></td>
<td>°C + 273.15 = K</td>
</tr>
<tr>
<td>Energy/Heat quantity</td>
<td>$\frac{ML^2}{T^2}$</td>
<td>J (Joule)</td>
<td>Btu</td>
<td>Btu x 1055 = J</td>
</tr>
<tr>
<td>Power</td>
<td>$\frac{ML^2}{T^3}$</td>
<td>W</td>
<td>HP</td>
<td>HP x 745.7 = W</td>
</tr>
<tr>
<td>Latent heat</td>
<td>$\frac{L^2}{T^2}$</td>
<td>kJ kg⁻¹</td>
<td>Btu lb⁻¹</td>
<td>Btu lb⁻¹ x 2.326 = kJ kg⁻¹</td>
</tr>
<tr>
<td>Specific heat</td>
<td>$\frac{L}{T^2}$</td>
<td>°C</td>
<td>Btu lb⁻¹ °F</td>
<td>Btu lb⁻¹ °F x 4.187 = kJ kg⁻¹ °C</td>
</tr>
<tr>
<td>Pressure</td>
<td>$\frac{M}{T^2}$</td>
<td>Pa (Pascal) = N m⁻²</td>
<td>lb ft⁻²</td>
<td>lb ft⁻² x 47.88 = Pa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bar (×10⁵ = Pa)</td>
<td>lb in⁻²</td>
<td>lb in⁻² x 6895 = Pa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in water (4°C)</td>
<td>in water 249.1 = Pa</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>in mercury (0°C)</td>
<td>in mercury 3386 = Pa</td>
<td></td>
</tr>
<tr>
<td>Torque</td>
<td>$\frac{ML^2}{T^3}$</td>
<td>Nm</td>
<td>lb ft</td>
<td>lb ft x 1.356 = Nm</td>
</tr>
<tr>
<td>Velocity</td>
<td>$\frac{L}{T}$</td>
<td>m s⁻¹</td>
<td>ft min⁻¹</td>
<td>ft min⁻¹ x 5.08 x 10⁻³ = m s⁻¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ft s⁻¹</td>
<td>ft s⁻¹ x 0.305 = m s⁻¹</td>
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<tr>
<td>Viscosity (Dynamic)</td>
<td>$\frac{M}{T^2}$</td>
<td>Pa s (Ns m⁻²)</td>
<td>lb s ft⁻¹</td>
<td>lb s ft⁻¹ x 47.88 = Pa s</td>
</tr>
<tr>
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<td></td>
<td>Poise (dyne s cm⁻²)</td>
<td>Poise x 0.1 = Pa s</td>
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<tr>
<td>Viscosity (Kinematic)</td>
<td>$\frac{L^2}{T}$</td>
<td>m² s⁻¹</td>
<td>ft² s⁻¹</td>
<td>ft² s⁻¹ x 9.29 x 10⁻² = m² s⁻¹</td>
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<td></td>
<td>Stokes (cm² s⁻¹)</td>
<td>in² s⁻¹</td>
<td>in² s⁻¹ x 6.452 x 10⁻⁴ = m² s⁻¹</td>
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<td></td>
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<td>Stokes x 10⁻⁴ = m² s⁻¹</td>
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<tr>
<td>Luminous intensity</td>
<td>–</td>
<td>candela (Cd)</td>
<td>candle (int)</td>
<td>candle x 0.981 = Cd</td>
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<tr>
<td>Luminous flux</td>
<td>–</td>
<td>lumen (1m)</td>
<td>(lm = 1Cd sr)</td>
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<tr>
<td>Illuminance</td>
<td>lux</td>
<td>foot candle</td>
<td>ft candle x 0.1076 = lx</td>
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<tr>
<td></td>
<td>(lx = 1m m⁻²)</td>
<td>lumen ft⁻²</td>
<td>lm ft⁻² x 0.1076 = lx</td>
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<tr>
<td>Luminance</td>
<td>Cd m⁻²</td>
<td>foot lambert</td>
<td>ft lambert x 3.426 = Cd m⁻²</td>
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<td></td>
<td></td>
<td>candela in⁻²</td>
<td>Cd in⁻² x 1550 = Cd m²</td>
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<tr>
<td>Radiation activity</td>
<td>dis s⁻¹</td>
<td>Bq</td>
<td>Ci</td>
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<tr>
<td></td>
<td></td>
<td>1Ci = 3.7 x 10¹⁰ Bq = 3.7 x 10⁶ MBq = 0.007 TBq</td>
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<tr>
<td></td>
<td></td>
<td>1 mCi = 37 x 10⁶ Bq = 37 MBq = 3.7 x 10⁻⁵ TBq</td>
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<tr>
<td></td>
<td></td>
<td>1 μCi = 37 000 Bq = 0.037 MBq = 3.7 x 10⁻⁶ TBq</td>
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<tr>
<td></td>
<td></td>
<td>1 Bq = 2.7 x 10⁻⁵ μCi = 2.7 x 10⁻⁴ mCi = 2.7 x 10¹¹ Ci</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 MBq = 27 μCi = 0.027 mCi = 2.7 x 10⁻⁵ Ci</td>
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<tr>
<td></td>
<td></td>
<td>1 TBq = 2.7 x 10⁷ Ci = 2.7 x 10⁴ mCi = 27 Ci</td>
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Units and Abbreviations

Radiation absorbed dose

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<th>J/kg</th>
<th>Gy</th>
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<tr>
<td></td>
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<td>1Gy = 1 J kg⁻¹ = 100 rad</td>
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<tr>
<td>kg</td>
<td>1mGy = 100 mrad</td>
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<tr>
<td>1μGy = 0.01 mrad</td>
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Dose equivalent

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<th>rad × Q</th>
<th>Sv</th>
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<tr>
<td></td>
<td>1Sv = 100 rem</td>
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</tr>
<tr>
<td></td>
<td>1mSv = 100 mrem</td>
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</tr>
<tr>
<td></td>
<td>1μSv = 0.1 mrem</td>
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Temperature

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<th>°Fahrenheit</th>
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<td>–10</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>0</td>
<td>32</td>
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</tr>
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<td>50</td>
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<td>20</td>
<td>68</td>
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<td>30</td>
<td>86</td>
<td>86</td>
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<tr>
<td>40</td>
<td>104</td>
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<td>122</td>
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<td>90</td>
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<tr>
<td>100</td>
<td>212</td>
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Useful abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACoP</td>
<td>Approved Code of Practice – from the HSE</td>
</tr>
<tr>
<td>ACTS</td>
<td>The UK Advisory Committee on Toxic Substances (<a href="http://www.hse.gov.uk/aboutus/meetings/iacs/acts/">www.hse.gov.uk/aboutus/meetings/iacs/acts/</a>)</td>
</tr>
<tr>
<td>ALARP</td>
<td>As low a reasonably practicable</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute (<a href="http://www.ansi.org/">www.ansi.org/</a>)</td>
</tr>
<tr>
<td>BOHS</td>
<td>British Occupational Hygiene Society (<a href="http://www.BOHS.org">www.BOHS.org</a>)</td>
</tr>
<tr>
<td>CAD</td>
<td>Chemical Agents Directive (details at <a href="http://europa.eu/">http://europa.eu/</a>)</td>
</tr>
<tr>
<td>CAS Number</td>
<td>A unique identifying number assigned to a hazardous substance by the Chemical Abstracts Service (<a href="http://www.cas.org/">www.cas.org/</a>)</td>
</tr>
<tr>
<td>CIBSE</td>
<td>Chartered Institute of Building Services Engineers (<a href="http://www.cibse.org/">www.cibse.org/</a>)</td>
</tr>
<tr>
<td>COMAH</td>
<td>Control of Major Accident Hazards Regulations (<a href="http://www.hse.gov.uk/comah/">www.hse.gov.uk/comah/</a>)</td>
</tr>
<tr>
<td>ECHA</td>
<td>European Chemicals Agency (<a href="http://echa.europa.eu/">http://echa.europa.eu/</a>)</td>
</tr>
<tr>
<td>EU</td>
<td>European Union (<a href="http://europa.eu/">http://europa.eu/</a>)</td>
</tr>
<tr>
<td>HPA</td>
<td>Health Protection Agency (<a href="http://www.hpa.org.uk">www.hpa.org.uk</a>)</td>
</tr>
<tr>
<td>IARC</td>
<td>International Agency for Research on Cancer (<a href="http://www.iarc.fr">www.iarc.fr</a>)</td>
</tr>
<tr>
<td>IDLH</td>
<td>Immediately Dangerous to Life or Health (<a href="http://www.cdc.gov/niosh/idlh/idlh-1.html">www.cdc.gov/niosh/idlh/idlh-1.html</a>)</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organization (<a href="http://www.iolo.org">www.iolo.org</a>)</td>
</tr>
<tr>
<td>IOELV</td>
<td>Indicative Occupational Exposure Limit Values from the EU (<a href="http://ec.europa.eu/social/main.jsp?catId=153&amp;langId=en&amp;intPagId=684">http://ec.europa.eu/social/main.jsp?catId=153&amp;langId=en&amp;intPagId=684</a>)</td>
</tr>
<tr>
<td>IUPAC</td>
<td>The International Union of Pure and Applied Chemistry (<a href="http://www.iupac.org/">www.iupac.org/</a>)</td>
</tr>
<tr>
<td>NOEL</td>
<td>No observed effect level</td>
</tr>
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</table>
Units and Abbreviations

SI
Systeme international d’unités (www.bipm.org/en/si/)

STEL
Short-term Exposure Limits (See EH40)

TLV
Threshold Limit Value is a type of OEL used in the USA and elsewhere. TLV’s are published by the American Conference of Governmental Industrial Hygienists (www.acgih.org/tlv/)

WASP
Workplace Analysis Scheme for Proficiency. A quality assurance scheme for occupational hygiene analysis managed for HSE by the Health and Safety Laboratory (www.hsl.gov.uk/centres-of-excellence/proficiency-testing/wasp.aspx)

WATCH
The Working Group on the Assessment of Toxic Chemicals, which is a subcommittee of ACTS (www.hse.gov.uk/aboutus/meetings/iacs/acts/index.htm)

Abbreviations in the text

ACDP
Advisory Committee on Dangerous Pathogens (www.dh.gov.uk/ab/ACDP/)

ACGIH
American Conference of Governmental Industrial Hygienists (www.acgih.org/)

ACH
Air Changes per Hour (ventilation)

ALARA
As Low As Reasonably Achievable

ALI
Annual Limits of Intake (radiation)

APF
Assigned Protection Factor (respirator)

ART
Advance REACH Tool (www.advancedreachtool.com/)

BMGV
Biological Monitoring Guidance Values (details in HSE publication EH40, www.hse.gov.uk/COSHH/)

BS EN
British Standard – European Norm (www.standardsuk.com/)

CA
Control of Asbestos regulations (www.hse.gov.uk/asbestos/regulations.htm)

CE
Conformity marking system for products (www.bsigroup.com/en/ProductServices/About-CE-Marking/)

CEN
European Committee for Standardisation (www.cen.eu/)

CFU
Colony Forming Units

CHIP
Chemical (Hazards Information and Packaging for Supply) Regulations (www.hse.gov.uk/chip/)

CLW
Control of Lead at Work regulations

CNW
Control of Noise at Work regulations (www.hse.gov.uk/noise/regulations.htm)

COSHH
Control of Substances Hazardous to Health Regulations (www.hse.gov.uk/coshh/)

COSHH-Essentials
An initiative from the HSE designed to help small and medium size companies manage supplied chemicals at work (www.coshh-essentials.org.uk/)

CVW
Control of Vibration at Work regulations (www.hse.gov.uk/vibration/)

DAC
Derived Air Concentrations (radiation)

DL
Derived Limits (radiation)

DNA
Deoxyribonucleic acid

EH40
The guidance document published annually by HSE Books, which contains the complete list of UK OELs. EH40 (www.hse.gov.uk/COSHH/)

ELF
Extremely Low Frequency (radiation)

EMF
Electro-Magnetic Field
Units and Abbreviations

- **FFP**: Filtering Facepiece (respirator)
- **FTIR**: Fourier Transform Infrared spectroscopy (chemical analysis)
- **GHS**: Globally Harmonised System for the classification and labelling of hazardous substances (www.hse.gov.uk/ghs/)
- **GMP**: Good Manufacturing Practice
- **HPLC**: High-performance liquid chromatography (chemical analysis)
- **HSE**: Health and Safety Executive (www.hse.gov.uk)
- **HSG**: Health and Safety Guidance publications (from HSE)
- **HVL**: Half-Value Layer (radiation)
- **ICNIRP**: International Commission on Non-Ionizing Radiation Protection (www.icnirp.de/)
- **ICRP**: International Commission on Radiological Protection (www.icrp.org/)
- **IOM**: The Institute of Occupational Medicine. An independent research and consulting organisation in Scotland (www.IOM-world.org)
- **IR**: Infrared (also IRA, IRB and IRC to signify parts of the infrared spectrum)
- **IREQ**: Required clothing insulation (thermal)
- **ISLM**: Integrating Sound Level Meter
- **ISO**: International Standards Organisation (www.iso.org)
- **LAA**: Laboratory Animal Allergy
- **LEL**: Lower Explosive Limit
- **L_{EP,d}**: Daily noise exposure level
- **L_{EP,w}**: Weekly noise exposure level
- **LEV**: Local Exhaust Ventilation
- **LPS**: Lipopolysaccharide
- **MDHS**: Methods for the Determination of Hazardous Substances (www.hse.gov.uk/pubns/mdhs/)
- **MMM**: Man-Made Mineral Fibres. Also known as synthetic mineral fibres or man-made vitreous fibres (those MMMF with a glassy structure)
- **MMVF**: Man-Made Vitreous Fibres (see MMMF)
- **MRE**: Mining Research Establishment
- **MSDS**: Material Safety Data Sheet (see also SDS, which is the preferred terminology)
- **MDHS**: Methods of Determination of Hazardous Substances (www.hse.gov.uk/pubns/mdhs/index.htm)
- **NIOSH**: National Institute for Occupational Safety and Health (www.cdc.gov/niosh)
- **OECD**: Organisation for Economic Co-operation and Development (www.oecd.org/)
- **OVA**: Organic Vapour Analyser
- **PAH**: Polycyclic Aromatic Hydrocarbons
- **PF**: Protection Factor (respirator)
- **PND**: Persona Noise Dosimeter
- **PNIHL**: Personal Noise Induced Hearing Loss
- **PPE**: Personal Protective Equipment (www.hse.gov.uk/pubns/indg174.pdf)
- **PPE**: Personal Protective Equipment
- **P_{peak}**: Peak sound pressure level
- **PTFE**: Polytetrafluoroethylene
- **PUF**: Polyurethane Foam
- **PVC**: Polyvinylchloride
- **Q**: Quality factor (radiation)
- **REACH**: Registration, Evaluation, Authorisation and restriction of Chemicals regulations (http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm)
Units and Abbreviations

RNA    Ribonucleic Acid
RPE    Respiratory Protective Equipment
(SCOEL) Scientific Committee on Occupational Exposure Limits. An independent committee set up by the EU
(SDS)  Safety Data Sheet
SEG    Similarly Exposed Group of workers
SIMPDES Safety in Mines Personal Dust Sampler
SPL    Sound Pressure Level
TLD    Thermoluminescent Dosimeters
TWA    Time-Weighted Average concentration (See EH40)
UKAS   UK Accreditation Service (www.ukas.com/)
UV     Ultraviolet (also UVA, UVB and UVC to signify different parts of the UV spectrum)
VBN    Viable But Non Culturable
VOC    Volatile Organic Compound
WBGT   Wet-Bulb Globe Temperature
WEL    Workplace Exposure Limits (www.hse.gov.uk/COSHH/table1.pdf)
WHO    World Health Organization (www.who.int/topics/occupational_health/en/)

Multiples of SI units

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<td>mega</td>
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PART 1

1 Introduction
CHAPTER 1

1 Occupational Hygiene and Risk Assessment

1.1 Introduction

“When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind...”

Lord Kelvin, *Popular Lectures and Addresses*

Scientists have always known that measurement is fundamental to making accurate statements about the world around us. The pioneers of occupational health were also enthusiastic about measuring exposure, even when this involved considerable effort to get reliable data. In recent years, it has become less fashionable to rely on measurement data and we have seen the development of sophisticated computer-based systems to estimate exposures, or health and safety professionals rely on their judgment to come to a conclusion about the risks in a particular situation. We support these approaches but we also recognise that which was clear to Lord Kelvin more than 100 years ago: measurements can provide a precise, reliable and objective description of a situation that is generally superior to the alternatives.

The science of human exposure encompasses assessment and control of exposure to hazardous agents that arise from work, in the home or elsewhere in the environment. It does not really matter whether you want to measure the exposure to diesel engine exhaust particulate of someone working as a truck driver or the exposure of someone else in the street where the truck is unloading: the underlying science is the same. Where differences do arise, they are in relation to who has responsibility to manage the exposures and what legislative regime applies. Occupational health professionals are concerned with establishing and maintaining a safe and healthy working environment. Occupational hygienists are the occupational health professionals who are focused on the prevention of ill health by intervening in the workplace to eliminate or reduce exposures to hazardous agents. There are other occupational health and safety specialists who may deal with different aspects of health and work, for example occupational physicians and nurses, safety advisors and ergonomists. However, no matter what the specific expertise of the
individuals they should all be aware of the principles of occupational hygiene to help them in their job.

Hazardous agents may be chemicals, loud noise, unseen radiations or many other things. The discipline of occupational hygiene groups hazardous agents into three categories: physical, chemical or biological agents. Psychological stressors are generally seen as being outside the remit of occupational hygiene. Physical agents include noise, vibration, electromagnetic radiation, ionizing and non-ionizing radiation, excessively hot or cold environments and abnormal atmospheric pressures. Chemical agents include harmful dusts, liquids, gases and vapours. Biological agents include bacteria, viruses and other materials of biological origin that are harmful to health. For convenience chemical and biological agents are often grouped together as substances hazardous to health.

The basis for occupational hygiene is the link between exposure to a hazard and the risk of illness arising from that exposure, where the ‘hazard’ is the potential for harm and the ‘risk’ is the chance that that harm may arise in a particular situation. In general, it is assumed that the higher the exposure someone experiences, the greater the risk to their health. Figure 1.1 shows an

![Figure 1.1 An idealized exposure–response relationship.](image-url)