LAND CONTAMINATION INCIDENTS:
MANAGEMENT RESPONSES
FROM A PUBLIC HEALTH PERSPECTIVE

EMMA E Eagles
November 2002
'E' is for Earth, by Emma, aged 8.

E is for the Earth and everyone in it,
Eagles in the Alps,
Eels in the Eastern sea,
Elephants in Ethiopia,
Everyday extinction happens.
Environment is crucial.
Here are 8 words
The Earth and everything in it is special.
ABSTRACT

Chemical incidents, whether deliberate or accidental, have the potential to cause widespread harm to human and environmental health. Whilst incident prevention is desirable in an increasingly industrialised society, accidents can and do happen so a well-structured multi-agency approach to incident response is essential. The project has focussed on the role of public health, since limited experience combined with the lack of standard procedures for managing incidents has resulted in problems being dealt with on an ad hoc basis from a public health perspective. A framework for incident management is proposed and tools and guidance to support and facilitate the public health response to a chemical incident presented, including a scale to rapidly assess and communicate the potential health impact of an incident. Public health practitioners have welcomed this guidance, which has been demonstrated to be both functional and effective.

In protecting human health it is imperative that pollution streams are not diverted to the environment and from one environmental medium to another. In the past soil was frequently used as a sink for contaminants and until recently has not been granted the same level of protection as air or water. Land contamination presents an interesting challenge since establishing a relationship between soil contamination and adverse health effects can be both complex and expensive. As a result, resources specifically for managing land contamination incidents have been developed.

Although this project has focussed on the needs of public health practitioners, the generic framework is available for other agencies involved in incident response to use and refine to suit their respective needs. The advantages of all agencies using the same basic framework include improved communication, minimised use of jargon, better understanding of roles and responsibilities and ultimately a more coherent and effective response.
TABLE OF CONTENTS

TABLE OF CONTENTS ......................................................... I
LIST OF APPENDICES ....................................................... V
TABLE OF FIGURES ........................................................... VI
    FIGURES ................................................................ VI
    TABLES ................................................................ VII
    INFORMATION BOXES .................................................... VIII
ACKNOWLEDGEMENTS ........................................................ X
LIST OF ACRONYMS ........................................................... X

EXECUTIVE SUMMARY ....................................................... E-1

1. CHEMICAL INCIDENTS, THE ENVIRONMENT AND HUMAN HEALTH
   1.1 DEFINITIONS ............................................................. 1-5
   1.2 THE ENVIRONMENT AND HUMAN HEALTH ................. 1-7
       1.2.1 Environmental Impact Assessment .................... 1-11
       1.2.2 Health Impact Assessment ............................ 1-12
       1.2.3 Integrated Assessment Approaches ................. 1-14

2. MANAGING LAND CONTAMINATION ................................. 2-1
   2.1 THE UK PERSPECTIVE ............................................. 2-1
   2.2 CHEMICAL INCIDENTS AND LAND CONTAMINATION .... 2-7
       2.2.1 Definitions .................................................. 2-7
       2.2.2 Incident Review .......................................... 2-9
       2.2.3 Land Incident Categories ............................. 2-15
   2.3 LEGISLATION .......................................................... 2-23
       2.3.1 Chronic/Historic Land Contamination ............. 2-23
       2.3.2 Acute Land Contamination .......................... 2-31
   2.4 THE ROLE OF REGULATORY AGENCIES AND STATUTORY BODIES 2-34
       2.4.1 Emergency Services .................................... 2-35
       2.4.2 Local Authority ......................................... 2-36
       2.4.3 Environment Agency .................................. 2-37
       2.4.4 Health Service ........................................ 2-38
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5.1</td>
<td>Guidance for the Public Health Management of Chemical Incidents</td>
<td>2-51</td>
</tr>
<tr>
<td>3.1</td>
<td>Categorising Chemical Incidents</td>
<td>3-2</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Existing Scales</td>
<td>3-3</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Developing a Scale for Chemical Incidents</td>
<td>3-7</td>
</tr>
<tr>
<td>3.1.3</td>
<td>Identifying Appropriate Parameters</td>
<td>3-9</td>
</tr>
<tr>
<td>3.1.4</td>
<td>Defining a 'Major Incident'</td>
<td>3-10</td>
</tr>
<tr>
<td>3.1.5</td>
<td>The Scale</td>
<td>3-12</td>
</tr>
<tr>
<td>3.2</td>
<td>Integrating a Scale for the Environment</td>
<td>3-16</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Results</td>
<td>3-19</td>
</tr>
<tr>
<td>3.3</td>
<td>Summary and Conclusions</td>
<td>3-20</td>
</tr>
<tr>
<td>4.1</td>
<td>Incident Timelines</td>
<td>4-2</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Closing the Loop</td>
<td>4-6</td>
</tr>
<tr>
<td>4.2</td>
<td>What do Public Health Practitioners Want/Need?</td>
<td>4-8</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Conclusions from Questionnaire</td>
<td>4-9</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Summary of Public Health Requirements</td>
<td>4-10</td>
</tr>
<tr>
<td>4.3</td>
<td>Developing Resources for Incident Response</td>
<td>4-11</td>
</tr>
<tr>
<td>4.4</td>
<td>Checklists</td>
<td>4-17</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Basic Acute Incident Checklist</td>
<td>4-18</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Event-specific Checklists</td>
<td>4-19</td>
</tr>
<tr>
<td>4.5</td>
<td>Training Resources</td>
<td>4-20</td>
</tr>
<tr>
<td>4.6</td>
<td>Conclusions</td>
<td>4-22</td>
</tr>
<tr>
<td>5.1</td>
<td>Review of Land Chemical Incidents</td>
<td>5-1</td>
</tr>
<tr>
<td>5.2</td>
<td>Land Incident Categories and Tools for Response</td>
<td>5-9</td>
</tr>
<tr>
<td>5.2.1</td>
<td>Acute Incident Categories</td>
<td>5-12</td>
</tr>
<tr>
<td>5.2.2</td>
<td>Chronic Incident Categories</td>
<td>5-13</td>
</tr>
<tr>
<td>5.3</td>
<td>Conclusions</td>
<td>5-17</td>
</tr>
</tbody>
</table>
LIST OF APPENDICES (VOLUME 2)

Appendix A: Case Studies
Appendix B: Definitions
Appendix C: Book Chapters
Appendix D: London Sector CBRN Project Group Meeting
Appendix E: Land Contamination and Human Health
Appendix F: The Role of the Fire Brigade in Chemical Incident Response
Appendix G: Questionnaires
Appendix H: Standards for Contaminated Soil
Appendix I: WHO Press Statement
Appendix J: Incident Timelines
Appendix K: Checklists
Appendix L: Incident Exercises
Appendix M: Fuel Incidents Literature Review
Appendix N: Review of Selected Fuel Case Studies
Appendix O: Articles Published in the Chemical Incident Report
Appendix P: Abstracts and Papers
Appendix Q: Portfolio Contents
<table>
<thead>
<tr>
<th>Figures</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1: Project components</td>
<td>1-5</td>
</tr>
<tr>
<td>Figure 1.2: Key inputs to environment and health decision-making</td>
<td>1-14</td>
</tr>
<tr>
<td>Figure 2.1: Links between air, land and water</td>
<td>2-3</td>
</tr>
<tr>
<td>Figure 2.2: Land incidents reported to the Environment Agency in 2001 by source</td>
<td>2-10</td>
</tr>
<tr>
<td>Figure 2.3: Land contamination incidents reported to CIRS</td>
<td>2-12</td>
</tr>
<tr>
<td>Figure 2.4: Incidents that resulted in land contamination categorised by ‘type’</td>
<td>2-12</td>
</tr>
<tr>
<td>Figure 2.5: Event evolution</td>
<td>2-19</td>
</tr>
<tr>
<td>Figure 2.6: Source-Pathway-Receptor Linkage</td>
<td>2-21</td>
</tr>
<tr>
<td>Figure 2.7: Percentage of new homes built on previously developed land</td>
<td>2-24</td>
</tr>
<tr>
<td>Figure 2.8: The relationship between derelict land, contaminated land and land affected by contamination</td>
<td>2-27</td>
</tr>
<tr>
<td>Figure 2.9: Number of land contamination incidents that respondents had been involved in managing</td>
<td>2-43</td>
</tr>
<tr>
<td>Figure 2.10: Would it be useful if health authorities had guidance on the public health management of land contamination?</td>
<td>2-44</td>
</tr>
<tr>
<td>Figure 3.1: Risk categories used by EPPIR</td>
<td>3-4</td>
</tr>
<tr>
<td>Figure 3.2: Chemical incident impact scale (CIIS)</td>
<td>3-13</td>
</tr>
<tr>
<td>Figure 4.1: Chemical incident timeline</td>
<td>4-3</td>
</tr>
<tr>
<td>Figure 4.2: Chemical incident management – closing the loop</td>
<td>4-8</td>
</tr>
<tr>
<td>Figure 4.3: Methodology for developing a public health risk assessment tool</td>
<td>4-12</td>
</tr>
<tr>
<td>Figure 4.4: Criteria for risk assessment</td>
<td>4-13</td>
</tr>
<tr>
<td>Figure 4.5: Identifying an unknown chemical</td>
<td>4-15</td>
</tr>
<tr>
<td>Figure 5.1: The cause of the problem</td>
<td>5-4</td>
</tr>
<tr>
<td>Figure 5.2: Location of land contamination incidents – current land use</td>
<td>5-5</td>
</tr>
<tr>
<td>Figure 5.3: Agencies involved in the management of land contamination incidents</td>
<td>5-5</td>
</tr>
<tr>
<td>Figure 5.4: Organic chemicals and duration of incident</td>
<td>5-6</td>
</tr>
<tr>
<td>Figure 5.5: Heavy metals and duration of incident</td>
<td>5-6</td>
</tr>
<tr>
<td>Figure 5.6: Top ten chemicals most frequently involved in land contamination incidents</td>
<td>5-7</td>
</tr>
<tr>
<td>Figure 5.7: Chemicals most frequently involved in acute land contamination incidents</td>
<td>5-7</td>
</tr>
</tbody>
</table>
Figure 5.8: Top ten chemicals most frequently involved in chronic land contamination incidents
Figure 5.9: Land incidents reported to CIRS in 1999 classified using the proposed categories
Figure 5.10: Incident management model for chronic land contamination incidents
Figure 6.1: Incidents involving fuel reported to CIRS by year
Figure 6.2: Checklist for public health response to acute incidents involving fuel

Tables
Table 2.1: Sources of land contamination
Table 2.2: Land contamination incidents categorised by ‘type’
Table 2.3: Land contamination incidents categorised by ‘event’
Table 2.4: Taxonomy for chemical incidents that result in land contamination
Table 2.5: Categorisation of land contamination incidents reported in 1999
Table 2.6: Differences between acute and chronic land contamination incidents
Table 2.7: Regulatory regimes that may be appropriate to use in managing land contamination incidents
Table 2.8: Ten exposure pathways considered in the CLEA model
Table 3.1: Some examples of scales used to describe natural events
Table 3.2: Categorisation scales
Table 3.3: Criteria used to evaluate potential biological threat agents
Table 3.4: Health impact severity scale
Table 3.5: Results from risk perception survey
Table 3.6: Scale for communicating the potential health impact of an incident
Table 3.7: Integrated human health and environmental impact scale for chemical incidents
Table 3.8: Environment Agency Pollution Incident Categories
Table 3.9: Incidents reported to CIRS in June 2002 categorised using CIIS
Table 4.1: Definitions of terms used in Figure 4.1
Table 4.2: Types of exercise
Table 5.1: CERCLA top ten priority list
Table 5.2: Land incident categories
Table 6.1: Incidents reported to CIRS January 1997 – December 2000
Information Boxes

Box 2.1: Secondary contamination of a UK beach 2-3
Box 2.2: Love Canal 2-7
Box 2.3: Cambridge Water Company versus Eastern Counties Leather 2-8
Box 2.4: Weston Quarries chemical incident 2-30
Box 2.5: Shifting the balance of power 2-39
Box 2.6: Probabilistic exposure models 2-47
Box 2.7: Bioavailability 2-48
Box 3.1: G7/G8 3-1
Box 3.2: Reasons for categorising chemical incidents 3-2
Box 4.1: Summary of requirements to support the public health risk assessment for chemical incident 4-11
Box 4.2: Initial response questions for all incidents 4-19
ACKNOWLEDGEMENTS

I can honestly say that I am now ready to take a break from studying (at least for a while!) and get a ‘proper job’. This should bring a sigh of relief to the countless number of people whom I would like to take this opportunity to thank for motivating, encouraging and inspiring me over the past four years.

Thank you first of all to my supervisor at CIRS, Dr Virginia Murray for providing me with the opportunity to work in a really exciting environment and for giving me the freedom and support to explore lots of ideas. Also thank you to everyone in CES at the University of Surrey especially my academic supervisors Dr Walter Wehrmeyer and Prof Roland Clift who have supported and encouraged me throughout and helped to resolve various ‘crises’ along the way and to Dr Chris France, Marylin Ellis and Sue Ponsford.

I would also like to thank my colleagues at CIRS in particular Graham Robertson for always listening, providing helpful comments and generally being brilliant. Faith and Fiona - I certainly would not be here today without you both. We had a lot of fun (and wine!)...but most importantly I think we made a great team! Joan, Helaina, Rico, Ben, Sarah, Jaimie, Robert, Richard, Nannerl, Jackie and Giovanni - thank you for all your comments and input throughout. Other colleagues I would like to thank include SpRs and CCDCs who have been on secondment to CIRS and attended training days especially Anna Gilmore, Joyshri Sarangi, John Bailey and Lynne Warner.

An extra big thank you to my EngD friends - Alex, Alice, Anthony, Carolyn, Catriona, Dave, Kostas, Kristian, Joe, Madds and Sy - with whom I have shared too many truly memorable moments to name and to Dave Donegan (London HEPA) for his excellent ideas, boundless encouragement and for being a truly special friend.

To my family, Mum, Dad and Louise (and Ross too!), I send huge thanks, more than I can describe in words, for their unconditional support and unfailing confidence in my ability to succeed and to my parents-in-law, Jean and David, thank you too for being there.

Finally my biggest thanks go to my best friend and husband for sticking by me through the ups and downs, for his understanding, enduring support, cunning motivational tactics, fixing the printer at 2am but most of all for never doubting that I could do it. Thanks Chris! xxx
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALPHA</td>
<td>Access to Learning for the Public Health Agenda</td>
</tr>
<tr>
<td>ASA</td>
<td>Ambulance Service Association</td>
</tr>
<tr>
<td>ATSDR</td>
<td>Agency of Toxic Substances and Disease Registry</td>
</tr>
<tr>
<td>BMA</td>
<td>British Medical Association</td>
</tr>
<tr>
<td>BMJ</td>
<td>British Medical Journal</td>
</tr>
<tr>
<td>BTEX</td>
<td>Benzene, Toluene, Ethylbenzene, Xylene</td>
</tr>
<tr>
<td>CBRN</td>
<td>Chemical, Biological, Radiological, Nuclear</td>
</tr>
<tr>
<td>CCDC</td>
<td>Consultant in Communicable Disease Control</td>
</tr>
<tr>
<td>CDC</td>
<td>Centre for Disease Control</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation and Liability Act</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation and Liability Act (US)</td>
</tr>
<tr>
<td>CIRS</td>
<td>Chemical Incident Response Service</td>
</tr>
<tr>
<td>CLEA</td>
<td>Contaminated Land Exposure Assessment</td>
</tr>
<tr>
<td>DEFRA</td>
<td>Department for Environment, Food and Rural Affairs</td>
</tr>
<tr>
<td>DETR</td>
<td>Department of the Environment, Transport and the Regions</td>
</tr>
<tr>
<td>DH</td>
<td>Department of Health</td>
</tr>
<tr>
<td>DNAPL</td>
<td>Dense non-aqueous phase liquids</td>
</tr>
<tr>
<td>DoE</td>
<td>Department of the Environment</td>
</tr>
<tr>
<td>EAI</td>
<td>Environment Accident Index</td>
</tr>
<tr>
<td>EHP</td>
<td>Environmental Health Practitioner</td>
</tr>
<tr>
<td>EIA</td>
<td>Environmental Impact Assessment</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FPHM</td>
<td>Faculty of Public Health Medicine</td>
</tr>
<tr>
<td>FSA</td>
<td>Food Standards Agency</td>
</tr>
<tr>
<td>HAZMAT</td>
<td>Hazardous material</td>
</tr>
<tr>
<td>HEPA</td>
<td>Health Emergency Planning Advisor</td>
</tr>
<tr>
<td>HIA</td>
<td>Health Impact Assessment</td>
</tr>
<tr>
<td>HIS</td>
<td>Health Impact Severity</td>
</tr>
<tr>
<td>HSE</td>
<td>Health and Safety Executive</td>
</tr>
<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
</tr>
<tr>
<td>ICRCL</td>
<td>Interdepartmental Committee for the Redevelopment of Contaminated Land</td>
</tr>
<tr>
<td>INES</td>
<td>International Nuclear Event Scale</td>
</tr>
<tr>
<td>IPCS</td>
<td>International Programme for Chemical Safety</td>
</tr>
<tr>
<td>IPPC</td>
<td>Integrated Pollution Prevention and Control</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>LA</td>
<td>Local Authority</td>
</tr>
<tr>
<td>LNAPL</td>
<td>Light non-aqueous phase liquids</td>
</tr>
<tr>
<td>MHIDAS</td>
<td>Major Hazard Incident Data Service</td>
</tr>
<tr>
<td>NCEC</td>
<td>National Chemical Emergency Centre</td>
</tr>
<tr>
<td>NHS</td>
<td>National Health Service</td>
</tr>
<tr>
<td>NIEH</td>
<td>Non-infectious Environmental Hazard</td>
</tr>
<tr>
<td>NPL</td>
<td>National Priorities List (US)</td>
</tr>
<tr>
<td>NRPB</td>
<td>National Radiological Protection Board</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic CO-operation and Development</td>
</tr>
<tr>
<td>PAH</td>
<td>Polyaromatic Hydrocarbon</td>
</tr>
<tr>
<td>PCB</td>
<td>Polychlorinated biphenyl</td>
</tr>
<tr>
<td>PCT</td>
<td>Primary Care Trust</td>
</tr>
<tr>
<td>PHLS</td>
<td>Public Health Laboratory Service</td>
</tr>
<tr>
<td>PPC</td>
<td>Pollution Prevention and Control</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>RSPU</td>
<td>Regional Service Provider Unit</td>
</tr>
<tr>
<td>SCIEH</td>
<td>Scottish Centre for Infection and Environmental Health</td>
</tr>
<tr>
<td>SGV</td>
<td>Soil Guideline Value</td>
</tr>
<tr>
<td>SHA</td>
<td>Strategic Health Authority</td>
</tr>
<tr>
<td>SNIFFER</td>
<td>Scottish and Northern Ireland Forum for Environmental Research</td>
</tr>
<tr>
<td>TPH</td>
<td>Total Petroleum Hydrocarbons</td>
</tr>
<tr>
<td>US EPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>UST</td>
<td>Underground Storage Tank</td>
</tr>
<tr>
<td>VOC</td>
<td>Volatile organic compound</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

1. Introduction

The overall objectives of the Engineering Doctorate (EngD) Programme in Environmental Technology are to create graduate Research Engineers "with the necessary background knowledge, skills and experiences to understand the relationship between the environment, technology and business and to apply this understanding to the development and promotion of corporate strategy" (University of Surrey/Brunel University, 2002).

In addition the course handbook states that Research Engineers need to:

- be able to plan and execute flexible, innovative research and development programs that respond to customer needs;
- form, work within, and where necessary, lead teams with multidisciplinary backgrounds;
- have expert knowledge in the field of environmental technology and be able to apply techniques that balance social and economic benefit against resource utilisation and environmental impact;
- possess a working knowledge of project management and business methods; and
- have excellent communication skills.

In order to demonstrate full attainment of these objectives, the final thesis is presented as a portfolio of the work undertaken throughout the four-year project (the 'Portfolio') comprising a thesis, a series of appendices to support the work presented and other key documents, which demonstrate innovations and contributions to knowledge.

The complete contents of the Portfolio, including assignments from the EngD programme of courses, are listed in Appendix Q, along with a brief description where applicable. Volume 1 contains the main body of the thesis with supporting appendices presented. All salient points from the progress reports submitted at six-monthly intervals throughout the duration of the project (Volume 2) have been
extracted and are provided in Volume 1. The full Portfolio is not enclosed, as it is too large to be submitted in its entirety. The examiners are welcome however to view any additional items from the Portfolio prior to the viva should they wish to do so. It will also be available in full for viewing at the viva examination.

The aims of this executive summary are to set the Portfolio within the context of ‘Environmental Technology’ and to direct the reader to the evidence within the thesis demonstrating innovations and contributions to knowledge. To achieve these aims it is divided into three main sections comprising: an overview of the project, a summary of the contributions to knowledge and finally a setting of the final project outputs within the context of environmental technology.

2. Project overview

Incidents involving chemicals, whether deliberate or accidental, can have far reaching implications in terms of their potential human and environmental health impacts. While preventing incidents is the clearly the most desirable option, it has been recognised that in an increasingly industrialised society accidents can and do happen. Additionally, the devastating impact of the terrorist attacks in the United States in September 2001 has raised awareness of the potential for a deliberate release of a chemical, biological, radiological or nuclear agent and the need to be prepared to respond to and manage any such incident effectively.

Unsurprisingly, there is no single organisation within the UK with all the expertise and resources required to effectively manage a ‘chemical incident’ (defined in Chapter 1). As a result incident response has to be a combined, co-ordinated procedure between many services and organisations including the emergency services, the Environment Agency, the local authority and the local public health department. Therefore a structured approach to incident management, along with easily accessible resources to facilitate an effective response to any potential or confirmed problem, has been identified as a key need and has been the principal issue addressed by the project.
In particular the project has focussed on the role of the National Health Service (NHS) and specifically public health practitioners in responding to chemical incidents since evidence shows that limited experience, combined with the lack of standard procedures, has resulted in the public health aspects of these problems being managed on an ad hoc basis. Furthermore it has been identified that lessons learned through managing incidents are unlikely to be reported in the wider public health arena since no formal mechanism or requirement to disseminate information has existed.

To support the public health response to chemical incidents, public health departments have service level agreements with one of the five Regional Service Provider Units (RSPUs) across the UK. The role of the RSPU is to provide the toxicological information needed to undertake hazard and risk assessments and to provide advice to assist in the protection of the health of the public.

This research project has been undertaken in collaboration with the Chemical Incident Response Service (CIRS) which is the RSPU based at the Medical Toxicology Unit, Guy's and St Thomas' Hospital NHS Trust in London. CIRS hold contracts with 21 strategic health agencies in NHS regions across England covering a population of around 37 million. CIRS has provided a unique environment in which to carry out the project, including the opportunity to spend time with public health practitioners to identify more precisely their resource needs and to test and explore proposed solutions in 'real' situations, thereby ensuring that the project outputs are both pragmatic and functional. Furthermore personal involvement in responding to actual chemical incidents has facilitated the collection of a significant database of information about how incidents have been managed, thereby facilitating identification of 'best practice' as well as areas for improvement.

Previously the information provided by CIRS has tended to be medically based and has not always taken into consideration the interactions that link human health with environmental quality (Chapter 1), including the potential for long-term environmental effects that could bring about an equal if not greater threat to human health. For example, a chemical spill onto land may migrate through to the
groundwater and pollute the drinking water supply which, if consumed might result in adverse health effects.

Consequently a key aim of this research project has been to establish a better understanding of pollution mechanisms within the environment, including the importance of ensuring that pollution streams are not diverted from one environmental medium to another.

A particular focus of the project has been land contamination (Chapter 2) since until recently soil has not been granted the same level of protection as air or water. Additionally land contamination is considered to present an interesting challenge from a management viewpoint because establishing a relationship between the presence of contaminants in the soil and reported adverse health effects is not always straightforward. A review of the literature has demonstrated however that land contamination has the potential to impact on human health and the environment, hence the need to develop a framework for dealing with such problems is considered to be justified. Research into the management of land contamination incidents is therefore both essential and timely although the need to address wider concerns, including risk communication, is also recognised. Furthermore, the effective management of ‘new’ land contamination incidents can contribute to the development of a more sustainable society by ensuring that future generations do not have a legacy of contaminated land to deal with.

3. Contributions to Knowledge

A key objective of the research project has been the development of a methodology to support role of public health practitioners in responding to chemical incidents. This has been met through developing a greater understanding of incident genesis and evolution and subsequently preparing and disseminating resources based on identifying best practice and lessons learned from past incidents. Significant project outputs can be categorised broadly as ideas and concepts that provide the philosophical overarching framework, and the more practical tools and resources that have been created around them. These have been divided into five categories:
1. A system for categorising chemical incidents

A scale to categorise the potential health and environmental impact of a chemical incident has been developed (Chapter 3) and five categories ranging from 'insignificant incident' to 'catastrophic incident' defined and illustrated with examples. The aim of the 'chemical incident impact scale' (CIIS) is to improve communication between the agencies involved in incident management and it is likely to be adopted at a national level.

Representatives from the Department of Health are currently reviewing a paper prepared for publication entitled “A categorisation system to communicate potential public health impacts of acute chemical incidents” (Appendix P).

2. A generic framework for chemical incident management

An additional project output has been the development of a generic framework for chemical incident management (Chapter 4), which recognises that although all incidents are different, patterns in the way events present and evolve can be identified. In the framework the incident management process is broken down into three key phases and may be illustrated initially using an incident timeline although subsequently a cyclical or ‘closed-loop’ framework has been proposed as it reflects better the dynamic process of incident evolution. A feedback mechanism has also been incorporated in recognition of the importance of updating emergency plans with observations and improvements from past incidents.

The framework has been used in creating guidance for chemical incident management, including tools for planning and response and, most importantly, is based upon lessons learned from past incidents and through practical experience rather than purely theoretical ‘best practice’.

3. Tools for planning and response

It is recognised that there are limited resources specifically for public health response to chemical incidents and that the majority of those that have been available outline what should be done rather than how to actually do it (Chapter 4).
A methodology for public health risk assessment, which considers both the health and environmental impacts of the incident, has been developed to reflect the needs of public health practitioners identified through consultation. Actions to be considered at each phase of the incident management process are divided into ‘general actions’ and ‘action to protect the health of the public’ and are presented in the form of a checklist. Suggested actions also reflect the seriousness of the incident measured on the chemical incident impact scale (CIIS). A series of supplementary event specific checklists, such as contamination of drinking water or allotment soil, have also been developed.

The development of the checklist design and layout has been an iterative process and incorporates suggestions from end users to ensure that the information is easy to find and use. However the checklists should be regarded as dynamic tools that can and should be modified and updated to reflect both current ‘best practice’ and the preferences of the public health practitioners who use them.

Checklists have been published in the Chemical Incident Report, a periodical produced quarterly by CIRS addressing issues within the field of chemical incident management and which can be downloaded from the CIRS website for use in the field.

4. Tools for land contamination incidents

After looking generally at chemical incidents, the project focussed on those that resulted in land contamination (Chapter 5). Patterns identified in land contamination incident evolution have then been used to develop both a categorisation scheme for such incidents and guidance for managing future problems.

Two distinct categories of land contamination incidents have been defined – acute and chronic - subsequently referred to as the ‘principal categories’. The term acute has been used to describe land contamination that results from a sudden one-off release of a chemical either directly to the soil, such as leak or spill from a tank, or indirectly via aerial deposition or firewater runoff. In contrast, chronic describes land contamination that has resulted from a continued or repeated release of chemical
substances over a period of time. Response time has been identified as the key parameter that determines the effectiveness of response for *acute* land contamination incidents, whereas for *chronic* land contamination incidents success is more likely to be determined by accurately establishing the most significant exposure pathways between the source of contamination and sensitive receptors. Further differences between *acute* and *chronic* incidents are identified and discussed (Chapter 2).

Detailed consideration has shown that the CIIS for acute chemical incidents (Chapter 3) may be used to categorise acute land contamination incidents since the majority of these problems result from leaks and spills i.e. acute chemical incidents. However, it is not appropriate for categorising chronic problems and therefore a separate system to identify and manage these incidents is required. A categorisation system for land incidents has therefore been developed (Chapter 5) in addition to the generic management model for chronic land contamination incidents. This has provided the basis for a chronic land checklist. To limit the number of checklists and to minimise duplication of information and confusion over which tools to use, the acute chemical incident checklist (Chapter 4) is considered however to be acceptable for use in responding to acute land contamination incidents. The main exception to this is for acute chemical incidents involving fuel since they were considered to present an interesting problem in terms of potential human and environmental health impacts (Chapter 6). As a result a detailed study of fuel incidents has been undertaken.

5. **Fuel incidents**

A retrospective review of past incidents reported to CIRS has revealed that around one third of all land contamination incidents have resulted from acute chemical incidents and of these 70% have involved fuel oils or chemicals used as fuel additives, including petrol, diesel, kerosene and heating oil (Chapter 6). The review has highlighted some of the distinguishing features that make acute incidents involving fuel unique in terms of the management response required including the complexity of the problems in terms of containment, clean up and decontamination. Given both the frequency of these incidents and the potential impact of such events on the health of the public, it has been realised that there is an urgent need for guidance for the management of acute fuel incidents. This has been developed and is
in the form of a checklist, which aims to integrate the actions of other agencies involved in managing the event as well as highlighting specific actions to protect the health of the public.

This work has been published in ‘Public Health Medicine’ and presented at a number of conferences both in the UK and internationally.

Although the project has focussed on the needs of public health practitioners, the generic framework and risk assessment methodology is available for other agencies involved in incident response to use and refine further to suit their respective needs. A number of advantages of all agencies using the same guidance in responding to incidents have been identified. These include improved communication, minimised use of jargon and better understanding of roles and responsibilities; ultimately resulting in a more coherent and structured response to chemical incidents. Furthermore the tools can be adapted to consider both deliberate and accidental releases of biological, radiological and nuclear agents in addition to chemicals.

4. Setting the Final Outputs in the Context of Environmental Technology

‘Environmental Technology’ is defined as the application of techniques that balance social and economic benefits against resource utilisation and environmental impact. Therefore the term environmental technology encompasses not only technical solutions to environmental problems, but also improvements in management processes and techniques to minimise environmental impact (Goodfellow, 2001).

Furthermore, since the ‘environmental challenge’ is driven by the views of society, emotive issues such as disposal of waste via landfill or incineration and releases to the environment from industrial processes, need to be managed effectively. When we think about the environment we tend to be concerned first and foremost with human health and in general, regulators such as the Environment Agency mirror this view. Indeed protection of human health and the resources on which we depend is often the only real concern of regulators under many legislative regimes concerned with environmental protection, including Integrated Pollution Prevention and Control (IPPC). However, human health is inextricably interlinked with wider environmental
issues (Chapter 1) so essentially human health and environmental impacts can be regarded as one and the same thing. The only real difference is that human health impacts are in effect a subset of wider environmental impacts.

The focus of this project has been on the improvement of management systems for responding to chemical incidents, with the aim being to prevent future events and to minimise the harm to human health from those incidents that will inevitably occur. As a result the project has embraced the concept of environmental technology in the widest sense by considering the socio-economic consequences of incident management alongside the more obvious technological challenges associated with the containment and cleanup of chemicals in the environment. This has included acknowledging the importance of public perception and concerns with regard to environmental contamination.

Using an iterative methodology to identify ‘best practice’ has resulted in the development of dynamic tools and resources that can be adapted and refined to reflect most effectively the changing views and expectations of society as well as legislative requirements. Furthermore a systematic approach to incident management is more cost-effective and less wasteful in terms of resource consumption and additionally the overall impact on human and environmental health both now and in the future is reduced. As a result the contributions of this project provide a more sustainable solution to chemical incident management.
1. CHEMICAL INCIDENTS, THE ENVIRONMENT AND HUMAN HEALTH

"We do not know when or if there will be a chemical attack, but we know, from our experience in handling other crises involving chemical accidents, that preparation saves time and saves lives”

- Dr Roberto Bertollini, Director, Division of Technical Support at the WHO Regional Office for Europe, 2002

The devastating impact and long-term consequences of the terrorist attack on the World Trade Centre in New York in September 2001 raised awareness internationally of the need to be prepared to respond effectively to an incident, which could potentially involve chemical, biological or nuclear agents.

Chemical incidents, whether deliberate or accidental, have the potential to cause widespread harm to both human health and the environment. Major catastrophes, such as the release of dioxins when a chemical reactor overheated in Seveso, Italy in 1976 and the explosion at Union Carbide in Bhopal, India in 1984, which resulted in many thousands of human casualties, are thankfully rare. However, between October 2000 and March 2001, the National Focus\(^1\) received 704 confirmed reports of acute chemical incidents. This figure is based on data provided by the four Chemical Incident Regional Service Provider Units\(^2\) (RSPUs) in England and Wales, the

\(^1\) The National Focus is a UK organisation funded by the Departments of Health for England, Scotland, Wales and Northern Ireland to co-ordinate work on response to chemical incidents and surveillance of health effects attributable to chemicals in the environment (DoH, 1997 cited by Bakhshi, 1997). The main activities of the National Focus are to improve NHS preparedness with respect to chemical incident management, to facilitate the response to chemical incident management and to advise the UK government of the potential public health impact of chemical incidents and to undertake public health surveillance of the impact of environmental chemicals (National Focus, 2002).

\(^2\) The role of the RSPUs, which are based in Birmingham, Cardiff, London and Newcastle, is to provide timely advice on public health, environmental, scientific, toxicological and epidemiological aspects of chemical incidents to medical professionals including GPs, A&E clinicians and public health practitioners.
Scottish Centre for Infection and Environmental Hazards (SCIEH), the Maritime and Coastguard Agency, the Ambulance Service Association (ASA) and the National Chemical Emergency Centre (NCEC).

Obviously preventing incidents from occurring in the first place is the most desirable option. However, it is important to recognise that in an increasingly industrialised society, accidents can and do happen. If appropriate action is not taken the potential to cause widespread harm to human and environmental health is high, yet the effective management of chemical incidents can contribute to the development of a more sustainable society by ensuring that future generations do not have a legacy of contamination to deal with. Therefore it is imperative that suitable procedures are in place and that plans have been tested so that incidents are correctly identified, appropriate actions are taken without delay and that subsequent management activities are effective. Yet tools and guidance to support those involved in responding to and managing chemical incidents are currently limited. Furthermore, inadequate feedback and the lack of a formal mechanism to ensure that lessons learned from past incidents are used in the development of guidance and procedures for future use, mean that valuable information is currently being lost.

To fill this information gap and the apparent need, this research project has made three key contributions.

The first project output is the proposal of a standard framework for the management of chemical incidents, which recognises that although all incidents are different, there are patterns in the way events evolve and can subsequently be managed. This has resulted in a better understanding of incident genesis and the proposed ‘incident timeline’ concept presented in Chapter 4 as well as a more thorough understanding of the key agencies that are likely to be involved in responding to an incident. Many agencies are involved in chemical incident response including the emergency services, the Environment Agency, the local authority and the local public health department so clearly defined roles and responsibilities and good communication are fundamental to achieving a successful outcome. The work in this project has focussed primarily on the role of the public health practitioner since limited
experience combined with a lack of suitable guidance has resulted in chemical incidents being managed on an ad hoc basis from a public health perspective. In a recent survey of Consultants in Communicable Disease Control (CsCDC) (Lefort & Pye, 2002) to assess their learning needs in respect of the possible deliberate release of biological agents, gaps in their learning about chemical releases were highlighted as a ‘most urgent need’ to be addressed. Furthermore 63% of respondents identified ‘protecting the environment’ as an area where they either do not have or want more readily accessible information.

As ‘hands on’ experience of public health practitioners in chemical incident management and environmental issues is often quite limited, public health departments have service level agreements with one of the five Regional Service Provider Units (RSPUs) across the UK. This research project has been undertaken in collaboration with the Chemical Incident Response Service (CIRS) which is the RSPU based at the Medical Toxicology Unit, Guy’s and St Thomas’ Hospital NHS Trust in London. CIRS hold contracts with 21 strategic health agencies in NHS regions across England covering a population of around 37 million. This has provided a unique environment in which to undertake the project work. A particular benefit has been the opportunity to test and explore ideas and apply them in ‘real’ situations, thus ensuring that project outputs are effective and functional.

The second project contribution is an improved understanding of chemical incidents that result in land contamination, or ‘land contamination incidents’, and the development of tools to support the public health response to this specific category of events. Research work has concentrated on land contamination incidents since these present an interesting challenge from a public health perspective not least because a causal relationship between exposure to contaminated soil and adverse health effects is difficult to establish. During the course of this research project, contaminated land has become increasingly important on the political agenda. A new legal framework for managing the identification, investigation and clean-up of contaminated sites that are considered to present a hazard or potential hazard to human health and the environment came into force on 1 April 2000. In addition, some of the supporting guidance documentation was published in March 2002 including the long-awaited
Contaminated Land Exposure Assessment (CLEA) model to derive site-specific soil guideline values. There is already a significant amount of research into the management and remediation of land contamination that has resulted from past industrial use and there is probably little original work that could be added to this. However, much of the information is not available in a form that public health practitioners can use in the event of an incident to determine the adverse health effects that could potentially be experienced following exposure to chemically contaminated soil. Investigation into land contamination incidents and their management from a public health perspective is therefore both timely and important.

It is therefore appropriate that this research project concentrates on land contamination that has resulted from chemical incidents to mitigate risks to human health and the environment. This ties in well with the original project brief which suggested that little work has been done to investigate the impact on human health and the environment from the uncontrolled release of chemicals onto land during a chemical spill and the subsequent contaminant migration through the subsurface environment.

Much of the research work from this section of the project has been included in a book being published by the Stationery Office entitled ‘The Environment and Public Health’ (Eagles et al, 2002). The book covers all types of chemical incident, but is primarily intended for use in responding to minor incidents rather than catastrophic or disaster events. The main objective is to provide an operational tool that can be used in the emergency response to all types of chemical incident. The primary audience is expected to be public health practitioners although much of the information is applicable to others involved in the management of chemical incidents, including the emergency services and local authority environmental health practitioners.

The third project output is a rapid response tool to be able to measure the potential public health impact of a chemical incident. Five categories of incident have been defined in terms of the potential number of people exposed and the severity of the health impact. These have been used to develop an incident categorisation scale, the
primary use of which is as a tool for communication although a number of additional uses have been recognised and are presented in Chapter 3.

A diagram to illustrate how each component of the project links together is presented in Figure 1.1.

Figure 1.1: Project components

1.1 Definitions

For surveillance and incident management purposes, it is important that the term ‘chemical incident’ is clearly defined in order that such incidents are easily identified. The National Focus define a chemical incident as, “an acute event in which there is or could be exposure of the public to chemical substances which cause, or have the potential to cause, ill health.” This is similar to the definition developed by the International Programme for Chemical Safety (IPCS) who use the
term to describe “an occurrence of public health concern caused by an acute release of a toxic or potentially toxic agent” (IPCS, 1999). The definition used by the Chemical Incident Response Service (CIRS) differs slightly, and describes a chemical incident as “an unforeseen event leading to acute exposure of two or more individuals to any non-radioactive substance resulting in illness or a potentially toxic threat to health” (O'Sullivan & Hill, 1991).

Interestingly all of the chemical incident definitions take into account the health impact of the event but none acknowledge the potential environmental implications, yet it is unlikely that an event that results in negative health consequences would give rise to negligible environmental damage. The Environment Agency does not appear to have a formal definition for a chemical incident or ‘pollution incident’ but defines four pollution incident categories. These take into consideration the impact on water quality, aquatic ecosystems, abstraction points, amenity value, agriculture/commerce and man, so human health effects are considered as one aspect among others.

The limited integration of environmental considerations into the chemical incident definitions is reflected in current procedures for the response and management of such incidents, which are discussed in Chapter 2. The relationship between human health and the quality of the environment will be explored more fully in the next section.

Whatever the differences or shortcomings of the definitions, there is little disagreement that the impact of a chemical incident, whether accidental or deliberate, can be minimised through effective planning and training of those who may be involved in responding to such an event. A meeting of IPCS held in Copenhagen in early 2002 recognised the importance of “international cooperation and close collaboration, planning and integration across a host of different sectors and experts. This allows a fast and efficient response in emergencies, and it also strengthens public services overall” (Coleman, 2002) and in particular highlighted the need for a common alert and response system for chemical incidents. In light of this, work
towards an international scale that will quickly identify the severity of an incident has been undertaken as part of this research project and is presented in Chapter 3.

It is also necessary when considering the impact on human health to define exactly what is meant by ‘health’. The World Health Organisation (WHO) defined health as “a complete state of physical, mental and social well-being, and not merely the absence of disease” (WHO, 1948 cited by Steinemann, 2000) thus explicitly incorporating many aspects of human welfare (BMA, 1999). This means that when considering the consequences of a chemical incident or other environmental pollution incident on human health, more than physical harm should be considered. Indeed experience suggests that the psychological impact of being exposed to potentially toxic chemicals can have a much longer lasting impact than the immediate adverse health effects. To reflect this ‘public health’ has been defined as "the science and art of preventing disease, prolonging life and promoting health through organised efforts of society" (FPHM, 2002). It is concerned primarily with health and disease in populations. Throughout this project, where reference is made to ‘public health’ it will refer to the function of those practitioners working in this field. The chief responsibilities of those working in public health are monitoring the health of a population, the identification of its health needs, the fostering of policies that promote health and the evaluation of health services (FPHM, 2002).

Finally it is important to establish a definition for ‘the environment’. It is defined in the UK Strategy on Sustainable Development as “external conditions or surroundings in which people, plants and animals live, which tend to influence their development and behaviour” (DoE, 1994 cited by BMA, 1999). This includes social, cultural and economic conditions that contribute to ‘quality of life’ as well as physical conditions, such as the quality of air, land and water.

It is important also that pollution streams are not diverted from one environmental medium to another, possibly more sensitive, medium. Although air, land (soil) and water are inextricably interlinked until recently soil has not been granted the same level of protection as air or water. For example comprehensive European Community policies have existed for air and water for many years, but this is not the situation for
soil. There are a number of reasons why this may be. Firstly soil is perceived to be dirty - we often refer to it as ‘dirt’ - so contamination may be less obvious than contaminated air or water that may have a strange taste or odour. Secondly human interaction with soil is less frequent than with the other environmental media. Contaminants do not disperse as far or as quickly in soil as they do through air and water so any adverse health effects may be very localised and also exposure may occur several years after the initial pollution incident. Nevertheless, it is now believed that soil pollution should be given the same priority as pollution of air or water (RCEP, 1996; Sims et al, 1997); Senesi et al (1999) describe soils as the most important environmental compartment functioning as a sink for trace elements released by human activities. These issues will be covered in more detail in Chapter 2.

The remainder of this chapter is dedicated to looking at the interrelationships that exist between humans and the environment and considering the advantages of addressing the impacts of a chemical or other pollution incident simultaneously.

1.2 The Environment and Human Health

Human health is increasingly recognised as being strongly influenced by environmental components e.g. clean air and water (Cirone & Duncan, 2000), although the link between exposure to environmental pollutants and the subsequent human health impact is often not clear (Ehrmann & Stinson, 1994). This can create difficulty in environmental decision-making as regulation and mitigation of environmental problems is frequently based on the need to prove the likelihood of an adverse health effect and the underlying cause-effect relationship (Laws & Sagar, 1994). Nevertheless in 1972 the United Nations (UN) recognised “the link between environmental destruction and human welfare” (Zaidi, 1994) although it is acknowledged that the nature of environmental hazards and threats varies considerably from country to country. They include problems driven by poverty, for example, inadequate supply of water and waterborne disease, as well as natural disasters, such as earthquakes and volcanoes. Many effects are trans-boundary and
cannot be regulated at a local or even national level (BMA, 1999) and hence require international collaboration if they are to be effectively controlled.

In the UK, since the Clean Air Acts of 1956 and 1968, the environmental debate has widened to include many pollutants and potential health hazards (DoE & DoH, 1996). More recently the UK Government’s Sustainable Development Strategy, published in 1994, made it clear that health considerations are one of the primary concerns for environmental protection and consequently sustainable development policy. Furthermore in 1996 the environment was included as a key area for consultation within the Health of the Nation strategy “the central plank of government policy on health in England, which forms the main context for planning in the NHS into the next millennium” (National Audit Office, 1996).

The general population often identifies health, education and employment as key areas of concern. They do not, however, place such importance on the environment, even though recognition of the impact that anthropogenic activity has on the environment has become an increasingly important concern of populations and governments throughout the world. Bumingham and Thrush (2001) carried out a study among groups in disadvantaged communities to look at attitudes to the environment. Findings in their report ‘Rainforests are a long way from here’, suggested that people were concerned about their own surroundings, but they felt distanced from wider environmental issues and the way they are debated. “Our study suggests that cleaning up buildings, derelict sites and streets would considerably improve the quality of life in these areas. Long-term solutions to problems in the local environment require policy makers to take a joined-up approach to environmental, social and economic policies that recognises the way they all affect each other.” (Bumingham, 2002).

Steinemann (2000) suggests that by showing how changes in the environment affect human health, support for the effort to protect and promote environmental quality can be generated. This alludes to the suggestion that humans are essentially anthropocentric and that all efforts to protect the environment are merely an attempt
to protect human health... "we are agents of consumption living in a world of consumerism and consumption of resources" (Banner, 1998).

Cirone and Duncan (2000) have also proposed an approach for integrating people and ecological entities into risk assessment. They suggest that if lines of evidence linking human and ecological endpoints were examined in a holistic process, there would be opportunities to identify the harm to society from actions which may seem in the best interest of humans but not necessarily beneficial to biological integrity. As human beings we seem to have a notion of obligation to be 'nice' and protective towards other species and the environment and follow the 'precautionary principle' in decision making much of the time. But in the words of Kermit the Frog, "...it seems to me that if you wait until the frogs and toads have croaked their last to take some action, you've missed the point..."(Riger, 1993). Sadly we are not as proactive as we could be in taking pre-emptive steps to protect the environment. We often miss the point, which presents a fundamental stumbling block in working towards a sustainable future.

Regardless of the motive or driving force behind raising environmental awareness, it is clear that there is no single solution to complex environment and health problems and this substantiates the need to develop integrated approaches that pool information, expertise and common resources (Green et al, 2000).

Perhaps the most logical way forward is to integrate health and environmental policy more closely, to develop a more joined-up approach for assessing health and environmental risk and to consider human health and the environment simultaneously as part of a fully integrated system. Yet it would seem that the inter-relationships, though not always fully understood, are not currently addressed and that there has been little or no attempt to look for cumulative, synergistic or antagonistic responses (Cirone & Duncan, 2000). This argument has been presented in a number of journal publications, including Environmental Impact Assessment Review, which presented a series of papers in a special issue in 1994 entitled "Human Health and the Environment: Unanswered Questions, Unquestioned Answers". The aim was "to bring together the insights of environmental and health
care professionals ...to help each group understand how the other thinks about risk ...and how better health risk assessment can enhance decision making about environmental risk” (Susskind & Hill (eds.), 1994).

In the next section, current approaches to assessing the environmental and human health impact of industrial processes and incidents will be discussed. Particular attention will be given to Environmental Impact Assessment (EIA) and Health Impact Assessment (HIA). Although not directly applicable to the assessment and management of chemical incidents, the integration of EIA and HIA approaches has been more widely discussed in the published literature so offers the clearest and most persuasive arguments with regard to why the two fields should be integrated. Furthermore there are number of similarities pertaining to the type of information used in carrying out an assessment for EIA, HIA and chemical incident response and management.

1.2.1 Environmental Impact Assessment

There are many definitions for Environmental Impact Assessment (EIA) but essentially it is a systematic process in which the environmental consequences of a proposed project are collected and examined in advance. Its purpose is to aid decision-making by allowing a number of alternative proposals to be considered.

In the UK, EIA was initially an ad hoc process carried out by local-planning authorities and developers (Glasson et al, 1995) but in 1985 an EC directive introduced a uniform system for undertaking EIAs across member states. The directive (85/337) makes an EIA mandatory for ‘Annex 1’ projects, which includes oil refineries, power stations and chemical installations.

An environmental baseline is established - a description of the present state of the environment prior to any development - and then the likely impacts of the proposed project are identified and summarised in a checklist or matrix. Impacts considered typically include soil and geology, flora and fauna, water quality, air quality, employment and traffic. Subsequently an Environmental Impact Statement (EIS) is...
prepared. In principle this process is not dissimilar to that carried out following a chemical incident although there is currently no formal methodology to guide the post-incident assessment.

Steinemann (2000) examined the use of EIA for combining the environment and health and investigates to what extent health impacts are currently analysed in EIAs. The report builds on previous studies that have also studied the gaps between EIA and human health including a book published by the British Medical Association (BMA) in 1999. In general these confirmed the general lack of attention to human health impacts in EIAs as well as revealing inconsistent and unclear definitions.

Steinemanns report discusses the results of an empirical study of 42 EIAs undertaken in the US. It concludes that health impacts are generally not mentioned and where they have been considered, the focus is on single cause, single effect and single generation effects rather than cumulative impacts or inter-generational effects. Similar conclusions can be drawn from the review of 39 Environmental Impact Statements commissioned by the BMA to examine reporting of impacts on human health; human health issues received adequate coverage in only 28% of the statements (BMA, 1999). Steinemann suggests that two of the reasons for the lack of attention to human health risks are the analytical complexity (multiple causes and multiple effects, lag time between causes and effects, uncertain mechanisms, individual susceptibilities etc.) and the lack of clear procedures or methodologies for assessing health implications. The BMA echoes these observations but also adds that legislation fails to make human health impact assessment an explicit requirement and is therefore perceived to be less important.

1.2.2 Health Impact Assessment

Within the literature HIA is described as a methodology that enables the identification, prediction and evaluation of the likely changes in health risk (both positive and negative) of a policy, programme, plan or development on a defined population. The impacts considered could be direct or indirect, immediate or delayed and should take into account physical, mental and social impacts (BMA, 1999).
Whereas EIA must always be prospective and carried out as part of the project proposal to identify all potential impacts, a HIA could be carried out before, during or after a proposal has been accepted. The three types of HIA are described as (Ison, 2000):

*Prospective* - conducted before the implementation of a proposal and involving the assessment of potential health impacts, which creates the opportunity to make changes.

*Retrospective* - conducted after the implementation of a proposal and involving assessment of apparent health impacts associated with the proposal, which can be used to provide information for similar situations in the future.

*Concurrent* - conducted during the implementation of a proposal and involving assessment of health impacts as they are recognised so action can be taken to mitigate any negative effects and minimise harm as required.

There is no definitive methodology for HIA although several toolkits are being developed (Barnes & Scott-Samuel, 2000). However, in general the ‘environmental’ component of the HIA process includes an assessment of health risks through the evaluation of hazards and risks, an understanding of the impact of environmental contamination on human health (toxicology), consideration of exposure standard and the quantification of health risks. This is analogous to the process undertaken to assess the health impact following a chemical incident.

HIA does not exist as a separate or parallel procedure but as a component of EIA, which is ideal as it supports and encourages an integrated approach to health and the environment. However as outlined above, adequate emphasis is not always placed on assessing the health impact of many projects. Steinemann (2000) makes a number of suggestions for improving human health impact assessment within EIA, which include addressing sources of health impacts, rather than just symptoms, incorporating qualitative information into health risk assessments and promoting collaboration between environmental and public health professionals.
These suggestions will be borne in mind in developing an integrated tool and guidance for the management of chemical incidents, presented in Chapter 4.

1.2.3 Integrated Assessment Approaches

"Worldwide, mechanisms for fully integrated action on environmental and health issues are quite limited. In the UK, for example, it has been found that while legislation gives scope for coverage of human health issues, this is not regarded as a priority by most public authorities" - British Medical Association (1999), p33.

The interaction between humans and the environment is complex and involves many aspects of our living, working and recreational activities (Green et al, 2000). So combining human health and environmental concerns in the same risk assessment process requires a diverse range of objectives to be considered and incorporated in the decision-making methodology (Figure 1.2).

Figure 1.2: Key inputs to environment and health decision-making
(Source: Green et al, 2000)

This presents a challenge because, as highlighted earlier in this chapter, people do not have a common value system or knowledge base with respect to ecological and environmental issues (Cirone & Duncan, 2000). There may also be limited understanding of human physiology and toxicology for example. Although many people now have access to the Internet and are able to obtain detailed information on
the risks associated with various chemicals and industrial processes, this information has not always been peer reviewed and so may be inaccurate or misleading or perhaps require careful interpretation (Eagles et al, 2002).

In traditional risk assessment processes, such as Environmental Impact Assessment, considerable emphasis is placed on acquiring quantitative data that could be regarded as scientifically rigorous. However, it should be borne in mind that often in assessing health and environmental impacts, qualitative information is more readily obtainable and as useful, if not more so, than quantitative data. For example, in living close to a landfill site where there may be odour issues, a diary from local residents may provide more compelling evidence to support concerns of potential harm to human health than routine monitoring of emissions from the site. This is not to suggest that quantitative data is not important, but that the use of qualitative information in the decision-making process should not be overlooked or dismissed as either biased or unreliable.

Regardless of the decision-making methodology used, any system that aims to combine the assessment of both health and environmental impacts needs to be transparent and the basis of the decision, as well as any areas of uncertainty, should be communicated clearly to stakeholders, including the public. Green et al (2000), who summarise a meeting held at the Institute for Environment and Health at the University of Leicester in 1999, draw similar conclusions. They discuss the importance of integrated strategies to protect environmental quality and human health and suggest that harmonising risk assessment procedures and improving stakeholder involvement is the most effective way that this can be achieved.

Since an unquestionable link between human health and the quality of the environment has been established, risk assessment methodologies developed as part of this research project should aim to employ more integrated approaches in order to minimise harm to human health and the environment and to prevent diversion of the impact from one to the other.
2. MANAGING LAND CONTAMINATION

Although the link between the quality of the environment and human health has been recognised for centuries, it is only fairly recently that soil has been identified as an important exposure route to potentially toxic substances. To substantiate this a press release in April 2002 saw the launch of a soil protection policy from the European Commission, which sets out the steps to achieve more complete protection of soils in the future (European Commission, 2002). The Communication is in response to 'concerns about the degradation of soils in the EU', and because 'soil is a vital and largely non-renewable resource and has not been the subject of comprehensive EU action so far'. It describes the functions and policy-relevant features of soil, the main threats to it and relevant current EU policy. The Communication acknowledges that man's interaction with soil has been both beneficial and negative over many centuries but that soils are coming under increasing threat from human activities. It also highlights other soil problems linked to industrial sites. The press release also states that the Commission will establish with Member States a complete picture of the extent of soil contamination throughout the European Union so that best practice and remedial techniques can be identified and put into practice. Currently the European Environment Agency estimates that there are between 300,000 and 1.5 million contaminated sites in Europe.

This chapter looks at soil and in particular land contamination that has resulted either from past industrial use or through direct or indirect contamination following a chemical incident. Legislation and guidelines for the management of land contamination in the UK are presented, followed by a discussion of the roles and responsibilities of statutory bodies. Particular focus is on the public health management of land contamination as we continue to explore the inter-relationships between environmental hazards and human health.

2.1 The UK Perspective

Land contamination is a widespread problem in the UK (Bell & Ball, 1995). Much results from past industrial activity and often sites have been abandoned and left
derelict for many years. A lack of legislative control gave rise to poorly managed waste disposal activity in the past, including the indiscriminate placement of industrial fill which has resulted many old industrial sites containing a heterogeneous mix of ground or ‘made ground’ (Finney & Dye, 1998) and mixtures of chemicals that are potentially hazardous to human and environmental health. Previously published estimates of the amount of land in the UK affected by contamination vary widely from 50,000 to 300,000 hectares, amounting to around 100,000 sites although the Environmental Agency estimates that between 5,000 and 20,000 may be a problem (Environment Agency, 2002).

In addition ‘new’ contamination of soil may result from industrial processes, such as the dumping of waste or effluent discharge, or chemical incidents, including leaks, spills, fires, explosions etc. Chemical incidents may give rise to direct contamination of the soil, such as a leak of fuel from an underground storage tank, or indirect contamination, such as runoff of contaminated surface water or deposition of particulates from a fire.

The dispersion of contaminants released to the environment is controlled by a complex set of processes that include various forms of transport and cross-media uptake (Asante-Duah, 1998). Soil, as well as being a ‘sink’ for contaminants, often provides a pathway to the other environmental media – air and water including surface water and groundwater (Figure 2.1) - and hence may also be regarded as a ‘source’ of contamination.

Whilst soil or land may be contaminated directly, there will always be the potential for secondary (indirect) contamination, and for another environmental medium to be affected if the source is not contained and mitigated in an appropriate and timely manner. An example of secondary contamination is presented in Box 2.1. There is also potential for food contamination if crops are grown in contaminated soil, as some plants are able to absorb and accumulate significant amounts of chemicals from the soil through their root systems. For example leafy vegetables are well known as cadmium accumulators (Mortvedt & Beaton, 1996).
Figure 2.1: Links between air, land and water.

Box 2.1: Secondary contamination of a UK beach (Goodfellow et al, 2001)

The land immediately behind a beach used by naturists and for line fishing and offshore commercial fishing for crab and lobster, was the site of a former gasworks. In April 1997 a local resident reported that there were reduced numbers of fishing bait on the beach and the fisherman also noticed a sulphurous smell and visible signs of oil whilst digging for bait. The information was passed on to the Environment Agency, who carried out sampling of sediment and seawater. Visual observation of the area showed the existence of patches of oily film on the sea, a phenolic smell, and sightings of pieces of “blue billy” (ferric ferrocyanide). An investigation was initiated, including further sampling.

A report was produced in January 1998, which concluded that the beach was affected by pollution and the most likely source was the former gasworks. A very high concentration of polyaromatic hydrocarbons (PAHs) (75 550 mg/kg) was reported in one sediment sample, and also a high concentration of cyanide (1 g/l) in seepage water. Subsequently a detailed environmental investigation of the beach including sediment, seepage and seawater sampling was conducted, the results of which were used to determine whether there was risk to the health of the public and if the beach should be closed to public access. Contaminants identified included ammonia, benzo(a)pyrene, phenol, cyanide, arsenic, manganese, and iron. Analytical results were compared with contaminated land and drinking water standards.

It was concluded that the beach was contaminated, but at the concentrations found it was decided that the contamination did not pose a risk to the health of the beach users and no action was taken to close the beach.
Land contamination can result from a point or non-point source. Point sources refer
to discrete, localised discharges of contaminants into the environment and include
emissions from an industrial chimneystack, a leak of fuel from an underground
storage tank or discharge of effluent to a river. Usually the contaminant is
 identifiable and can often be measured. Non-point or diffuse sources are releases of
contaminants into the environment over a wider area. Examples include traffic
emissions and contamination with radon gas in homes built on granite. The majority
of land contamination incidents result from point sources of contamination.

Sources of contamination that can affect all environmental media fall into one of two
categories:

**natural sources**: many pollutants within the environment have natural as
well as anthropogenic sources. For example, the geology in different areas of
the country will influence the background level of certain chemicals in the
soil. For example, arsenic and radon levels in soil in Cornwall are very high
compared to other parts of the United Kingdom.

**anthropogenic sources**: an anthropogenic (or man-made) source is used to
describe any process or facility that has the potential to release chemicals that
could result in contamination of environmental media, for example a factory,
a farm or a landfill site. Anthropogenic sources of contamination can broadly
be divided into three subgroups:

- historical legacies
- planned emissions from industry (regulated by the Environment
  Agency or Local Authority)
- unplanned emissions i.e. accidental releases

Many industrial processes have the potential to give rise to environmental
contamination. As a result the Department of the Environment (now the Department
for Environment, Food and Rural Affairs – DEFRA) prepared around 50 Industry
Profiles, which provide information on the processes, materials and wastes
associated with individual industries including information on the potential
contaminants. Similar information, which identifies potential land contaminants from
a number of industrial processes, is contained within 'Potential Contaminants for the Assessment of Land - CLR8' published jointly by DEFRA and the Environment Agency (DEFRA, 2002) and the Pollution Prevention and Control (PPC) Technical Guidance Notes developed by the Environment Agency, the Scottish Environmental Protection Agency and the Northern Ireland Environment and Heritage Service. Some examples of processes and potential contaminants are highlighted in Table 2.1.
Table 2.1: Sources of Land Contamination (adapted from Harrison, 1994)

<table>
<thead>
<tr>
<th>Source</th>
<th>Example</th>
<th>Likely contaminants could include:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derelict industrial sites</td>
<td>Gas works</td>
<td>Phenols, Tars, Cyanides, Arsenic, Cadmium</td>
</tr>
<tr>
<td></td>
<td>Electrical industries</td>
<td>Copper, Lead, Zinc, PCBs, Solvents</td>
</tr>
<tr>
<td></td>
<td>Tanneries</td>
<td>Chromium</td>
</tr>
<tr>
<td></td>
<td>Scrapyards</td>
<td>Metals, PCBs, Hydrocarbons</td>
</tr>
<tr>
<td>Atmospheric fallout</td>
<td>Fossil fuel combustion</td>
<td>Oxides and acid radicals of S and N</td>
</tr>
<tr>
<td></td>
<td>Vehicle exhaust</td>
<td>Lead, Polyaromatic Hydrocarbons (PAHs)</td>
</tr>
<tr>
<td></td>
<td>Metal smelting operations</td>
<td>Arsenic, Cadmium, Copper, Chromium, Nickel, Lead, Antimony, Zinc</td>
</tr>
<tr>
<td></td>
<td>Chemical industries</td>
<td>Organic micropollutants, Mercury</td>
</tr>
<tr>
<td></td>
<td>Waste disposal by incineration</td>
<td>Dioxins, Furans</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>Farm manure</td>
<td>Arsenic and Copper in pig and poultry manure</td>
</tr>
<tr>
<td></td>
<td>Sewage sludges</td>
<td>Rich in heavy metal and organic pollutants - PAHs and PCBs</td>
</tr>
<tr>
<td></td>
<td>Composts from domestic waste</td>
<td>Metals</td>
</tr>
<tr>
<td></td>
<td>Mine wastes</td>
<td>Coal mines - SO₄ etc., Metalliferous mines - Cadmium, Copper, Lead, Zinc, Barium, Uranium</td>
</tr>
<tr>
<td></td>
<td>Seepage of leachate from landfills</td>
<td>Ammonia, Organic compounds</td>
</tr>
<tr>
<td></td>
<td>Ash from fossil fuel combustion</td>
<td>Heavy metals</td>
</tr>
<tr>
<td>Incidental accumulation of contaminants</td>
<td>Corrosion of metal in contact with the soil</td>
<td>Zinc from galvanised metal, Copper and Lead from roofing, scrapyards etc.</td>
</tr>
<tr>
<td></td>
<td>Leakage from underground storage tanks</td>
<td>Petrol, Chlorinated solvents</td>
</tr>
<tr>
<td></td>
<td>Sports and leisure activities</td>
<td>Lead from gun shot and fishing weights</td>
</tr>
<tr>
<td></td>
<td>Chemicals used in treatment processes e.g. agriculture</td>
<td>2,4-D, 2,4,5-T containing Dioxins, Boron and Arsenic compounds</td>
</tr>
<tr>
<td></td>
<td>Herbicides</td>
<td>Lead, Cadmium, Nickel and Mercury from discarded batteries</td>
</tr>
<tr>
<td></td>
<td>Insecticides</td>
<td>Chlorinated hydrocarbons</td>
</tr>
<tr>
<td></td>
<td>Fungicides</td>
<td>Copper, Zinc, Mercury, organic molecules</td>
</tr>
<tr>
<td></td>
<td>Acaricides</td>
<td>Tar Oil</td>
</tr>
<tr>
<td></td>
<td>Fertilisers</td>
<td>Cadmium and Uranium impurities in phosphates</td>
</tr>
</tbody>
</table>
2.2 Chemical Incidents and Land Contamination

The previous section highlighted that the UK has a legacy of land contamination problems as a result of past industrial activity and that ‘new’ land contamination may result from chemical incidents. Chemical incidents that may result in land contamination include leaks, spills, fires, explosions etc and could involve one or more chemicals.

2.2.1 Definitions

The problem with the definitions for ‘chemical incident’ highlighted in Chapter 1 when referring to land contamination incidents, and in particular historic problems, is that it is questionable whether old industrial sites that are contaminated due to the nature of past activity on the site can be described as ‘chemical incidents’ according to current definitions. For example, long-standing and historical contamination such as Love Canal (See Box 2.2) (Johnson & Covello (eds.), 1987; Jackson, 1996) can hardly be described as ‘an acute release’ or ‘an unforeseen event’.

Box 2.2: Love Canal (Woodey & Euripidou, 2001)

In 1896 William Love began digging a canal (3,000 feet long, 80 to 100 feet wide and 15 to 40 feet deep) to serve as a water power conduit connecting Lake Ontario and Lake Erie. It was never completed. However the Hooker Chemical Company, located west of the canal, used the site as a dumping ground for the chemical by-products of its manufacturing processes. More than 40,000 tonnes of chemical waste as well as municipal wastes were dumped. Once the canal was filled the company placed a thick clay cap over the site having already lined the bottom of the site with clay. The land was then sold to the local education board in 1953 for $1.00.

In the mid 1950s a school and later a housing estate were built on top of the waste dump. In the early 1970s the site was found to be leaking. Residents complained of respiratory problems and skin irritations and reported chemical sludges leaking into their basements giving off noxious fumes. Children reported falling knee deep into smelly tar pools. Samples of soil and water taken from the area of the old waste dump were heavily contaminated with a number of chemicals. After a great deal of pressure from local action groups, in 1978 the government declared a State of Emergency and many residents were evacuated.
Such problems may occur as a consequence of the fact that knowledge of the toxic effects of the chemicals used in industrial processes in the past was insufficient at the time. An example that illustrates this argument is the case of Cambridge Water Company versus Eastern Counties Leather plc (Refer to Box 2.3).

**Box 2.3: Cambridge Water Company versus Eastern Counties Leather plc.**

During the 1970s perchloroethylene (PCE), a cleaning solvent used in the tanning process carried out by Eastern Counties Leather, had seeped into the ground beneath the concrete floor of the tannery as a result of regular small spillages when the drums were tipped into cleaning tanks (ENDS, 1993). It was later discovered that the PCE had migrated through the subsurface and entered the aquifer underlying the site. In 1983 PCE contamination was identified in a water supply borehole used by Cambridge Water two kilometres from the site. Cambridge Water brought a civil claim against Eastern Counties Leather. The court ruled in favour of Eastern Counties Leather considering that the seepage of PCE below the concrete floor would not have been reasonably foreseeable by a supervisor at the time nor would it have been foreseeable that detectable quantities of PCE would have been found in the water supply borehole (ENDS, 1993).

An old site may also present a risk to the health of the public if a redevelopment opportunity requires extensive excavation. This may lead to contaminated areas being exposed or new pathways between the contaminant source and sensitive receptors (the person, product or part of the environment that will potentially be affected by the chemical contamination) being created. Also, children gaining unauthorised access to a derelict industrial site may potentially be exposed to a cocktail of chemicals, which could result in acute, or chronic, adverse health effects. Hence, historic land contamination may present an acute hazard to health. This is illustrated in Case Study 1, Appendix A.

So although it may not obvious at first glance, the public health impact of a land contamination incident may be significant, whether it has resulted from past land use or a more recent event and could result in acute or chronic adverse health effects. Familiarity with the nature and type of land contamination incidents reported to CIRS suggested that although incidents present themselves in many different ways, some similarities and patterns could be identified. It was therefore proposed that
simple definitions for land contamination incidents should be developed based on key observations associated with the incident type and likely contaminants.

By using clearer definitions to categorise land contamination incidents, problems can be more easily identified and the most appropriate response and management actions that should be taken in order to minimise the impact of the events determined.

2.2.2 Incident Review

The most appropriate way to gain a better understanding of the causes and 'types' of land contamination incidents, in order to develop working definitions, was to analyse past incidents. After searching though electronic databases and journals it became apparent that few reports of chemical incidents that had resulted in land contamination had been published. Some information about incidents reported to the Environment Agency was available on their website. This is summarised below. In addition a review of incidents reported to CIRS was undertaken.

Information about land incidents is collected and reported to the Environment Agency separately from land contamination incidents to CIRS and this represents a weakness in both systems. It is not possible to correlate CIRS incidents with Environment Agency incidents since there is not a mechanism in place for the two organisations to share information unless they both become independently involved in responding to the same incident.

2.2.2.1 Data from the Environment Agency

The majority of pollution incidents are reported to the Environment Agency by members of the public through the Environment Agency’s 24 hour a day pollution hotline.

In 2001 there were almost 34,000 substantiated pollution incidents and in total, land contamination was found at 10,016 of these. The majority of incidents resulted from containment or control failures (leaks or spills). Of the land incidents reported, 22 had a major impact on the environment and 484 incidents had a significant impact.
The four pollution categories are defined and discussed in more detail in Chapter 3. Figure 2.2 highlights the sources of these land contamination incidents. The ‘Other’ category, which accounts for over 50% of the land incidents reported to the Environment Agency, includes ‘contaminated land’ and ‘domestic/residential’ although in 60% of cases (34% overall), the source of contamination was not identified.

Figure 2.2: Land incidents reported to the Environment Agency in 2001 by ‘Source’

![Pie chart showing land incidents reported to the Environment Agency in 2001 by source.]

### 2.2.2.2 Data from CIRS

At CIRS incident details are recorded on paper (incident report forms) and filed chronologically. Some of the information from the incident report form is entered into a database because the National Focus requires the data for the national surveillance of chemical incidents. The CIRS database contains electronic information about all of the incidents reported to CIRS since 1996. For each incident this includes a record of the chemical involved, the number of people exposed and the number of people actually affected in addition to a summary of the incident circumstances.

A database search revealed that it was almost impossible to search accurately for and identify certain types of incident, for example those that have resulted in land contamination. This is mainly because the way in which incidents are categorised is not consistent. Each incident is described by a single category and it is very much at
the discretion of the person responsible for data input at the time to determine how each incident is categorised. Also there is the possibility that an incident could be described by more than one of the current incident types.

For many incidents, the category is obvious such as ‘fire’ or ‘explosion’ and often the incident category describes what actually happened or the ‘event’. However, for other incidents the ‘event’ may not always be obvious or the contamination may be the result of more than one event. These incidents are more difficult to categorise and are often classified according to the environmental medium affected such as ‘land’, ‘water’, ‘air’ or ‘food’. Consequently it makes it almost impossible to identify all incidents that have affected a specific medium.

Also as a consequence of research projects based at CIRS looking specifically at air, land and water incidents, an additional system for categorising incidents was implemented with an option to specify if there was a release to air, soil, water or drinking water. Unfortunately this system does not appear to have worked very well, as a number of incidents that should be indicated as lying in one of the above categories are not and yet incidents that do not fall into any of the categories are.

Figure 2.3 indicates the number of land contamination incidents and Figure 2.4 the type of land contamination incidents reported to the Chemical Incident Response Service (CIRS) between February 1996 and September 2001. Figure 2.3 highlights an increase in the number of incidents reported to CIRS over the six-year period. It is important to consider whether these figures represent an actual increase in the number of incidents occurring or simply an increase in the number reported. The latter is the most likely explanation because of improved reporting procedures over the time period and the provision of more specialised training, which could have resulted in a heightened awareness of the potential for environmental contamination to result in adverse health effects. If this is the case then the need to ensure that appropriate management procedures are in place to be able to manage these problems effectively becomes more apparent.
Figure 2.3: Land contamination incidents reported to CIRS.

Figure 2.4 indicates that around half of the incidents reported are categorised as land; otherwise incidents are either categorised according to the ‘event’ which caused the incident, for example a leak or spill, or the environmental medium that affected the soil, for example dust or particles from the air. In addition, a number of the incidents that have been categorised as water have been a direct result of a land contamination problem. For example, organic chemicals in soil (such as those that may result from a fuel leak) may be able to contaminate drinking water by penetrating or permeating through the pipe material. (Refer to Case Studies in Appendix N). A number of requests for information were also received.

Figure 2.4: Incidents that resulted in land contamination categorised by ‘type’.
These different ways of categorising land contamination incidents substantiate the concept that land (or soil) is both a sink and a source for contaminants and that the three environmental media – air, land and water - are inextricably interlinked.

In addition to the more general review of incidents, a detailed review of land contamination incidents reported to CIRS in 1999 was undertaken. This year was selected because the same person had been responsible for data input throughout the whole year so the quality of information was likely to be relatively consistent. Groundwater contamination was also included in addition to land contamination as it was considered that in order for groundwater to become contaminated, it was highly likely that land must have been contaminated in the first place and vice versa.

Once all of the land incidents had been identified, the following details were recorded:

- Circumstances
- Chemical involved
- Type (National Focus definition)
- Event (CIRS definition)

The reason that two schemes for categorising incidents exist is that the CIRS database was established with definitions for ‘event’ prior to the requirement to report chemical incident details to the National Focus. Consequently an extra field had to be added to facilitate collection of the specific surveillance data required. These definitions are listed in Appendix B.

A search was carried out on the incident ‘type’ and ‘event’ fields of the database, with ‘land’ entered as the search criterion.

- **18** incidents were highlighted with land as the incident type (CIRS definition).
- **15** incidents were highlighted with land as the event (National Focus definition).
The thorough search through paper copies of incidents revealed that there had been a total of 55 incidents that had resulted in land contamination in 1999. However, this total includes all of the incidents that were categorised as 'land' for example concerns about adverse health effects from waste disposal sites. Tables 2.2 and 2.3 show how the land contamination incidents in 1999 were categorised. Interestingly the information in Table 2.2 does not tally with those highlighted in Figure 2.3 (page 2-12). This can be explained by the disparity in the way incidents are currently categorised and the fact that duplicate entries exist in the database (these were identified in the more detailed search).

An area for further investigation is the disparity between the categorisation of incidents according to the different definitions for 'type' and 'event'. The audit of land incidents reported in 1999 highlighted a number of examples where the entries in these two fields were different. Variation appears where analogous category definitions do not exist in both schemes; for example, requests for information are categorised by CIRS as 'Info' whereas the Focus definitions require selection of a specific event. Although there is similarity for some categories, overall this represents a weakness in the reporting system. Therefore it is questioned why there needs to be two categories and whether it would be possible to combine the fields
into one system with very clear definitions which is likely to improve the quality of the data used for surveillance.

Since incidents vary greatly in terms of complexity, the level of CIRS input required for their management differs. The quality and detail of the information recorded about an incident reflects this disparity and completion of incident report forms is inconsistent. Although minimal information may be sufficient for surveillance purposes, an in-depth investigation may require more details. Therefore, it is suggested that a more comprehensive incident report form should be developed.

Finally, incident reporting procedures currently used within CIRS are very much focused on the requirements of the National Focus for their surveillance purposes. This means that a significant amount of detail is potentially being lost, in particular environmental information such as details of sampling strategies, any remedial action taken and what influenced the decision.

This project aims to provide the building blocks to ameliorate these weaknesses, to improve incident reporting and response based on 'best practice' from past incidents.

2.2.3 Land Incident Categories

Following consideration of the circumstances of the incidents reported to CIRS, it is proposed that land contamination incidents can broadly be divided into two categories - acute incidents and chronic or persistent problems. These incident categories are based on the source of the problem and do not reflect the human health effects that result from exposure to chemically contaminated soil or the impact on the environment, but can be helpful in identifying the most appropriate management actions that will ensure an effective and timely response and thus, hopefully, reduce the potential for adverse health effects.

The definitions proposed suggest that land contamination that results from a sudden, one-off release of a chemical either directly to the soil, such as leak or spill from a tank, or indirectly via aerial deposition or firewater runoff should be referred to as an
acute incident. In contrast, the term chronic problem should be used to describe land contamination that is considered to have resulted from a continued or repeated release of chemical substances over a period of time, typically in smaller doses than with acute incidents. The environmental effect in an acute incident results almost invariably from a single identifiable cause, whereas the environmental effect of a chronic incident typically is a function of accumulation. This taxonomy is outlined in Table 2.4 and is also presented in ‘Land contamination — acute versus chronic problems’, which has been submitted to Land Contamination and Reclamation. A copy of the abstract is included in Appendix P.

Table 2.4: Taxonomy for chemical incidents that result in land contamination.

<table>
<thead>
<tr>
<th></th>
<th>Acute</th>
<th>Chronic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>• Contamination is due to a sudden, specific, identifiable cause</td>
<td>• Contamination likely to be a result of accumulation over a prolonged period of time</td>
</tr>
<tr>
<td></td>
<td>• Often one-off event</td>
<td>• Frequently continuous event</td>
</tr>
<tr>
<td></td>
<td>• Identifiable source of contamination</td>
<td>• Origin and cause of contamination may not be identifiable</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>• Fire water run-off into surface water</td>
<td>• Poorly contained waste disposal facility</td>
</tr>
<tr>
<td></td>
<td>• Petrol spill onto land</td>
<td>• Former industrial site</td>
</tr>
</tbody>
</table>

If these definitions are used to categorise the land contamination incidents reported in 1999, then it can be determined that there were 29 acute and 26 chronic problems (Table 2.5). It should be emphasised that this categorisation of acute and chronic land contamination incidents refers to the source of contamination. This should not be confused with the acute and chronic health and environmental effects that may result from exposure and refers to the receptor part of the source-pathway-receptor linkage, which is described more thoroughly in the next section. The inconsistency in units used to report the amount of chemical released can be noted which highlights a disparity in the reporting of incidents, an issue which will be discussed in greater detail subsequently.
Table 2.5: Categorisation of land contamination incidents reported in 1999.

<table>
<thead>
<tr>
<th>Acute incidents</th>
<th>Chronic incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Gas from contaminated soil containing organic chemicals, including solvents.</td>
<td>* Allotment to be sited next to a housing estate built on a former ash tip.</td>
</tr>
<tr>
<td>* Organic chemicals detected in drinking water - linked to previous spill of petrol.</td>
<td>* Local Authority investigation of 4 potentially contaminated sites prior to implementation of new CL legislation</td>
</tr>
<tr>
<td>* Children playing with white asbestos dumped in field near house.</td>
<td>* Soil arsenic levels of 33000ppm found on a site during routine sampling.</td>
</tr>
<tr>
<td>* Well water contaminated with benzene - water table potentially contaminated.</td>
<td>* Elevated levels of solvents used to make bottles found in soil and groundwater samples collected from old industrial packaging site now used for housing.</td>
</tr>
<tr>
<td>* Leak of kerosene heating oil from private tank contaminated water supply.</td>
<td>* High concentrations of free cyanide detected &amp; blue stones on surface of old gravel quarry (no record of use as waste site).</td>
</tr>
<tr>
<td>* Petrol explosion in drains.</td>
<td>* Mustard gas/phosgene found on new golf course. WW1 grenades found.</td>
</tr>
<tr>
<td>* Spill of red diesel onto land contaminated soil under block of flats.</td>
<td>* Planning application to develop site containing degreasing solvents.</td>
</tr>
<tr>
<td>* Rupture of kerosene tank resulted in spill (~ 80 gallons) under house.</td>
<td>* Heavy metals found in soil sample taken following subsidence at a private residence</td>
</tr>
<tr>
<td>* Leak of approximately 50000 litres of unleaded petrol into the ground.</td>
<td>* High levels of heavy metals and toluene found in garden of residential property.</td>
</tr>
<tr>
<td>* Leak of petrol from garage may have contaminated a borehole/groundwater.</td>
<td>* Elevated levels of arsenic found in soils samples taken council owned adventure playground, part of it used for growing vegetables.</td>
</tr>
<tr>
<td>* Yellow bubbly substance coming through road; smells unpleasant</td>
<td>* Lead contamination in soil under bridge coated in lead paint.</td>
</tr>
<tr>
<td>* Petrol spill on petrol station forecourt. Fuel pooled under houses.</td>
<td>* Allotment soil found to be contaminated with arsenic, zinc, copper and PAHs. Groundwater also affected.</td>
</tr>
<tr>
<td>* Leak of kerosene from a tractor in adjacent field contaminated water.</td>
<td>* 'Blue Billy' (ferric ferrocyanide) found on old gasworks site near to a school.</td>
</tr>
<tr>
<td>* Phthalates detected in soil samples taken at a primary school.</td>
<td>* Elevated levels of heavy metals detected in soil samples collected following reports of a subsidence problem.</td>
</tr>
<tr>
<td>* Drinking water contamination - permeation of contaminants through water pipes.</td>
<td>* Stream adjacent to old leatherworks site contaminated with chemicals used on site.</td>
</tr>
<tr>
<td>* PAHs detected in water supplies to 2 properties - creosote spill.</td>
<td>* Redevelopment of a former tannery site contaminated with chromium.</td>
</tr>
<tr>
<td>* Spill of kerosene in domestic property, filtered through to land and has permeated plastic water supply pipe.</td>
<td>* Old industrial site contaminated with arsenic (soil and groundwater).</td>
</tr>
<tr>
<td>* Leak of unleaded petrol in neighbouring garden.</td>
<td>* Drainage from a tip potentially polluting an inland watercourse.</td>
</tr>
<tr>
<td>* Private water supply contaminated with ~100 litres heating oil.</td>
<td></td>
</tr>
<tr>
<td>* Domestic heating oil pipe outside residential property cracked.</td>
<td></td>
</tr>
<tr>
<td>* Oil spill in harbour washed up over harbour wall onto gardens in high winds.</td>
<td></td>
</tr>
<tr>
<td>* Kerosene heating oil spill into private well.</td>
<td></td>
</tr>
<tr>
<td>* Drinking water contaminated - heating oil pipe in same trench as water pipe.</td>
<td></td>
</tr>
<tr>
<td>* 45 gallon drum of pyrene spilled on the side of a road in a gully</td>
<td></td>
</tr>
<tr>
<td>* Heating oil spill in house has leaked under floorboards.</td>
<td></td>
</tr>
<tr>
<td>* Leak of ~150 gallons of kerosene accumulated under floorboards of property.</td>
<td></td>
</tr>
<tr>
<td>* Chemical spill into alley way adjacent to children’s playground.</td>
<td></td>
</tr>
<tr>
<td>* Drinking water contaminated with hydrocarbons – no obvious spill.</td>
<td></td>
</tr>
<tr>
<td>* Surcharge from a public sewer onto allotments.</td>
<td></td>
</tr>
</tbody>
</table>
Reflection of the incidents summarised in Table 2.5 exposes further differences between acute and chronic land contamination incidents. A synopsis of some of these is presented in Table 2.6.

A comprehensive retrospective review of all land contamination incidents reported to CIRS between February 1996 and September 2001 is presented in Chapter 5.

Table 2.6: Differences between acute and chronic land contamination incidents

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Acute</th>
<th>Chronic</th>
<th>More information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential environmental impact</td>
<td>Usually acute impact; potential for chronic impact if incident not managed effectively.</td>
<td>Usually chronic impact unless material on-site is disturbed e.g. sinking of boreholes</td>
<td></td>
</tr>
<tr>
<td>Potential health impact</td>
<td>Acute exposure: acute or chronic effects</td>
<td>Acute or chronic exposure: acute or chronic effects</td>
<td></td>
</tr>
<tr>
<td>Response time</td>
<td>Key factor in effective response</td>
<td>Less important as contamination is likely to have been present for some time</td>
<td>Subsection 2.2.3</td>
</tr>
<tr>
<td>Source-Pathway-Receptor</td>
<td>Once hazard is contained, establishing S-P-R used to guide subsequent management options</td>
<td>Accurately establishing S-P-R is key factor in provision of effective response</td>
<td>Subsection 2.2.3</td>
</tr>
<tr>
<td>Information available</td>
<td>Likely to be quite limited – incident type and location</td>
<td>Land use and chemical contaminant usually known; detailed site report may be available</td>
<td>Subsection 2.2.3</td>
</tr>
<tr>
<td>Risk communication</td>
<td>Provision of information to minimise exposure</td>
<td>Consideration of perceived impacts as important as actual impacts</td>
<td>Subsection 2.2.3 &amp; Appendix C2</td>
</tr>
<tr>
<td>Legislation</td>
<td>Policy on land contamination is to prevent the creation of new contamination; there are a range of regimes aimed at achieving this</td>
<td>Part II A of the Environmental Protection Act 1990 makes provision for the identification and remediation of sites that present a significant risk to human health and/or controlled waters</td>
<td>Section 2.3</td>
</tr>
<tr>
<td>Roles and responsibilities of key agencies</td>
<td>Emergency services involved in initial response; local authority/Environment Agency take lead in incident investigation</td>
<td>Local authority/Environment Agency usually take lead role</td>
<td>Section 2.4</td>
</tr>
<tr>
<td>Tools and Guidance</td>
<td>Limited information available</td>
<td>New guidance recently released</td>
<td>Section 2.5</td>
</tr>
<tr>
<td>Exposure standards</td>
<td>No land specific acute exposure standards currently available</td>
<td>New soil guideline values (SGVs) derived using CLEA model available for small number of contaminants</td>
<td>Section 2.5</td>
</tr>
</tbody>
</table>

2-18
**Response Time**

As highlighted in Table 2.6, in managing acute incidents, response time is the most important factor. Once an incident has ‘started’ the management options available will be conditioned by circumstances specific to the incident. All subsequent efforts, including the remedial action taken, will be determined by how effective the emergency response has been (Iakovou *et al.*, 1996). This has been illustrated in Figure 2.5.

**Figure 2.5: Event evolution**
(Thames Water, 2001)

The graph indicates that there is a start point and then a time lapse before the event is recognised and reported. The number of incident management options available will begin to decrease as soon as the event starts. Hence a shorter time lapse between event start and event recognition usually means that there will be a wider range of containment/remedial options available.

Hasty decisions made during emergency response can exacerbate the long-term soil and groundwater problems (Toups & Goultry, 1995), which highlights the need for appropriate well tested response procedures that are readily accessible.

Response time is less important when responding to a chronic land contamination incident since contamination is likely to have been present for some time. Therefore
the number of options available for remediation is already limited and as a result the 'golden hour' - the time period following notification when decisions taken will have the greatest influence over the outcome - is likely to be longer. The concept of looking at how incidents are managed along a timescale (see Figure 2.5) from when the incident is identified - "event start" - to when the incident is declared over - "event close" - has been developed further as part of the scheme proposed in Chapter 4.

**Source-Pathway-Receptor linkage**

The key factor that determines the effectiveness of response to a chronic land contamination incident is likely to be the accurate identification of all potential sources of contamination and any sensitive receptors and establishing whether any exposure pathways exists between the two. The source-pathway-receptor linkage, illustrated in Figure 2.6, forms the basis for carrying out a risk assessment following any chemical incident (acute or chronic) and is not exclusive to land contamination. Information is collected about the nature and source of contamination and sensitive receptors are identified. Then it is necessary to determine whether a link, referred to as a migration pathway or 'exposure pathway', exists between the two. An exposure pathway could be direct contact with the contaminant, such as inhalation of smoke from a plume or ingestion of contaminated drinking water or indirect contact such as, the ingestion of vegetables grown in contaminated soil. In all cases it is essential that all potential exposure pathways be considered. It is often considered that unless there is an exposure pathway between receptors and a contaminant source, the presence of a chemical hazard does not present a risk. This is described in more detail in Section 2.3.

Goodfellow (2001) illustrated how the model could be used as a tool in managing chemical incidents (Figure 3, Appendix C3); the idea has since been adapted for use in a combined emergency response plan for chemical, biological, radiological and nuclear (CBRN) incidents that is being developed in London. CBRN incidents can be acute or chronic, accidental or deliberate, and result in adverse health and environmental impacts. More information about the CBRN project is presented in
Appendix D and the use of the source-pathway-receptor model in developing tools for responding to chemical incidents is explored in Chapter 4.

**Figure 2.6: Source-Pathway-Receptor linkage**
(adapted from Richards *et al*, 1996)

**Information available**

One of the important differences in acute and chronic land contamination incidents is the quantity of information that is likely to be available when the incident is recognised as having a potential impact on human and environmental health and the appropriate organisations contacted. For example, notification of an acute incident may simply consist of the type of incident and the land use or location, such as ‘fire in a warehouse’ or ‘leak of chemical from tanker overturned on the motorway’. The chemical substance involved may not have been identified and it is unlikely that detailed information about the site and surrounding area will be available. In contrast, information that is almost always going to be available when a chronic incident is reported is the land use and the chemical contaminant. In some situations notification of a chronic problem may include a detailed site assessment containing a detailed site history, a list of known contaminants and results from an environmental sampling programme as well as information about the underlying geology and hydrogeology.
Risk communication

In all chemical incidents it is imperative that risk is communicated and managed effectively to ensure that members of the public are aware of any dangers and also to minimise any inappropriate media attention. This is true for both acute incidents, where information on preventing or minimising exposure through shelter or evacuation or advising residents not to drink potentially contaminated water is provided, and chronic problems, where communicating the potential risk to local residents is of paramount importance (see discussion below). Actual and perceived risks associated with chronic exposure to contaminants may need to be addressed.

Furthermore when a contaminated site is to be reclaimed and redeveloped a number of interested groups become involved. These include developers, financial backers, consultants, local authorities and the local community. The perceptions and concerns of these stakeholders will differ (Cairney, 1995). These concerns should be recognised and dealt with in order to minimise conflict and ensure the development is completed on time and within budget.

Whilst many concerns will be site specific, a number of generic anxieties can be identified. It seems rational to suspect that the determination that land is contaminated will have an effect on the value of adjacent property. The question of who is responsible financially for cleaning up any contamination found on the adjacent land may also need to be addressed. In addition there is the issue of health effects resulting from exposure to the chemicals present in the soil. A direct link between exposure to contaminated soil and human health effects is often difficult to establish and many of the examples that do exist have not been quantified. A number of reasons for this are suggested in the literature (see Abrahams, 2001; Oliver, 1997; Thornton, 1993). However, perception of the potential hazards associated with a chemical or chemicals can provoke a great deal of anxiety. This is further amplified by speculation and rumours when appropriate information is not available. In addition, adverse media attention can have a deleterious effect on an already sensitive situation. Therefore the health and environmental impact of a potentially contaminated site cannot be considered in isolation; stakeholder perception and involvement is paramount to the successful completion of a
redevelopment project and indeed the management of any chronic land contamination incident.

The effective communication of risks to human health and the environment from exposure to contaminated soil is of growing importance. Gaining the trust of the general public in order to be considered a reliable provider of information should be a fundamental aim. Clear and appropriate information should be provided and made available to all of the key stakeholders, including local residents. It is therefore suggested that risk management strategies need to be built into the statutory consultation process. Nevertheless, merely making information available is not the solution. It must be communicated effectively and there must be a provision for feedback. There should be a dynamic consultation process whereby local residents are able to request further information, voice concerns and be satisfied with the response.

2.3 Legislation

One of the key distinctions between acute and chronic land contamination incidents highlighted in Table 2.6 is the legislative approach to such issues in the UK. Therefore, in this section the way in which land contamination problems are currently regarded from a legislative viewpoint will be explored. The discussion is followed by a summary of the roles and responsibilities of regulatory agencies and statutory bodies. The section concludes with a review of the tools and guidance currently available for managing both the health and environmental impact of chronic land contamination problems.

2.3.1 Chronic/Historic Land Contamination

There is increasing demand to develop former industrial sites for residential housing and new industry as this has the two-fold advantage of reducing the burden on rapidly diminishing land resources whilst at the same time improving the quality of the local environment. This also meets one of the objectives of the government’s sustainable development strategy in which land use, and in particular the re-use of
previously developed land, is one of fifteen headline indicators. Figure 2.7 indicates that the percentage of new housing in England provided on previously developed land and through conversions of existing buildings has increased in recent years.

Figure 2.7: Percentage of new homes built on previously developed land

However, when previously used land is redeveloped it is important that any lingering contamination on the site does not present a continuing threat to human and environmental health.

Consequently land contamination can be viewed from two policy perspectives (Vegter, 2001):

- Environmental problems: polluted sites that endanger human health or ecological safety;
- Spatial planning problems: derelict land that does not cause any immediate risk but which must be treated if the land is to be developed for housing or other ‘sensitive’ use, such as school or nursery or allotments.

For many years local authority officers have regulated the process of planning and redevelopment. During this time many contaminated sites have been developed and although controls will have been imposed via the town and country planning development control system (Braithwaite, 2000a), there have been instances where developments were granted planning permission and allowed to proceed with no
recognition of the presence of potentially harmful contaminants in the ground (Peters & Blake, 1999).

This unsatisfactory situation was recognised under the Environmental Protection Act 1990 where it was proposed that all local authorities should compile a register of all land known to have been used for contaminating activities – Section 143 (Peters & Blake, 1999). However, in 1993 the proposals that would have implemented Section 143 were withdrawn because it was considered that (Lane & Peto, 1995):

- registers based on potential contamination would not discriminate sufficiently between clean land and contaminated land
- there was no means for deregistering land once it had been cleaned up
- registration did not tackle remediation of the land or the persons liable for the remediation and
- registration of land that had been used for certain contaminative purposes might discourage the development of Brownfield\(^1\) land, causing land values to fall and increasing the pressure on the development of Greenfield\(^2\) land.

In light of this a government policy review of the arrangements for controlling contaminated land and meeting the costs of remediation was instigated. As part of the process a consultation document, 'Paying for our Past' (DoE, 1994a), was issued. The outcome of the policy review and conclusions from the consultation paper was the 'Framework for Contaminated Land' (DoE, 1994b).

Section 57 of the Environment Act 1995 created a new legal framework for managing the identification, investigation and remediation of contaminated sites that are considered to present a hazard or potential hazard to human health and/or the environment. The provisions which came into force on 1 April 2000, were inserted

\(^1\) Defined as 'previously developed land which is that which is or was occupied by a permanent structure and associated fixed surface infrastructure' (Environment Agency, 2002)

\(^2\) Defined as 'land that has not previously been developed; its current uses are usually for agriculture, forestry, recreation or nature conservation'. Greenfield land in some circumstances may also be contaminated land (Environment Agency, 2002).
into the Environmental Protection Act 1990 under Part IIA, and for this reason are frequently referred to as Part IIA. The regime is intended to be complementary to the planning regime and other regulatory regimes, for example Waste Management Licensing and Integrated Pollution Prevention and Control (IPPC) permits. Where these can be used to deal with contamination, then Part IIA will not generally apply (Crowcroft, 2000). However, this would appear sometimes to ignore the potential contamination of land adjacent to former industrial sites that has been or is to be redeveloped. An example is presented in Case Study 2, Appendix A.

Part IIA places a statutory duty on local authorities to identify land that is contaminated in their area to prioritise areas of greatest concern and to co-ordinate the implementation of remedial action if required. Within 15 months of the Contaminated Land Regulations coming into force (in June 2001), each local authority had to prepare a written strategy detailing how they proposed to do this. The strategies also contain detailed information about the local area such as past and current land use, an overview of the geology and hydrogeology and the identification of water systems including aquifers used for drinking water abstraction.

Following an initial investigation by the local authority a site may be designated a ‘special site’ by the local authority. The types of contamination and conditions that distinguish special sites are detailed in the legislation. The Environment Agency is responsible for the assessment, monitoring and regulation of special sites (see below).

2.3.1.1 Defining Contaminated Land

One of the main difficulties in seeking to identify ‘contaminated land’ is that contamination refers simply to the presence of a foreign substance in the soil, which does not necessarily lead to harm or damage (Bell & Ball, 1995). Taking this into consideration, land could be contaminated but pose no threat to human or environmental health. Part IIA of the Environmental Protection Act 1990 however, defines contaminated land as “land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land that significant harm is being caused or there is the significant possibility of
such harm being caused; or pollution of controlled waters is being, or is likely to be, caused” (DETR, 2000). This legal definition of ‘contaminated land’ is fairly new and was created by the Environment Act 1995. Prior to this time it was accepted that contamination should ‘be regarded as a general concept rather than as something capable of exact definition and measurement’ (Finney & Dye, 1998).

Contaminated land, as defined under Part IIA can only be regarded as a subset of the wider legacy of land affected by contamination (Environment Agency, 2002). As a result ‘land affected by contamination’ has been defined and includes Part IIA land, land which has not been formally determined by the local authority as contaminated but where contamination exists and also land where there is contamination but a significant pollution linkage has not been established. There are further definitions for Brownfield land, Derelict land and Greenfield land. All of these definitions are different but not mutually exclusive as illustrated in Figure 2.8 and could be used to describe the same piece of land (Environment Agency, 2002). It is difficult to estimate how many contaminated sites there are in the UK and the extent to which they are contaminated because of the inconsistent use of these terms and definitions.

Figure 2.8: The relationship between derelict land, contaminated land and land affected by contamination
(Source: The Environment Agency, 2002)
The proposed definition for ‘chronic land contamination’ developed in Section 2.2.3 might be considered to exacerbate this problem. However, it is used to describe the presence of contaminants in soil above ‘background’ levels as a result of a continued or repeated release of chemical substances over a period of time and is therefore synonymous with the Environment Agency’s definition for ‘land affected by contamination’. In particular the definition for chronic land contamination incorporates low levels of contamination that may or may not present an actual hazard to human or environmental health but nevertheless trigger concern amongst local residents. Thus the definition provides a good foundation on which to base a management response that can take into consideration perceived as well as actual risk to human and environmental health. This idea is developed further in Chapter 4.

2.3.1.2 *Is it ‘contaminated land’?*

The basis of the ‘contaminated land’ definition is complex and it incorporates the concept of risk assessment procedures and considerations (Peters & Blake, 2000). Land is only legally contaminated if an exposure pathway can be established between a source of contamination and a sensitive receptor (Clifton *et al*, 1999) so the definition does not address the potential adverse reaction that may be generated by local residents or other stakeholders if a site is found to contain elevated levels of chemicals that are not considered to present a hazard, i.e. significant harm or the possibility of significant harm. This could create problems from an incident management perspective as stakeholder involvement and co-operation is key to effective response and management.

In order to determine whether a site is ‘contaminated land’, a risk assessment based on the source-pathway-receptor model (Figure 2.7, Section 2.2.3) is undertaken. The relationship between a contaminant source, an exposure pathway and a receptor is referred to in Part IIA as a “pollutant linkage”. Once a pollutant linkage has been established, the local authority must determine if it is significant; i.e. as a result of that pollutant linkage, is significant harm (or the significant possibility of significant harm) being caused?
The following are situations where harm may be regarded as "significant" according to the statutory guidance (Peters & Blake, 2000):

- death, disease, serious injury, genetic mutation, birth defects or the impairment of reproductive functions in humans
- other irreversible harm to the ecological system
- substantial damage to, or failure of buildings
- disease or other physical damage or death of livestock or crops
- the pollution of controlled waters (including groundwater, inland water and estuaries)

A literature review was carried out to identify whether any links between exposure to contaminants in the soil and chronic or acute toxic effect, serious injury or death to humans had been published. Results are presented in Appendix E. It was concluded that whilst direct links between soil quality and human health are often difficult to establish and many of the examples that do exist have not been quantified, some relationships between exposure to elevated levels of trace elements in soil and adverse health effects in humans have been recognised. For example it was mining waste containing cadmium and zinc that had been dumped in the river and subsequently used for drinking water and the irrigation of crops that caused itai itai disease in Japan shortly after the end of the Second World War. Soil samples collected were found to contain an average of 6 parts per million cadmium and this increased to 125 parts per million in the rice (Keller, 1992; CIRS, 1999).

However, Smith (1991) (cited by Beckett (1993)) provides a very thought provoking quote ....

"It should also be recognised that some of the possible effects of exposure of humans to chemicals are so intangible, when set against the variations in human well-being, that it will never, except in a few unfortunate cases, be possible to demonstrate a cause and effect relationship between exposure to a contaminated site and current, or more probably future, ill health...to ask to be shown a site where exposure to a particular level of contamination has caused harm is rarely a sensible question to ask. We do not generally have the tools, or the time, to be able to answer it."

2-29
Nevertheless, should a significant pollutant linkage be established, remedial action would be required. Risks can be mitigated by removing or isolating the contamination (hazard) / source, breaking or intercepting the exposure pathway(s) or isolating receptors i.e. evacuation of the local exposed or potentially exposed population if there are human health risks. The latter is however only considered feasible in an emergency or in an acute land contamination incident and then only as a temporary measure. Evacuation essentially leads to more dereliction - the problem that was supposed to be being solved (Vegter, 2001). In land contamination incidents, residents are only likely to be evacuated if there is considered to be an explosion hazard (refer to Appendix N) or if there is considered to be a significant risk to human health. The Love Canal case presented previously provides an extreme example of this kind of event and a further more recent example from the UK is illustrated in Box 2.4.

Box 2.4: Weston Quarries chemical incident (Staples, 2000)

Two quarries acquired in 1917 were used for the disposal of slurry and other more varied waste including drums of chemicals, building rubble and other solid waste. Once infilling was complete (1970’s), the quarries were capped with a thin layer of ash and soil and horses now graze on the land. Since 1993, an investigation into the nature and extent of contamination on the site has been undertaken. This has involved a full desktop study followed by routine sampling. Investigations revealed the presence of many substances including hexachlorobutadiene (HCBD) in a number of borehole samples. The effects of HCBD on humans at low levels of exposure via inhalation are unknown.

Subsequent indoor air quality measurements in houses adjacent to the quarries revealed the presence of HCBD at concentrations ranging from 2 to 8 parts per billion (ppb), with one house having an exceedingly high concentration of 1000ppb. Over two hundred properties in the village have now been tested and HCBD has been detected in twenty-one households, affecting more than seventy adults and children. Most have relocated to alternative accommodation to reduce exposure, but a few continue to reside in their properties.

In the UK the level of remediation undertaken on a particular site is based on a ‘suitable for use’ approach. This means that risks to human health and the environment are assessed based on the current land use and any remedial action
undertaken should ensure that those risks are mitigated. It is considered that risks from contaminated land can be satisfactorily assessed only in the context of specific uses of the land (whether current or proposed), and that any attempt to guess what might be needed at some time in the future for other uses is likely to result either in premature work (thereby distorting social, economic and environmental priorities) or in unnecessary work (thereby wasting resources) (DETR, 2000). Nevertheless, the cost of remediation is often an overriding factor in decisions made (Vegter, 2001). The 'suitable for use' criteria are also applied when local authorities are evaluating potential remediation strategies.

Vegter (2001) indicates that current practice favours the source-oriented approach to remediation, which might involve removal of the contaminated soil from the site for disposal or treatment (ex situ), or degrading the chemical on site (in situ) although many approaches focus on the removal of the pathway, such as capping sites and covering with clean material or putting in barriers. Some approaches lead to more certainty than others; some take less time but are more expensive. For example, whilst eliminating the exposure pathway by inserting a barrier between the source of contamination and receptors is a fairly straightforward containment method and may be effective initially, there is no certainty of the integrity of the barrier in the long term; the barrier may perhaps become damaged or chemicals beneath it may continue to migrate downwards and laterally and lead to widespread contamination. A wider discussion of some of the options available for the clean up of contaminated land is presented in Appendix C3.

2.3.2 Acute Land Contamination

The draft circular on contaminated land states that the first priority for the Government’s policy on land contamination is to prevent the creation of new contamination and there are a range of regimes aimed at achieving this including Pollution Prevention and Control (PPC) which is discussed briefly below. Other regimes that may apply in some acute land contamination incidents are summarised in Table 2.8.
Table 2.7: Regulatory regimes that may be appropriate to use in managing acute land contamination incidents

<table>
<thead>
<tr>
<th>Regulatory regime/legislation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control of Major Accident Hazards Regulations 1999 (COMAH)</td>
<td>With regard to the management of chemical incidents, COMAH regulations relate to the preparation of on-site and off-site emergency plans at establishments where specified dangerous substances are kept in specified quantities.</td>
</tr>
<tr>
<td>Environment Act 1995</td>
<td>Introduced new legal provisions for contaminated land and prompted the creation of the Environment Agency</td>
</tr>
<tr>
<td>Environmental Protection Act 1990 (EPA)</td>
<td>Contains the bulk of current provisions on air pollution from stationary sources, waste management and disposal, the integrated control of the most potentially polluting processes (IPC), litter, the environmental impact of genetically modified organisms, noise and statutory control of environmental nuisances</td>
</tr>
<tr>
<td>Integrated Pollution Control (IPC) &amp; Integrated Pollution Prevention and Control (IPPC)</td>
<td>Abnormal releases to land would have to be reported immediately to the regulator</td>
</tr>
<tr>
<td>Statutory Nuisance (Sections 79 and 80 of EPA 90)</td>
<td>Local authorities are required to inspect their areas in order to detect the presence of ‘statutory nuisances’; this includes any accumulation or deposit that is prejudicial to health, or a nuisance e.g. environmental pollution issues such as odours, smoke noise and in some land contamination cases.</td>
</tr>
<tr>
<td>Waste Management Licensing</td>
<td>Contamination may arise from an illegal deposit of controlled waste</td>
</tr>
<tr>
<td>Water Industries Act</td>
<td>This Act covers water services and supply and requires that a consent must be obtained from the relevant water undertaker (normally a water company) in order to discharge trade effluent into public sewers.</td>
</tr>
<tr>
<td>Water Resources Act</td>
<td>Protection of water against pollution and other water resource management. It is an offence to discharge trade effluent, other poisonous or polluting material or solid waste into controlled waters unless consent to discharge has been obtained from the Environment Agency who is the enforcing authority for this Act.</td>
</tr>
</tbody>
</table>
The reason for including more detail on IPPC than the other regulatory regimes is that health agencies are statutory consultees for IPPC applications, which presents a new set of challenges for public health practitioners with regard to understanding industrial processes and environmental issues. Indeed, IPPC goes further towards integrating the assessment of health and environmental impacts within the same process than previous regulatory systems.

2.3.2.1 Pollution Prevention and Control (PPC) (Lodge, 2000; Eagles et al, 2002)

One of the aims behind the Environmental Protection Act (EPA) 1990 was to introduce an integrated system of pollution control to consider the potential impact on all three environmental media both when deciding on the most appropriate industrial processes to use and for setting discharge consents. Its purpose is to prevent the diversion of pollution streams from one environmental medium to another possibly more sensitive medium. For example, by installing a flue gas desulphurisation unit on a power station to prevent emissions of sulphur to the atmosphere, liquid discharges and solid sulphur containing waste are created. Integrated Pollution Control (IPC) provided a system which allowed the impact of all potential discharges across all three environmental to be considered and required the ‘most polluting’ industries, defined by the pollutants produced and the size of the operation, to apply for a permit that specified the permitted emissions.

In October 1996 the European Commission published a Directive on Integrated Pollution Prevention & Control (IPPC) to come into effect on 31st October 1999. Member States had to introduce a regulatory system to ensure that particular industries take action to achieve "an integrated approach to pollution control" in order to secure "a high level of protection for the environment as a whole" when considering both ‘routine’ and ‘accidental’ releases. The definition of pollution in the Directive includes releases to air, land or water "which may be harmful to human health". The IPPC Directive has been introduced into England and Wales through the Pollution Prevention and Control (PPC) Regulations 2000, which came into effect on 1 August 2000. Essentially the aims of the regime are to reduce pollution, recover as much waste as possible, dispose of residual waste in ways least damaging to the
environment, promote efficient energy use, avoid accidents and limit their consequences should they occur and return the site to a satisfactory state after use.

The regulations require that certain bodies, including health agencies, must receive a copy of each application, and that the public have an opportunity to comment. Health agencies have 28 days to make representations, which should include an analysis of the potential health impacts. In particular, health agencies are required to advise on any particular local health problems that they perceive to be relevant, consider the likely impact of releases on human health (both acute and chronic), identify priority substances for control, from both routine and potential accidental releases and comment on any additive pollution from other processes in the area that could potentially give rise to adverse health effects among the local population.

2.4 The Role of Regulatory Agencies and Statutory Bodies

In the previous Section, attention is drawn to the difference in approach between historical contamination and recent contamination from a legislative viewpoint. The fact that risk-based methodologies for contaminated land management and remediation are restricted to historic contamination and that new pollution due to negligence is considered differently is highlighted. In response to this Vetgter (2001) claims “this distinction is a political choice and does not imply that the science of risk assessment, and hence similar management systems, cannot be applied for pollution caused by recent activities”. Whilst this may be true, the way in which acute problems present and are subsequently managed is fundamentally different. In particular the roles and responsibilities of key organisations involved in responding to and managing the incidents is not necessarily the same and in many cases is not clearly defined. This can result in confusion and unnecessary duplication of tasks between the different organisations.

The prime objectives of any service or organisation responding to an emergency are:

- to save lives;
- prevent escalation of the disaster;
- relieve suffering; protect property and the environment;
• aid criminal investigation and judicial, public, technical or other inquiries;
• notify the public, encourage self help and recovery and to restore normality as soon as possible

(Barry & Japp, 1997)

Therefore considering the wide ranging nature of these objectives, it is hardly surprising that there is no single organisation within the UK with all the expertise and resources required in the event of a major incident and that any response to an emergency must be a combined and co-ordinated procedure between all services and organisations involved (Barry & Japp, 1997). However, how and to whom an incident is reported will vary. The next section outlines typical response patterns with regard to the agencies involved in incident management and highlights the differences between response to acute and chronic land events.

2.4.1 Emergency Services

In an acute land contamination incident the immediate or emergency response usually involves the emergency services and in most cases the fire service will take a lead role. A wider discussion of the role of the fire service in responding to a chemical incident is presented in Appendix F. Once the problem has been contained, advice can be sought on the most appropriate method for decontamination. Responsibility for leading the clean-up operation is then passed to the Environment Agency (or other regulatory body) although fire service equipment and other resources may be used.

When dealing with acute incidents that involve hazardous materials, frequently referred to as HAZMATS, the primary aim is to remove the risk of explosion and prevent pollution of controlled waters. Most UK fire services have acquired appropriate equipment for responding to such events including ‘Grab Packs’ (which contain putty for sealing leaks, absorbent pads, a clay mat etc.) in addition to dedicated environmental protection units. The equipment carried on dedicated units is agreed between the fire service and the Environment Agency at a local level. This is principally because the nature of incidents is likely to vary. For example if the area
is heavily industrialised then there is greater potential for a chemical spill than in the countryside although it could be argued that agricultural chemicals, such as fertilisers and pesticides, stored and used in large quantities present an equally significant hazard.

Alternatively, in some circumstances where there is no urgent threat to the health of the public and no emergency per se, such as a leak of petrol onto land close to a river, the Environment Agency may request the assistance of the fire service to deal with immediate containment of the problem. In this situation the fire service take on the role of contractors to the Environment Agency.

In contrast the Emergency Services are rarely involved in responding to chronic land contamination problems as they seldom present an acute threat to health. The main exception to this is the treatment of exposed workers who have become ill after working on contaminated sites with inadequate personal protective equipment (PPE). The Ambulance Service may be called upon to treat casualties and transport those exposed to Accident and Emergency departments for further treatment.

2.4.2 Local Authority

In general environmental health practitioners (EHPs) in local authorities are concerned with assessing, controlling and managing those aspects of the natural and built environment that can affect human health. EHPs attempt to control these factors by using legislation and other methods such as education or persuasion (Fairman et al, 2001).

There is often confusion over the role of EHPs in acute chemical incidents and much of this arises from the lack of a specific duty for local authorities (Fairman et al, 2001). In spite of this, local authorities will frequently play a key role in responding to and managing chemical incidents and may take responsibility for risk communication, environmental sampling and analysis, and clean up of the affected area. In contrast, for chronic land contamination problems the role of the local authority is clearly defined in legislation.
Local authorities have the primary regulatory role under Part IIA of the Environmental Protection Act 1990, which reflects their existing functions under the statutory nuisance regime, and also complements their role as planning authorities (DETR, 2000). The role of local authorities under Part IIA is to inspect their areas and identify contaminated land, to determine whether any particular site is contaminated land and finally to act as the enforcing authority for all contaminated land that is not designated as a Special Site.

As the enforcing authority, the local authority has four main tasks:

- to establish who should bear responsibility for the remediation of the land
- to decide what remediation is required, make sure that this work is undertaken and if necessary serve a remediation notice
- where a remediation notice is served, determine who should bear what proportion of the liability for meeting the costs of the work and
- to record certain information about the regulatory action on a public register.

In addition, building regulators and building control have responsibility to ‘sign off’ the remediation work if it is undertaken as part of a redevelopment project.

2.4.3 Environment Agency

The Environment Agency has an important role to play in conserving the land both in seeking to prevent pollution and also in helping to make land safe when it has become contaminated. It has a number of regulatory responsibilities, including IPPC. In addition, Part IIA of the Environmental Protection Act 1990 provides for certain land to be classified as a Special Site (as defined in the Contaminated Land (England) Regulations [2000]). Land cannot be designated as a Special Site unless the local authority has first identified it as contaminated land (Environment Agency, 2000). In these situations the Environment Agency takes over from the local authority as the enforcing authority.
There are three main groups of cases that may be designated as Special Sites (DETR, 2000):

**water pollution cases** where the contaminated land is affecting controlled waters and their quality. For example, wholesomeness of drinking water, surface water classification criteria or major aquifers.

**industrial cases** where contaminated land which is, or has been, used as a site for industrial activities either poses special remediation problems or is subject to regulation under other national systems. Examples are waste acid tar lagoons, oil refining, explosives, IPC sites, IPPC installations and nuclear sites.

**defence cases** where contaminated land involves Ministry of Defence estate. This includes any contaminated land at current military, naval, air force bases and other properties.

### 2.4.4 Health Service

According to the British Medical Association (BMA), the medical profession has an important role to play in exploring risks to human health from the environment so that hazards can be controlled, diminished or eliminated (BMA, 1999) and that doctors should "play an active part in managing the environment in the interests of public health" (BMA, 1991).

To minimise the impact of an acute chemical incident on human and environmental health, an effective and timely response from the health service is imperative. This is in contrast to an epidemiological investigation, such as confirming a link (or otherwise) between an adverse health effect and a specific industrial process which is a much more long-term undertaking. The impact of an incident on the health of the public may not be immediately apparent and delayed or long-term (chronic) health effects may result from an exposure. Therefore, surveillance and monitoring of sensitive receptors, both human and environmental, which have been exposed or potentially exposed to the chemical(s) is crucial. Yet the health service contribution as an integral part of the emergency response team is only slowly being recognised (Bakhshi, 1997) and there is limited guidance available to those working in public health to assist in managing these incidents.
The National Health Service (NHS) is currently going through a fundamental change process in terms of structure and service delivery. As a result, established arrangements for co-ordinating the NHS response to emergencies and managing the public health consequences of such events are no longer appropriate or viable (Donegan, 2002). Until April 2002, it was the responsibility of health authorities to co-ordinate the health aspects of the response to chemical incidents (also referred to as non-infectious environmental hazards – NIEHs). This included the protection of the health of, and provision of care to, those who have been or may be exposed to a chemical hazard (NHSME, 1993), for example providing advice to the local authority if there was a contaminated site where there were valid concerns with regard to the health of the public. However, at the time of writing (September 2002) all health authority functions and responsibilities are being transferred to either primary care trusts (PCTs) or to strategic health authorities (SHAs).

On 24th September 2002 guidance on the role of PCTs in planning for, and responding to, major incidents was published (NHSE, 2002). This is intended to replace the chapter covering the role of the health authority in ‘Planning for major incidents: the NHS guidance’ and reflect the responsibilities outlined in ‘Shifting the Balance of Power: The Next Steps’ (Box 2.5).

Box 2.5: Shifting the balance of power

http://www.doh.gov.uk/shiftingthebalance/index.htm

_Shifting the Balance of Power_ is the programme of change brought about to empower frontline staff and patients in the NHS. It is part of the implementation of the NHS Plan and has already led to the establishment of new structures. That is only one step and the main objective will be to foster a new culture in the NHS at all levels, which puts the patient first. The main feature of change has been giving locally based primary care trusts the role of running the NHS and improving health in their areas. This has meant abolishing the previous health authorities and creating new ones that serve larger areas and have a more strategic role. The Department of Health is also refocusing to reflect these changes, including the abolition of its regional offices.
The three main roles of PCTs, highlighted in the report, are to improve the health of the community, secure provision of high quality services and integrate health and social care locally. From an emergency planning and incident response perspective, this includes assessing the impact on health and health services of every potential major incident, initiating and supporting the public health response to the incident where appropriate and arranging follow up if necessary of persons affected or exposed to risk.

It is intended that SHAs will lead the strategic development of the local health service and manage the performance of the PCTs and NHS trusts within a specified geographical area. They will also be responsible for the creation of a strategic framework for the development of services across the full range of local NHS organisations, and the continued support to local organisations to secure improvement to the NHS. Regional Directors of Public Health (RDPHs) will be accountable for ensuring that there are appropriate high quality health protection arrangements (covering infectious diseases and other risks to health including NIEHs) in place in all locations in their region. In addition they will be accountable for managing and coordinating the health aspects of the Government’s response to emergencies and disasters (DoH, 2002).

Furthermore, on 10th January 2002, the Chief Medical Officer's report 'Getting Ahead of the Curve: A strategy for combating infectious diseases' was published. The report was written following September 11th and the subsequent anthrax outbreaks in the US when the need for integrated responses to CBRN incidents became apparent. The main recommendation of the report was to combine the existing functions of the Public Health Laboratory Service (PHLS), National Radiological Protection Board (NRPB), Centre for Applied Microbiology and Research (CMR) and the National Focus for Chemical Incidents and to bring together into one agency key professions working in health protection, which includes Consultants in Communicable Disease Control (CCDCs), Health Emergency Planning Advisors (HEPAs) and Infection Control Nurses. The aim of the new ‘Health Protection Agency’, which will be launched in April 2003, is to
provide 'an integrated approach to protecting the public against infectious diseases and chemical and radiological hazards' (DoH, 2002).

The launch of the Health Protection Agency in April 2003 provides the opportunity to reconsider and to substantiate the role of public health practitioners in responding to chemical incidents and to ensure that appropriate tools and guidance are in place for a more integrated approach to the management of these events in the future. Yet a British Medical Journal editorial on major chemical incidents published in 1991 observed that health professionals are more used to disaster planning for major trauma than for mass chemical exposure (Baxter, 1991). Whilst incidents that lead to mass chemical exposure such as Bhopal (Pershagen, 2001; Gunnell, 1993;) are rare, they have the potential to produce serious adverse health effects in large numbers of people. However, more important from a public health viewpoint are the numerous less serious incidents (Pershagen, 2001). Evidence suggests that few public health practitioners have been trained in managing such events or have access to the resources required for identification, investigation, mitigation or prevention of health effects in humans that can arise from chemical incidents (Hill & O’Sullivan, 1992). This reference is from a report written ten years ago and yet experience over the past four years has shown that although a number of improvements have been made, in the overall scheme of things little has changed.

2.4.4.1 Public health and land contamination

It is important to appreciate that under the Contaminated Land Regulations, local authorities and the Environment Agency, not public health practitioners, have regulatory control over contaminated land. Therefore in general the potential role of the health service in land contamination incident management is poorly understood by other agencies involved.

This was reflected in responses to a short questionnaire survey, conducted as part of this project, posted to local authority officers involved in managing land contamination incidents. Responses revealed that little consideration had been given to the role or potential role that public health may play in responding to and managing these issues. The aim of the questionnaire, a copy of which has been
provided in Appendix G, was to determine the extent to which local authorities had discussed their strategies for identifying and managing the contaminated land with the local health agencies. The survey was sent to around 300 local authority environmental health departments across the UK shortly after the implementation of the Contaminated Land Regulations in April 2000. The covering letter sent with the questionnaire requested that the person with responsibility for managing contaminated land issues within the local authority should complete it. Only 30 questionnaires were returned giving a response rate of 10%. Whilst this is low and may not be considered a representative set of responses there was an even geographical spread and the data collected provides some indication of the current situation. In addition to the postal questionnaires, short interviews and discussions with a number of local authority officers who are directly involved in contaminated land management were held.

In order to gain an idea of the level of experience that the respondent had in managing land contamination incidents, the first question requested information about the number of incidents that they had personally been involved in. Results presented in Figure 2.9 indicated that while experience varied widely the majority of respondents had managed less than 10 incidents.

A series of questions was included to determine whether the local authority had consulted the health authority\(^3\) with regard to the new contaminated land legislation and the preparation of the area inspection strategy. Results highlighted that only 5% of respondents had been involved in limited consultation but that also 80% had not consulted with public health colleagues at all. Follow-up interviews revealed that generally the reason for lack of consultation with public health was that the role of public health practitioners was poorly understood, although in some cases there was a view that public health practitioners do not have a role in managing land contamination incidents.

\(^{3}\) At the time of the survey the majority of public health practitioners were based in Health Authorities.
Yet the health and environmental consequences of a land contamination incident cannot be considered in isolation, as stakeholder perception of the risks and their involvement in the decision-making process is paramount to an effective response. ‘Contaminated land’ is very strictly defined within the legislation, which requires a significant pollutant linkage to be established before land is legally regarded as contaminated. Nevertheless a site that is not found to be ‘contaminated land’ (as defined by the legislation) may be perceived by local residents to present a hazard to their health. Consequently, whilst a definitive link between the presence of chemical contaminants in the soil and any reported adverse health effects may be difficult to establish, it is imperative that all potential exposure pathways are investigated and the potential for harm to result from exposure eliminated. This requires the involvement of public health practitioners who are often trusted by the public to provide appropriate and unbiased information whilst at the same time able to maintain good working relationships with other key agencies (and industry) involved in managing and investigating the incident.

“Public health practitioners are seen as prominent members of the community and as the healers and guardians of the health of individuals. They are also among those who are seen as the most trusted sources of information on risks, including chemical risks” (Hu, 1996).
In light of this, it is suggested that public health practitioners should be considered to have a central role in providing an effective and timely response to land contamination incidents. Interestingly this view was supported by a number of respondents to the questionnaire. 40% thought it would be a good idea for public health practitioners to have specific guidance on managing the public health impact of land contamination incidents (Figure 2.10). In particular the need for a risk assessment tool to consider the impact of an incident on the health of the public was raised, which should include site investigation, toxicology and sampling.

As a result a review of the resources available for the assessment of land contamination was undertaken. The next section aims to outline some of the tools and guidance that are currently available, recognise any limitations and identify apparent needs.

Figure 2.10: Would it be useful if health authorities had guidance specifically on the public health management of land contamination?

2.5 Tools and Guidance

Until recently, the lack of official guidance and procedures for managing land contamination problems has resulted in many environmental consultants developing their own risk-based methodologies for assessing contaminated land. These are not available in the public domain and are not often published extensively in the literature. Hence it is difficult to be able to list a comprehensive guide to the tools
that exist and are currently in use in the UK to assess and manage either acute or historic (chronic) land contamination incidents (land contamination incidents).

Until March 2002, which saw the long awaited introduction of the CLEA (Contaminated Land Exposure Assessment) model, there were no UK models for site-specific public health risk assessment. CLEA is a human exposure assessment tool. Associated with it is a series of guidance documents aimed at improving the management of land contamination that has resulted from past industrial land use and is considered to present a potential hazard to human health and/or the wider environment. Research to develop a scientific framework for assessing the risks to human health from land contamination was initiated by the Department of the Environment (now DEFRA) in response to a House of Commons Select Committee on the Environment report. The launch of the CLEA model and supporting guidance documentation had been delayed by several years because of the level of consultation required.

Prior to the introduction of CLEA, the Environment Agency in collaboration with external consultants carried out an evaluation of some of the tools and models that are available for use in the UK for land contamination risk assessment (Butler & Petts, 2000). They identified that a number of qualitative and quantitative methods for assessing the risks posed to human health following exposure to contaminated soil have been developed worldwide. The risk assessment models evaluated were Risk*Assistant and RBCA from the US and RISC-HUMAN from the Netherlands. These are all computer-based tools.

RISK*ASSISTANT is a model used to predict local exposures. It incorporates data on chemical concentrations in the environment and enables the user to consider a range of possible exposure cases. It also includes sensitivity analysis capabilities to test the impact of different assumptions on exposures and risks (Hampshire Research Institute, 1999).

The RBCA (Risk-based corrective action) model integrates assessment of the site or affected area, selection of the most appropriate remedial action and monitoring with
risk and exposure assessment practices recommended by the US EPA. It is both
detailed and prescriptive providing a consistent process that can be used to make
decisions regarding a given site that are protective of both human health and the
environment. The process is implemented in a tiered approach with subsequent levels
requiring more complex data and analysis thus allowing rapid decisions to be made
as necessary with further investigation undertaken as required (ASTM, 1996).

RISC HUMAN (Risk Identification of Soil Contamination) is a model for
determining human exposure to soil contaminants using expertise on the presence
and behaviour of contaminants in soils. (Van Hall Instituut, 2001). Because of the
large variety of human exposure on contaminated sites, different model approaches
developed by the Dutch National Institute of Public Health and the Environment
(RIVM) are included in the model. These include CSOIL, which is a model for
assessing human exposure to contaminants in soil and VOLASOIL, which is a model
that has been developed for risk assessment where there are volatile soil contaminants.

The main conclusion of the Environment Agency report was that the models all
perform well and could be of use in the UK but that none was easy to use. Also since
there are a lot of assumptions underpinning the models, a thorough understanding of
these was considered essential because they may not be applicable to a UK situation
(Butler & Petts, 2000). A methodology not included in the review was that developed
by the University of Nottingham in collaboration with the Scottish and Northern
Ireland Forum for Environmental Research (SNIFFER). The SNIFFER framework is
a paper-based tool for deriving numeric targets to minimise the adverse human health
effects of long-term exposure to contaminants in soil according to the source–
pathway–receptor risk assessment framework. The assessment criteria derived on a
site-by-site basis can be used in establishing whether concentrations of substances in
soil are unacceptable in terms of chronic risks posed to human health and in
informing remediation objectives (University of Nottingham, 2000).

The SNIFFER framework, Risk*Assistant, RISC-HUMAN and RBCA are
deterministic models meaning they are dependent on the selection of a single input
value for each system parameter. Subsequently a single value for the average daily exposure is generated. In contrast CLEA is a probabilistic model (See Box 2.6).

Box 2.6: Probabilistic exposure models (DEFRA, 2002)

The probabilistic model replaces some single value parameters in the exposure assessment with a family of values selected from a defined probability distribution. Each time the model estimates exposure, it selects a value from this family. By repeating the assessment, a probabilistic model builds a range of predicted exposures rather than providing a single outcome. This allows the assessor a better understanding of the sensitivity of the assessment to parameter uncertainty and variability, and allows more informed judgements about its degree of conservatism.

The CLEA model, which models exposure rather than uptake with the exception of lead, contains eight system parameters that lie within a range of possible values rather than requiring a single user-specified value. The model uses a Monte Carlo simulation to generate a range of predicted exposures rather than a single value. This provides for a better understanding of the sensitivity of the assessment to parameter uncertainty and variability (DEFRA, 2002).

Ten exposure pathways are considered in the model (Table 2.8). Allowances are made for uncertainty and the model takes into consideration the bioavailability (refer to Box 2.7) of the contaminant. Also included in the model is ‘source apportionment’. For example, when looking at the risks of exposure to a substance it is important to first consider how overall exposure to that substance can occur, and to identify all potential routes of exposure, before determining how much of the daily intake could be reasonably attributable to exposure to contamination in the soil (Harrison, 2000).

Table 2.8: Ten exposure pathways considered in the CLEA model

<table>
<thead>
<tr>
<th>Outdoor ingestion of soil</th>
<th>Skin contact with indoor dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor ingestion of dust</td>
<td>Outdoor inhalation of fugitive dust</td>
</tr>
<tr>
<td>Consumption of home-grown vegetables</td>
<td>Indoor inhalation of dust</td>
</tr>
<tr>
<td>Ingestion of soil attached to vegetables</td>
<td>Outdoor inhalation of soil vapour</td>
</tr>
<tr>
<td>Skin contact with outdoor soil</td>
<td>Indoor inhalation of soil vapour</td>
</tr>
</tbody>
</table>
Box 2.7: Bioavailability (Paustenbach et al, 1992)

Environmental contaminants are able to cross biological barriers with varying degrees of efficiency but when they are bound to soil particles, the efficiency of uptake decreases. The bioavailability of a chemical is the percentage of the chemical in soil that is absorbed by humans. Chemicals in soil are usually absorbed to a lesser degree than chemicals in pure form. Factors which affect the bioavailability of a chemical are:

- the physiochemical properties of the contaminant
- the environmental matrix in which it is present
- the nature of the biological membrane

Soil guideline values (SGVs) have been derived using the CLEA for three different land use scenarios: residential, allotments and commercial/industrial. The model scenarios incorporate some generic assumptions, which are published and explained (DEFRA, 2002). Work is currently being undertaken to develop SGVs for open spaces such as parks (ENDS, 2002).

SGVs are to be used in establishing whether a site poses actual or potential risks to human health in the context of the existing or intended use of the site. So although ‘standard’ values have been determined for each land use scenario, site-specific information is required to determine whether the generic assumptions incorporated within the CLEA model mean that the SGVs derived are directly applicable or if there are parameters within the model that need to be modified. To date SGVs have been derived for arsenic, cadmium, chromium, selenium, nickel, lead and inorganic mercury; separate toxicology reports have been written for each and it is anticipated that others will be developed in the future. It should be noted that the SGVs have been derived for chronic exposure to contaminants in the soil and that there are currently no guidelines for acute exposure.

SGVs derived using the CLEA model are intended to replace the levels developed in 1983 by the Interdepartmental Committee for the Redevelopment of Contaminated Land (ICRCL) (ICRCL, 1987), which were set as guidelines for redevelopment. These introduced the concept of ‘threshold’ concentrations, which were non-legally binding values for contaminants in the soil based on the intended land use. Threshold or ‘trigger’ values were suggested for 20 substances, principally inorganic
contaminants, including heavy metals and those chemicals frequently encountered at
gasworks sites. For a number of the substances, action levels were also suggested.
Below the 'threshold' value, the site could be regarded as uncontaminated and above
the 'action' value, the presence of a contaminant was regarded as unacceptable, so
some kind of remedial action was required. Between the two values, there was a need
to make an "informed judgement" based on site-specific circumstances about the
acceptability of the level of contamination on the site.

The ICRCL guidance was not mandatory and its application has led to a wide
variation in the policies and interpretation used by different local authorities (Peters
& Blake, 1999). Furthermore the values were developed for use in determining the
level of clean-up required when re-developing a contaminated site and not for use in
determining whether a site presented a hazard to human health. Beckett (1993) has
stated that 'evidence of continuing misuse of ICRCL trigger concentrations has been
accumulating'. This implies that the trigger values have not only been applied when
sites are being redeveloped but elsewhere to determine how contaminated a
particular site is. Yet the reason that ICRCL values have been widely used in the UK
for the assessment and remediation of contaminated land is principally due the
absence of anything more appropriate rather than a misunderstanding of the basis on
which the ICRCL values were developed.

Dutch guidelines for contaminants in soil have also been quoted in addition to or
instead of ICRCL values in UK contaminated land reports. Further information about
these guidelines and other standards for contaminated land is provided in Appendix
H.

Whilst guidance has been developed for the management of chronic land
contamination incidents, little consideration has been given to the provision of
guidance for the management of acute land contamination incidents that have the
potential to give rise to adverse public health impacts. Furthermore it would seem
that the majority of models that do exist for assessing the risks associated with
exposure to contaminated land are based on chronic exposure from chronic events
and aim to determine levels to be used for site remediation. These levels may not be
appropriate for use in responding to short-term (acute) exposures that may result as a consequence of an acute event. The Environment Agency has commissioned a research project to address some of these issues, which is due for publication later this year (Environment Agency, 2002). The final report will set out model procedures to enable a qualitative assessment of risk to human health following an acute exposure. Procedures addressing the wider impact of the event on the health of the public are not covered. As acute land contamination incidents have the potential to cause significant harm to human health the increasing need to develop procedures for responding to these events becomes apparent.

One model, which is only applicable to the acute phase of an accident and not for long-term assessment, is the ‘Environment Accident Index’ (EAI). EAI has been developed by the Defence Research Establishment in Sweden on behalf of the Rescue Services Agency and the Environmental Protection Agency for use as a simple tool to guide further risk assessment to be performed following a chemical incident.

EAI is calculated by multiplying the acute toxicity to living organisms in water by the stored or transported amount of the chemical and the chemical mobility. The latter is considered to be a function of consistency, solubility and the surrounding environment including the distance to the nearest well or watercourse, the depth of groundwater, and the thickness and type of soil. The numerical output calculated is compared to a graded classification scale, which indicates the level of further risk assessment required.

Unfortunately EAI considers only the environmental consequences of the incident and not the potential impact on human health. Also it only looks at releases to land and water, including groundwater, and not to air so does not take account of the inter-relationships that exist between the environmental media. Therefore its applicability as a tool for responding to and managing a land contamination incident is limited.
Overall it would appear that there are few appropriate tools available for managing acute land contamination incidents and none that either adequately consider the potential impact of a land contamination incident on the health of the public or facilitate an effective public health response. As a result a more general review of existing procedures for the public health management of chemical incidents has been undertaken and is summarised in the next section.

2.5.1 Guidance for the Public Health Management of Chemical Incidents

Murray and Goodfellow (2002) undertook a review of published incident response procedures as part of a review of mass casualty chemical incidents occurring naturally or as a result of industrial activity or deliberate release and the problems experienced in medical and public health response. The aim of the review was to identify any procedures available to assist in the management of chemical incidents. The particular focus was on the management of chemical incidents and environmental hazards by public health practitioners in order to minimise the impact of such hazards on the health of the public. This covers a wider remit than just the management of casualties, which is considered to be largely the responsibility of hospital accident and emergency clinicians. The review was aimed specifically at establishing whether there are any published procedures for use in the emergency response to chemical incidents, rather than for use as an emergency planning tool. The main conclusion of the report was that the only guidance for the public health management of chemical incidents that does exist, focuses on pre-incident planning for such events and does not provide easy to follow procedures for responding to and managing chemical incidents as they evolve. Additionally procedures tend to outline what needs to be done rather than how to actually do things and are consequently not as practical as they could be.

Useful references highlighted in the review include Chapter 8 of 'Planning for Major Incidents – The NHS Guidance', which lists different types of incidents, outlines special features of chemical incidents and addresses local, regional and national responsibilities and planning. Also 'Health Aspects of Chemical Accidents – Guidance on Chemical Accident Awareness, Preparedness and Response for Health
Professionals and Emergency Responders' (OECD Environment Monograph No. 81, 1994) contains three guidance documents to assist managers and other decision makers in developing appropriate policies for chemical accident prevention, preparedness and response and to treat health aspects of chemical accident prevention, preparedness and response in a more detailed and technical way. In addition a checklist for action is presented, comprising a series of items set out as a memory aid concerning what needs to be done in planning and implementing health related chemical accident prevention, preparedness and response measures.

The Chemical Incident Response Service has also written and published through The Stationery Office a number of useful guidance documents as part of the 'Chemical Incident Management Series'. These include books aimed specifically at Public Health Physicians (Irwin et al, 1999), Accident and Emergency Clinicians (Fisher et al, 1999) and Local Authority Environmental Health Practitioners (Fairman et al, 2001) as well as the 'Chemical Incident Handbook’ (Farrow et al, 2000), which contains summary toxicological information for hundreds of chemical substances. A further book in the series entitled ‘The Environment and Public Health’ has been prepared as part of this research project in collaboration with two other Research Engineers based at the Chemical Incident Response Service and the director of CIRS, Dr Virginia Murray. The book is currently in press and it is anticipated that it will be published by end of 2002.

A further reference source is available from the International Programme for Chemical Safety (IPCS, 1999) who has published a book entitled ‘Public Health and Chemical Incidents’. This document describes how countries can improve the public health response to acute chemical incidents and ensure a better outcome for the health of their populations. It is divided into three main sections covering policy, public health response and a suggested framework into which the public health function can be built. In addition a series of appendices contain further information including a list of acronyms and a glossary.

As previously indicated, although these references provide useful information about preparation prior to a chemical incident, there is little information available that can
be accessed and used during an incident to guide the response thus highlighting the need for further work to develop appropriate tools and resources. Additional issues that need to be addressed include provision of training and training material.

CODA

It is appropriate that this research project concentrates on developing procedures for responding to and managing acute chemical incidents and specifically those that result in land contamination. This ties in well with the original project brief, which suggested that little work had been done to investigate the impact on human health and the environment of an uncontrolled release of chemicals onto land during a spill. However, since the human health impact of a chronic land contamination incident has not been considered in any great detail from the viewpoint of the public health practitioner who may have a key role to play in the effective management of an incident, this reinforces the need for further work.

Recognition of the limitations of current resources for integrating health and environmental assessment and management of chemical incidents would suggest that rather than focusing on land contamination incidents, a new and more general methodology should be developed. Section 2.4.4 outlined the public health function in responding to chemical incidents. Using this as a basis, key needs of those responding to such events can be identified including the provision of tools to guide the public health response and management.

In general chemical incidents are currently managed on an ad hoc basis, either because of limited experience or lack of appropriate resources. Therefore one of the key aims is to consider whether developing a standardised approach to chemical incident management results in a more effective and consistent response. Since all incidents are different, tools need to be flexible enough to ensure that all possible outcomes are considered and allowances are made for situations where a decision is required even if limited information is available. However, experience gained whilst working at CIRS over the past four years has indicated that it may be possible to group incidents into a finite number of categories. These categories can either reflect the impact of the incident and hence the level of response required or the type of
incident, such as those currently used by CIRS and the National Focus for surveillance purposes.

Additionally an important issue to consider is whether it is feasible to integrate the decision-making processes that are used to assess impacts on human health and the environment since current procedures seem to be aimed at either one or the other.

The work presented in Chapters 3, 4 and 5 will aim to answer the following questions:

- How can we improve chemical incident identification and notification and better communicate the risk that an incident presents to human health?
  - Is it appropriate to devise a categorisation scale for all chemical incidents, to be able to distinguish between a 'major incident' and a 'minor event' from a human health perspective? How useful would this be?
  - How can this be extended to consider the impact on the environment simultaneously?

- If chemical incidents, and in particular land contamination incidents, can be grouped into a limited number of categories, can we use these to develop generic tools and guidance for incident response and management?

- Are there benefits to identifying patterns in the way that incidents are currently managed? How can we use this information to gain a better understanding of the genesis and chronology of incidents and subsequently improve chemical incident management procedures?

- How can we combine diverse factors to provide an effective tool to concurrently assess the impact of chemical incidents on both human health and the wider environment?
3. CHEMICAL INCIDENT CATEGORISATION

In the months following September 11th 2001, interest in emergency planning and preparedness has escalated. The importance of inter-agency communication at a national and international level in providing an effective response to an accidental or deliberate chemical attack was highlighted repeatedly, and subsequently the need for a common alert and response system to communicate to potential health impact of an acute chemical incident was raised (Chapter 1). There has been a major drive within the UK to enhance the skills and knowledge of public health practitioners in particular, and to cascade information on to other medical professionals (Murray, 2001).

In this chapter the value of developing a rapid response tool to be able to measure the potential public health impact of a chemical incident is considered. No such scale currently exists yet the benefits of such a tool has been recognised nationally, by the Department of Health, and internationally by the World Health Organisation (see Appendix I for a copy of the press release) and G7/G8 (See Box 3.1). Initially the impact on human health from an acute chemical incident was considered in isolation but subsequently the possibility of integrating environmental concerns was contemplated.

Box 3.1: G7/G8 (G8 Information Centre, 2002)

Since 1975, the heads of state or government of the major industrial democracies have been meeting annually to deal with the major economic and political issues facing their domestic societies and the international community as a whole. The 6 countries at the first Summit, in 1975, were France, the United States, Britain, Germany, Japan and Italy. They were joined by Canada in 1976, by the European Community in 1977 and Russia in 1998. The G7/G8 provides an important occasion for leaders to discuss major, often complex international issues, and to develop the personal relations that help them respond in effective collective fashion to sudden crises or shocks. The Summit also gives direction to the international community by setting priorities, defining new issues, and providing guidance to established international organizations. At times it arrives at decisions that address pressing problems or shape international order more generally.
3.1 Categorising Chemical Incidents

Incident categorisation systems can be used to improve the management of acute chemical incidents, thereby minimising harm to human health and the environment. In addition they can be used as an aid to planning the level of response required, assessing the impact on resources and as a means of describing an incident that has occurred; in the early stages of response to communicate information between the different agencies involved in managing the event as well as to the general public; and, once the problem has been resolved, as a tool for surveillance (refer to Box 3.2).

Box 3.2: Reasons for categorising chemical incidents

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health and environmental impact</td>
<td>Categories can also be used to predict the potential impact of an event on human health and the wider environment. Some chemical incidents have the potential to result in widespread damage whereas others will only affect the local area.</td>
</tr>
<tr>
<td>Resource impact</td>
<td>Impact categories can be used to determine the potential impact of an event on resources, for example, support staff and equipment. The resource impact of an event will vary from agency to agency and will be influenced in part by the type of the event. Some chemical incidents may require environmental sampling and long-term monitoring; others may require an extensive health assessment of the exposed population.</td>
</tr>
<tr>
<td>Communication</td>
<td>The key to mitigating the impact of an incident lies firstly in effective communication – the right information at the right time to the right people (Barry &amp; Japp, 1997). Therefore a categorisation system that provides a consistent means of describing an incident that has occurred can be used in the early stages of response to communicate information between the different agencies involved in managing the event as well as to the general public.</td>
</tr>
<tr>
<td>Surveillance</td>
<td>If all incidents are described on a similar scale, it is easier to see patterns in the numbers and types of events occurring and to use this information to allocate resources, focus training requirements or improve response procedures for the future.</td>
</tr>
</tbody>
</table>
To some extent a scaling system might be used to meet a combination of these demands. However, this chapter focuses on the development of a classification system for communicating information about an acute event quickly and effectively. The aim is to develop a system to be used primarily as a tool for describing an event in the first phase following its recognition to improve inter-agency communication, and also international communication in the early stages following a potential terrorist attack and to define and describe a ‘major incident’ and a ‘no impact incident’ from a public health perspective.

3.1.1 Existing Scales

The idea of being able to categorise events to enable an assessment of their potential impact is not new and incidents and events are categorised in many different ways. However, an initial search showed that very few categorisation systems for assessing the impact of an event have been published. There may be a large number of unpublished categorisation systems that are being used for specific purposes by companies, but they remain inaccessible and are perhaps irrelevant for the purpose here of identifying a general system of categorisation that improves the management response to acute chemical incidents.

A number of hazard ranking systems for chemicals were identified (mostly American); for example, categorisation of chemicals for transportation according to their chemical and physical properties and a classification system for hazardous materials designed by the National Fire Protection Association (ATSDR, 2001). Whilst these provided examples of how chemicals (and perhaps incidents) can be grouped, the impact of an event or incident was not considered.

In addition there are categorisation tools that are principally used for planning. An example of such a scale is that presented in the risk analysis report prepared by the Arctic Council’s Emergency Prevention, Preparedness and Response (EPPR) Working Group (September 1998). This document contains the qualitative risk
matrix that the eight Arctic nations\footnote{The eight Arctic nations are Canada, Finland, Greenland, Iceland, Norway, Russian Federation, Sweden, USA} are using to identify and assess potential environmental hazards. All pollution incidents are considered to fall in one of four categories, which reflect the probability that the incident will occur and the magnitude of the threat (Figure 3.1).

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure3.1.png}
\caption{Risk categories used by EPPR}
\end{figure}

This two by two matrix is a fairly simple way to categorise risks and has been used on a number of occasions to carry out risk comparisons. For example, the Scottish and Northern Ireland Forum for Environmental Research (SNIFER) publication on communicating understanding of contaminated land risk (SNIFER, 1999), includes a figure which illustrates a range of hazards – from smoking to genetic engineering – and how they are typically perceived based on degree of familiarity and degree of fear.

A number of scales for categorising incidents exist for natural events and include the Beaufort scale (wind speed), the Fujita tornado intensity scale, the Richter and modified Mercalli scales (earthquakes), and the Torino scale (asteroid collision) (Binzel, 2000) - Table 3.1.
<table>
<thead>
<tr>
<th>Name of scale</th>
<th>Use</th>
<th>Description of scale</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaufort scale</td>
<td>- created in 1805 help sailors at sea estimate wind speed via visual observations - later modified for use on land</td>
<td>- 12 categories for wind speeds of less than 1 to greater than 119 km/hour - for each category a description and observations have been outlined</td>
<td>Beaufort force: 0 Description: Calm Observations: Smoke rises vertically Beaufort force: 8 Description: Gale Observations: Twigs break from trees, difficult to walk.</td>
</tr>
<tr>
<td>Fujita tornado intensity scale</td>
<td>- to classify tornadoes and sometimes the damage done by other wind storms</td>
<td>- 6 categories for tornadoes (F0-F6) based on the amount and type of wind damage - for each category a description and observations have been outlined</td>
<td>Category F0: Gale tornado (40-72 mph); light damage. Some damage to chimneys; break branches off trees; push over shallow-rooted trees; damage to sign boards. Category F5: Incredible tornado (261-318 mph); Incredible damage e.g. strong frame houses lifted off foundations and carried considerable distance.</td>
</tr>
<tr>
<td>Richter scale</td>
<td>- devised in 1935 to identify the magnitude of an earthquake - value calculated reflects the amount of energy released</td>
<td>- logarithmic scale</td>
<td>Modified Mercalli Scale: I Richter magnitude: &lt;3.4 Numbered per year: 800000 Characteristics: Recorded only by seismographs</td>
</tr>
<tr>
<td>Modified Mercalli Scale</td>
<td>- less precise and measures the intensity of the earthquake</td>
<td>- outlines characteristic effects of shocks in populated areas for 12 categories</td>
<td>Modified Mercalli Scale: VII Richter magnitude: 5.5 – 6.1 Number per year: 500 Characteristics: Slight building damage; plaster cracks, bricks fall</td>
</tr>
<tr>
<td>Torino Scale</td>
<td>- communication tool for astronomers and the public to assess the seriousness of predictions of close encounters by asteroids and comets - colour coded scale (5 categories)</td>
<td>- an object is assigned a 0 to 10 value based on its collision probability and its kinetic energy</td>
<td>Number on Torino scale: 0 Description: likelihood of a collision is zero Category: White zone – event having no likely consequence Number on Torino scale: 8 Description: collision capable of causing regional destruction Category: Red zone – Certain collisions</td>
</tr>
</tbody>
</table>
Whilst these scales are essentially very different, there are some similarities.

For example:

- some kind of risk profiling
  - threat (any circumstance or event with the potential to cause harm)
  - likelihood of occurrence
  - impact/consequence
- one-dimensional numerical scoring system
- omission of management response

However, a far more appropriate scale than those described above which essentially depict categorised groups of natural phenomena, which could be adapted for use in categorising acute chemical incidents, is that used to describe biological hazards. Biological hazards are most frequently categorised according to the number of people affected and the size of the affected area. For example, a disease that tends to be restricted to a particular region is endemic whereas an outbreak of disease that affects a much greater number of people than is usual for the locality or that spreads to regions where it is ordinarily not present is an epidemic. The World Health Organisation (WHO) has a preparedness plan for influenza pandemics, which provides a basis for WHO to determine its response to such situations as they are assessed. Other classification systems for biological agents are based on hazard and containment, for example that described by the Advisory Committee on Dangerous Pathogens (1995).

Information about the WHO scale and four other scales is included in Table 3.2. The first of these is the International Nuclear Event Scale (INES), developed by International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of OECD (Organisation for Economic Co-Operation and Development) in the aftermath of the Chernobyl catastrophe to provide a means of promptly communicating to the public in consistent terms the safety significance of events reported at nuclear installations (IAEA, 2001). The second scale in the table is that used by the Environment Agency to record all types of pollution incident across all aspects of the environment. The third scale in the table is that agreed by an international meeting of
experts by the International Programme on Chemical Safety (IPCS) and defines acute chemical incidents requiring public health involvement and four levels that describe the impact of the event on the health of the public (IPCS, 1999). Finally, in February 2002, the Centres for Disease Control and Prevention (CDC) in the US published a paper that outlined a method for 'Public Health Assessment of Potential Biological Agents' and outlined a methodology for placing agents in 1 of 3 priority categories based on a risk-matrix analysis process. The purpose of this categorisation system was to determine the biological agents for public health preparedness activities “to help co-ordinate planning efforts among federal agencies, state and local emergency response and public health agencies and the medical community” (Rotz et al., 2002).

3.1.2 Developing a Scale for Chemical Incidents

The term chemical incident is defined by IPCS as ‘an occurrence of public health concern caused by an acute release of a toxic or potentially toxic agent’ (IPCS, 1999) and therefore can include incidents ranging from a minor spill of a common acid in a laboratory to an explosion at a chemical plant resulting in exposure of a large population and significant degradation of the environment.

To make certain of the appropriateness of the scale and to ease dissemination and use, it was important to determine exactly what the chemical incident scale would be used for. It was decided that the incident categorisation system would be used as a rapid response tool to communicate the potential public health impact of a chemical incident between the agencies involved in managing the incident. The aim, then, was to devise a scale that may be used quickly as a means of describing the magnitude of a release of a chemical substance to communicate the severity of the incident and in so doing initiate the appropriate response.
<table>
<thead>
<tr>
<th>Name of scale</th>
<th>Use</th>
<th>Description of scale</th>
<th>Examples</th>
</tr>
</thead>
</table>
| WHO Influenza Pandemic Preparedness Plan          | • to assist medical and public health leaders to better respond to future threats of pandemic influenza | • preparedness levels defined which provide a basis for WHO to determine its response to such situations as they are assessed  
• 6 phases defined from inter-pandemic (phase 0) to end of pandemic (phase 5) |  
Within Phase 0, three levels have been defined:  
Phase 0, Preparedness Level 1: New influenza strain in a human case  
Phase 0, Preparedness Level 2: Human infection confirmed  
Phase 0, Preparedness Level 3: Human transmission confirmed  
Category: 3  
Description: serious incident (no off site risk) e.g. Vandelsos NPP, Spain 1989  
Category: 5  
Description: accident with off-site risk e.g. Three Mile Island NPP, USA, 1979 |
| International Nuclear Event Scale                | • developed in 1989 as a tool for communicating to the public safety significance of events reported at nuclear installations | • events classified on a scale of 8 levels from major accident (7) to deviation (0).  
• on-site and off site impacts are considered |  
Category 1: serious long-lasting or extensive damage to the environment or people  
Category 2: significant effect on the environment or people  
Category 3: minimal effect on the environment or people  
Category 4: no impact occurred |
| Environment Agency Pollution Incident Categories  | • 2-tier system looking at both the impact on Agency resources and the actual impact of environmental damage | • environmental impact for each incident recorded for the effect on water, land or air  
• highest selected criteria determines level of impact |  
Level 1: an acute release with no human exposure  
Level 2: an acute release with potential or actual exposure  
Level 3: an acute release where the suspected/actual release is related to ill health  
Level 4: an acute release giving rise to a civil defence or equivalent major emergency |
| International Programme on Chemical Safety        | • defining a chemical incident                                        | • definition of a chemical incident and 4 levels                                         |  
Category A: greatest potential for adverse public health impact with mass casualties  
Category B: some potential for large-scale dissemination  
Category C: currently not believed to present a high risk |
| CDC Biological Agent categories                  | • developed by CDC for public health assessment of potential biological terrorism agents | • 3 categories based on public health impact, dissemination potential, public perception & public health preparation |  |
3.1.3 Identifying Appropriate Parameters

Identifying the most appropriate criteria to consider when defining the categories required careful consideration of several alternatives. This encouraged broad systematic thinking about what is important about the incidents that are to be categorised and ranked (Morgan et al, 2000). Firstly the criteria used by CDC to evaluate potential biological threat agents were considered (listed in Table 3.3) although as they were used to categorise biological agents and not incidents they were not directly appropriate. However they did provide a good basis for discussions to evaluate the most appropriate parameters for the chemical incident scale.

<table>
<thead>
<tr>
<th>Parameter*</th>
<th>Factors considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public health impact</td>
<td>Potential for disease/death</td>
</tr>
<tr>
<td>Dissemination potential</td>
<td>Main routes of infection, stability of the agent and person to person transmissibility</td>
</tr>
<tr>
<td>Public perception</td>
<td>Pre-existing heightened public awareness and interest</td>
</tr>
<tr>
<td>Requirements for special public health preparation</td>
<td>Need for increased surveillance and stockpiling of antidotes</td>
</tr>
</tbody>
</table>

*For each agent a weighting from 0 to +++ was allocated for each of the four parameters.

Since the chemical incident scale would be used as a rapid response tool, in deciding which parameters to use it was important to identify the information that would be available in the early stages following notification that an incident had occurred.

It was suggested that chemical incidents could be categorised by:

- the incident impact – health, environmental, resource, overall
- something that is measurable – amount of chemical, number of people affected
- the type of incident – chemical hazard, event, location

The parameters selected on which to base the scale were:

- the number of people potentially exposed. This must take into consideration the incident location and time of day. For example, more people will be
exposed in the event of a chemical incident at a London underground station during rush hour than at three o’clock in the morning. It is important that the categorisation system reflects this difference.

- the observed severity of the impact on public health based on the health impact severity (HIS) scale. The HIS scale has been derived from the IPCS Poisoning Severity Scale (Persson et al, 1998) and the triage scale outlined in Major Incident Medical Management (BMJ Publishing, 1995) and is outlined in Table 3.4.

**Table 3.4: Health impact severity scale**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 None</td>
<td>• no symptoms or signs related to poisoning</td>
</tr>
<tr>
<td>2 Minor</td>
<td>• mild, transient and spontaneously resolving symptoms</td>
</tr>
<tr>
<td></td>
<td>• triage sieve P3 (green): needs treatment but can wait</td>
</tr>
<tr>
<td>3 Moderate</td>
<td>• pronounced or prolonged symptoms</td>
</tr>
<tr>
<td></td>
<td>• triage sieve (yellow): urgent treatment needed</td>
</tr>
<tr>
<td>4 Severe</td>
<td>• severe or life threatening symptoms</td>
</tr>
<tr>
<td></td>
<td>• triage sieve P1 (red): needs immediate resuscitation</td>
</tr>
<tr>
<td>5 Fatal</td>
<td>• death</td>
</tr>
<tr>
<td></td>
<td>• triage sieve P4 (black/white): death or expected death</td>
</tr>
</tbody>
</table>

These parameters were selected since this information is likely to be available, albeit in a crude format, in the early stages following notification that an incident has occurred and it is intended that initial use of the scale should occur as soon as possible.

**3.1.4 Defining a ‘Major Incident’**

Whilst experts may be able to describe an incident objectively in terms of specified attributes, deciding which of two incidents has the most significant impact on the health of the public requires value judgements (Morgan et al, 2000). For example, experience of dealing with a large number of chemical incidents may result in a
heightened awareness of the potential impact that such events may have on human health and the wider environment.

The process of categorising a large number of incidents into a small number of categories requires value judgements because different people and organisations have different concerns about risks (Morgan et al, 2000). In addition, there are trade-offs between the two main dimensions – the number of people exposed and the severity of the health impact. Is an incident where there are a few severely affected people a more or less significant incident than one with a greater number of affected people with minor adverse health effects? Therefore to gain an understanding of how different people perceive the seriousness of incidents, and also to confirm that incidents could be categorised using the selected parameters, a short survey was carried out.

A questionnaire listing 15 scenarios was circulated to 40 people who were asked to rank them as ‘Minor’, ‘Moderate’ or ‘Major’ incidents based on the number of people exposed and the health outcome based on the health impact severity (HIS) scale outlined previously. The response rate to the questionnaire was good (90%) and on the whole there was no significant difference between the responses received from those with experience of managing chemical incidents and those with limited or no experience (Table 3.5).

An exception to this was observed in the responses to scenarios five and eleven. In scenario five where there were 2 fatalities, those with experience in managing chemical incidents regarded this to be a less serious incident (average response=1.92) than those with limited or no experience (average response=2.73) (chi² =10.250, p=0.006). In scenario eleven, where there were 5 people with severe exposure, again those with experience in managing chemical incidents regarded this to be a less serious incident (average response=2.08) than those with limited or no experience (average response=2.54) (chi² =6.580, p=0.037). From an incident management perspective, a few severely injured or affected individuals are easier to cope with than many tens or hundreds of minor injuries in terms of the impact on resources. This is therefore perhaps the reason why the two scenarios perceived to be less
serious by those with incident management experience. Overall consistency in responses to each of the incident scenarios helped to confirm that it is possible to categorise incidents based on the selected parameters.

Table 3.5: Results from risk perception survey

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Number of people</th>
<th>Exposure</th>
<th>Average response</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>Moderate</td>
<td>Moderate</td>
<td>0.63</td>
</tr>
<tr>
<td>2</td>
<td>1050</td>
<td>Moderate</td>
<td>Major</td>
<td>0.50</td>
</tr>
<tr>
<td>3</td>
<td>1400</td>
<td>None</td>
<td>Minor</td>
<td>0.44</td>
</tr>
<tr>
<td>4</td>
<td>1600</td>
<td>Minor</td>
<td>Moderate</td>
<td>0.43</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>Fatal</td>
<td>Moderate</td>
<td>0.76</td>
</tr>
<tr>
<td>6</td>
<td>220</td>
<td>Severe</td>
<td>Major</td>
<td>0.00</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>Fatal</td>
<td>Major</td>
<td>0.16</td>
</tr>
<tr>
<td>8</td>
<td>360</td>
<td>Minor</td>
<td>Moderate</td>
<td>0.49</td>
</tr>
<tr>
<td>9</td>
<td>45</td>
<td>None</td>
<td>Minor</td>
<td>0.22</td>
</tr>
<tr>
<td>10</td>
<td>400</td>
<td>None</td>
<td>Minor</td>
<td>0.37</td>
</tr>
<tr>
<td>11</td>
<td>5</td>
<td>Severe</td>
<td>Moderate</td>
<td>0.54</td>
</tr>
<tr>
<td>12</td>
<td>600</td>
<td>Fatal</td>
<td>Major</td>
<td>0.00</td>
</tr>
<tr>
<td>13</td>
<td>70</td>
<td>Severe</td>
<td>Major</td>
<td>0.39</td>
</tr>
<tr>
<td>14</td>
<td>800</td>
<td>Minor</td>
<td>Moderate</td>
<td>0.47</td>
</tr>
<tr>
<td>15</td>
<td>980</td>
<td>Moderate</td>
<td>Major</td>
<td>0.50</td>
</tr>
</tbody>
</table>

3.1.5 The Scale

The IAEA scale could be used as a basis for a chemical incident categorisation system in combination with the IPCS scale. However it is unlikely that an incident involving the release of chemicals would reach the equivalent magnitude of a grade 6 or 7 nuclear/radiation incident or that a very minor release of chemicals – equivalent of a grade 1 nuclear/radiation incident - would do significant harm; indeed, such an event may not be detected. An example of such an incident might be a minor spill of a common acid in a chemical laboratory. Such an incident would be logged locally but it may not be routinely reported to either CIRS or to the Department of Health.

Incidents involving chemicals also differ from those involving the release of radioactive substances in that the latter can often be detected at low concentrations more easily than the former. Finally, our ability to predict the effects of exposure to low levels of radiation is greater than our ability to predict the effects of exposure to...
low concentrations of chemicals. These points have led us to think that the seven-point scale for nuclear events may not be ideal when dealing with chemical incidents. Initially, instead of a seven-point scale a three-point scale was proposed although this was later increased to five points.

It was decided that the chemical incident impact scale would comprise a single number that would indicate the severity of the impact and that each category would be colour-coded in a similar way to the IAEA nuclear event scale. Chemical incidents present multi-dimensional problems and it is therefore difficult to translate the impact of an event to a single number. However, by using a one-dimensional scale some immediate sense of context for the hazard is provided even if there is no understanding of the construction of the scale Binzel (2000).

The proposed scale is presented in Figure 3.2. If the average response results from the risk perception survey are superimposed onto the figure almost all points are within the same category on the scale. The only exceptions are due to the addition of categories 0 and 5, which represent insignificant and catastrophic events. A definition for each category or ‘grade’ has been written (Table 3.6) and examples of past incidents have been included to illustrate the application of the scale to ‘real’ events.

Figure 3.2: Chemical incident impact scale (CIIS)
### Table 3.6: Scale for communicating the potential health impact of an incident

<table>
<thead>
<tr>
<th>Category/Grade</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
</table>
| **4 Catastrophic incident** | Incident may result in  
- devastating impact on human health  
  - more than 1000 fatalities  
  - more than 10000 people with severe or life threatening symptoms | Bhopal, India 1994  
Cloud of methyl isocyanate released at pesticide plant following runaway reaction when water entered 45 tonne storage tank.  
(over 3000 fatalities, 170000 injured) |
| **3 Serious (major) incident** | Incident may result in  
- between 10 and 1000 fatalities  
  OR  
- over 100 people with severe or life threatening symptoms  
  OR  
- over 1000 people with pronounced or prolonged symptoms  
  OR  
- potential exposure of more 10000 people with mild, transient and spontaneously resolving symptoms or even if there are no adverse health effects (because of the potential resource implications required to effectively manage the situation and likely media interest) | Toulouse, France 2002  
Explosion completely destroyed petrochemical and fertiliser factory.  
(29 fatalities, more than 2500 injuries)  
Flixborough, England 1974  
Cyclohexane oxidation plant severely damaged by a large explosion.  
(28 fatalities, many injuries)  
Camelford, England 1988  
Concentrated aluminium sulphate discharged into a treated water reservoir resulted in major contamination of drinking water supplies.  
(over 20000 potentially exposed) |
| **2 Moderate incident** | Incident may result in  
- less than ten fatalities  
  OR  
- between 1 and 100 people with severe or life threatening symptoms  
  OR  
- between 10 and 1000 people with pronounced or prolonged symptoms  
  OR  
- over 100 people with mild, transient and spontaneously resolving symptoms  
  OR  
- potential exposure of more than 1000 people even if there are no adverse health effects (because of the potential resource implications required to effectively manage the situation and likely media interest) | Norfolk, England 1991  
Fire at a waste plastics factory gave rise to dense smoke plume.  
(46 casualties, many exposed)  
Aldicarb contamination of cucumbers served at school lunch.  
(50 students suffered acute gastroenteritis)  
Greater Manchester, England 1997  
Elemental mercury led to widespread contamination.  
(225 exposed, confirmed toxicity in 19) |
| **1 Minor incident** | Incident may result in  
- up to 10 people with pronounced or prolonged symptoms  
  OR  
- up to 100 people with mild, transient and spontaneously resolving symptoms  
  OR  
- potential exposure of between 10 and 1000 people with no adverse health effects reported (because of the potential resource implications required to effectively manage the situation and likely media interest) | London, England 1999  
CS gas release at comprehensive school.  
(42 students experienced adverse health effects)  
Derby, England 2000  
Leak of petrol in basement of residential property.  
(42 properties evacuated, no casualties, no adverse health affects) |
| **0 Insignificant incident** | Incident may result in  
- less than 10 people exposed to the chemical hazard  
- little or no impact on the health of the public | London, England 1999  
CS gas release at comprehensive school.  
(42 students experienced adverse health effects)  
Derby, England 2000  
Leak of petrol in basement of residential property.  
(42 properties evacuated, no casualties, no adverse health affects) |
Once an incident has been categorised, this information can be used in alerting all organisations that need to be aware of the event. One of the advantages of the scale is that it does not aim to replace any existing emergency procedures or major incident plans but to dovetail with existing tools. It provides a quick and easy way to communicate information about an incident that can then be used within each of the organisations to trigger the necessary internal response procedures. Developing such response procedures specifically for public health practitioners is explored in Chapter 4.

Obviously as time passes more information about the incident will become available – initially on the number and type of casualties and on local physical damage if, for example, an explosion has occurred. As symptoms and signs become apparent, information regarding the type of chemical involved may appear and later, analysis of air, soil, water and biological samples may confirm or refute initial opinions. In some cases the final answer may be long delayed. It is possible that the grading of an incident might be reduced as more data appears; conversely, upgrading may be required.

A short period of consultation with public health practitioners, the London Health Emergency Planning Advisors (HEPAs) and representatives from the Department of Health (DoH) provided positive feedback with regard to the applicability and use of the scale. However, it was noted that the different agencies that may be involved in responding to and managing chemical incidents, for example the emergency services and accident and emergency departments, will have their own criteria for declaring a ‘major incident’. A major incident can have a significant impact on one part of the health service, while leaving others relatively unaffected. In a similar way, an NHS major incident is not necessarily a major incident for other emergency services, such as police, fire or local authority services – and vice versa (Planning for Major Incidents, The NHS Guidance, 2000). Therefore, this category was re-named as ‘serious incident’ to minimise confusion and overlap with existing plans.
3.2 Integrating a Scale for the Environment

In Chapter 1 the benefits of assessing simultaneously the health and environmental impacts of a chemical incident were discussed. Since the proposed chemical incident impact scale (CIIS) has only considered the potential health impact, in this next section the idea of producing a parallel scale that could be used to categorise the environmental impact is explored.

There are a number of measurable endpoints of environmental contamination that could be used to categorise the environmental impact of an incident, including the number of fish killed in a polluted stream or closure of a drinking water abstraction point due to elevated contaminant levels. Pollution incidents are assessed by the Environment Agency both in terms of their impact on the environment and on Agency resources. They are then graded on a four-point scale, which ranges from 'serious long lasting or extensive damage to the environment or people' to 'no impact occurred'. These categories are not dissimilar to those used in the CIIS to grade the impact on human health so rather than developing a new categorisation system, the possibility of linking the Environment Agency’s pollution scale with the CIIS was considered.

The Environment Agency scheme has been merged directly with the CIIS, with the addition of an extra category to correspond to grade four or 'catastrophic'. This is to reflect a devastating environmental impact with widespread damage and irreversible harm (see Table 3.7). More detailed information about the Environment Agency’s categories is presented in Table 3.8.

To test the usefulness of the integrated scale, all incidents reported to CIRS over a one-month period (June 2002), were categorised retrospectively.
Table 3.7: Integrated human health and environmental impact scale for chemical incidents

<table>
<thead>
<tr>
<th>Category/Grade</th>
<th>Human health impact</th>
<th>Environmental impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4</strong> Catastrophic incident</td>
<td>Incident may result in:</td>
<td><strong>Devastating</strong></td>
</tr>
<tr>
<td></td>
<td>• devastating impact on human health</td>
<td>• widespread damage</td>
</tr>
<tr>
<td></td>
<td>• more than 1000 fatalities</td>
<td>• irreversible harm</td>
</tr>
<tr>
<td></td>
<td>• more than 10000 people with severe or life threatening symptoms</td>
<td></td>
</tr>
<tr>
<td><strong>3</strong> Serious incident</td>
<td>Incident may result in:</td>
<td><strong>Major</strong></td>
</tr>
<tr>
<td></td>
<td>• between 10 and 1000 fatalities OR</td>
<td>• persistent and extensive effects on quality</td>
</tr>
<tr>
<td></td>
<td>• over 100 people with severe or life threatening symptoms OR</td>
<td>• major damage to the ecosystem</td>
</tr>
<tr>
<td></td>
<td>• over 1000 people with pronounced or prolonged symptoms OR</td>
<td>• closure of a potable abstraction</td>
</tr>
<tr>
<td></td>
<td>• potential exposure of more 10000 people with mild, transient and spontaneously resolving symptoms or even if there are no adverse health effects (because of the potential resource implications required to effectively manage the situation and likely media interest)</td>
<td>• major impact on property</td>
</tr>
<tr>
<td><strong>2</strong> Moderate incident</td>
<td>Incident may result in:</td>
<td><strong>Significant</strong></td>
</tr>
<tr>
<td></td>
<td>• less than ten fatalities OR</td>
<td>• significant effect on quality</td>
</tr>
<tr>
<td></td>
<td>• between 1 and 100 people with severe or life threatening symptoms OR</td>
<td>• significant damage to the ecosystem</td>
</tr>
<tr>
<td></td>
<td>• between 10 and 1000 people with pronounced or prolonged symptoms OR</td>
<td>• non-routine notification of abstractors</td>
</tr>
<tr>
<td></td>
<td>• over 100 people with mild, transient and spontaneously resolving symptoms OR</td>
<td>• significant impact on property</td>
</tr>
<tr>
<td></td>
<td>• potential exposure of more than 1000 people even if there are no adverse health effects (because of the potential resource implications required to effectively manage the situation and likely media interest)</td>
<td>• reduction in amenity value</td>
</tr>
<tr>
<td><strong>1</strong> Minor incident</td>
<td>Incident may result in:</td>
<td><strong>Minor</strong></td>
</tr>
<tr>
<td></td>
<td>• up to 10 people with pronounced or prolonged symptoms OR</td>
<td>• significant damage to local ecosystems</td>
</tr>
<tr>
<td></td>
<td>• up to 100 people with mild, transient and spontaneously resolving symptoms OR</td>
<td>• marginal effect on amenity value</td>
</tr>
<tr>
<td></td>
<td>• potential exposure of between 10 and 1000 people with no adverse health effects reported (because of the potential resource implications required to effectively manage the situation and likely media interest)</td>
<td>• minimal impact to agriculture and/or commerce</td>
</tr>
<tr>
<td><strong>0</strong> Insignificant incident</td>
<td>Incident may result in:</td>
<td><strong>Unsubstantiated report</strong></td>
</tr>
<tr>
<td></td>
<td>• less than 10 people exposed to the chemical hazard</td>
<td>• no evidence can be found of a pollution incident having occurred</td>
</tr>
<tr>
<td></td>
<td>• little or no impact on the health of the public</td>
<td></td>
</tr>
</tbody>
</table>
**Table 3.8: Environment Agency Pollution Incident Categories**

<table>
<thead>
<tr>
<th>Category 1 (Major) Incident</th>
<th>Category 2 (Significant) Incident</th>
</tr>
</thead>
<tbody>
<tr>
<td>involves one or more of the following</td>
<td>involves one or more of the following</td>
</tr>
<tr>
<td>a) Persistent effect on water quality – potential or actual persistent effects on water quality or aquatic life due to a discharge or spillage to controlled waters of any substance which is likely to have a persistent impact on the use or quality of that water.</td>
<td>a) Notification of abstractors – potential or actual impact on water quality that necessitates notifying either surface water abstractors downstream of the incident location or groundwater abstractors in the vicinity of the discharge point</td>
</tr>
<tr>
<td>b) Closure of abstraction – closure of a potable water, industrial or agricultural abstraction necessary due to a pollutant either having reached or approaching that intake or abstraction borehole.</td>
<td>b) A significant fish mortality – a fish mortality of between 10 and 100 fish of any notable species. The lower limit of ten fish can be reduced if the fish affected are of a species of particular importance to the waters affected.</td>
</tr>
<tr>
<td>c) Extensive fish mortality – fish mortality in excess of 100 fish of any notable species.</td>
<td>c) Effect on invertebrate life – a readily observable effect on invertebrate life</td>
</tr>
<tr>
<td>d) Excessive breaches of Consent Conditions – a major or repeated failure of an effluent treatment plant, which results in an excessive contravention of consent conditions together with a readily observable impact on the receiving water.</td>
<td>d) Water unfit for stock watering – the water quality has been judged unfit for stock watering (and the Agency has advised those farmers accordingly)</td>
</tr>
<tr>
<td>e) Instigation of remedial measures – the instigation of extensive remedial measures by the Agency or other organisations either to forestall pollution or to alleviate the effect of a pollution incident, e.g. deployment</td>
<td>e) Bed of watercourse contaminated – the bed of the watercourse is heavily contaminated by fungal/bacteriological growths, sewage debris or particulate matter</td>
</tr>
<tr>
<td>f) Effect on amenity value – significant adverse effect on an important recreational activity or event in controlled waters.</td>
<td>f) Reduction in amenity value – aesthetic quality significantly affected in terms of appearance or odour so as to affect amenity value of downstream users, e.g. anglers or canoeists</td>
</tr>
<tr>
<td>g) Effect on conservation – significant adverse effect on a designate Site of Special Scientific Interest or other site of particular conservation importance.</td>
<td></td>
</tr>
</tbody>
</table>

**Category 3 (Minor) Incident** involves one or more of the following

- Notification of abstractors not necessary
- A fish mortality of less than 10 fish of any species not of particular importance to the waters affected
- No readily observable effect on invertebrate life
- Water has not been rendered unfit for stock watering
- Bed of watercourse only locally contaminated around point of discharge
- Minimal environmental impact and amenity only marginally affected

**Category 4 (Unsubstantiated) Incident**

A reported pollution incident, which upon investigation proves to be unsubstantiated, i.e. no evidence can be found of a pollution incident having occurred.

It is important to maintain an accurate record of such reports as cumulatively they represent a significant demand on resources (staff time, travel, etc.)
3.2.1 Results

A total of 51 incidents were reported to CIRS in June 2002, which is lower than average. There was sufficient information to categorise 35 of these (69%) using the proposed scale in terms of the impact on health, but only 3 in terms of the impact on the environment. The fact that information on the number of people exposed and the severity of the impact on human health was not available for all incidents was unexpected, since there is a section on the CIRS incident report form which requests information on the number of people exposed and affected. This was incomplete in many cases. However, the limited amount of environmental information was unsurprising. Current response procedures endeavour to manage only human and not environmental impacts of an incident and there is not currently a section of the CIRS incident report form dedicated to collecting specific environmental information.

The severity of the incidents reported in June 2002 in terms of potential human health impact is summarised in Table 3.10. There were no serious or catastrophic incidents reported in this one-month period and the majority of incidents (51%) were categorised as 'minor'. These included a leaking chlorine gas cylinder dumped on waste ground and a family exposed to carbon monoxide. In both of these cases less than ten people were exposed but all experienced pronounced or prolonged symptoms. In a further example, about thirty children were potentially exposed to mercury, which they had found in a toolbox when playing. Biological samples were collected even though no adverse health effects were reported.

All nine incidents categorised as ‘insignificant’ involved exposure of less than ten people with no reported adverse health impacts. These included a lorry carrying phosphoric acid found to be leaking in a college car park and consumption of tea containing kettle de-scaler.

The incidents categorised as ‘moderate’ using the CIIS included six fires in which several hundred people were exposed, for example a fire in a large plastics packaging warehouse, which resulted in a plume containing hydrogen chloride and white asbestos deposited in the gardens of local residents. Herbicide found in a reservoir
used to supply drinking water to over one thousand people was also categorised as a ‘moderate’ incident.

Table 3.9: Incidents reported to CIRS in June 2002 categorised using CHS

<table>
<thead>
<tr>
<th>Incident category</th>
<th>Number of incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

The aim of the CHS is to be able to categorise incidents quickly, to assess the potential health and environmental impact and to guide the subsequent public health response. Therefore there were a number of disadvantages to testing the scale retrospectively. Firstly, the incident category designated was based on complete information about each incident, which in some cases had been collected over a number of days or weeks of investigation. Secondly, the information required to categorise each incident was incomplete in a number of cases especially in terms of the environmental impact. If used to categorise incidents as they are reported it is anticipated that basic details could be requested. Finally it is recommended that the CIRS incident report form be updated to encourage and improve the collection of environmental information.

One advantage of testing the scale retrospectively was that it was possible to confirm the appropriateness of the category definitions and to demonstrate benefits of a clear categorisation system for use in incident surveillance.

3.3 Summary and Conclusions

The value of developing a rapid response tool to be able to measure the potential public health impact of a chemical incident was considered.
The aim was to be able to define and describe a 'major incident' (subsequently changed to 'serious incident') and to develop a scale for incident categorisation. Scales and systems for categorisation were acknowledged to have many potential uses, which could be broadly divided into three categories - tools for planning, tools for describing events and tools for response and communication. Following a review of a number of existing scales to identify useful features and to generate ideas, a scale for use in assessing the impact of a chemical incident was developed.

Five categories ranging from 'insignificant incident' to 'catastrophic incident' have been defined and illustrated with examples selected from past incidents. The scale is based on two parameters – the number of people potentially exposed and the severity of the health impact. As time passes more information will become available so it is possible that the grading of an incident might be reduced as more data appears; conversely, upgrading may be necessary. Subsequently the possibility of merging the Chemical Incident Impact Scale (CIIS) with the Environment Agency's pollution incident scale as a means of integrating human health and environmental impact assessment was considered. The integrated scale was tested retrospectively over a one-month period and results demonstrated its usefulness as a tool to categorise incidents in terms of the potential hazard to human health. However, the limited environmental information currently recorded, made it difficult to quantify its potential value as an integrated assessment tool.

Although the capabilities of the tool for inter-agency risk communication have not been tested, this highlights an opportunity for further research. There is also the possibility that the scale could be expanded and used to communicate the severity of all CBRN incidents, the importance of which has been delineated in Section 2.2.3, but this is also beyond the scope of this research project.

It is hoped that in due course the scale will be adopted nationally and internationally and therefore constitute a significant contribution to knowledge.
4. TOOLS FOR PLANNING AND RESPONSE

Chapter 3 highlighted that the proposed scale for categorising chemical incidents should dovetail with existing emergency procedures used by the organisations involved in incident response and management. However, when the public health role in managing incidents was presented in Section 2.4 it was noted that although the importance of their contribution as an integral part of the emergency response team is recognised, appropriate tools and information to support and facilitate an effective response are currently limited. The main exception to this is a manual for public health response to chemical incidents produced by Goodfellow (2001) as part of an Engineering Doctorate project based at CIRS. The main focus of the project was chemical incidents that result in water contamination and as a result, tools and guidance reflect this area of interest. It is anticipated that the work outlined in this chapter will be used in combination with the manual, much of which has been included in the forthcoming Stationery Office publication (Eagles et al, 2002).

The aim of this chapter is to design a methodology that can be used in developing tools for planning and response that meet with the needs of public health practitioners. The incident management process has been broken down into a number of key stages and the use of incident timelines to describe how incidents evolve is outlined. This idea is based on the observation that patterns in the way events present and progress can be identified and used to formulate a generic framework around which tools for planning and response to chemical incidents can be created.

The role of public health at each stage of the management process is then considered and the question ‘what do public health practitioners want/need?’ is posed. The desired output is a specification on which practical resource requirements can be based and against which the effectiveness of any output can be measured.

The remainder of the chapter is dedicated to the development of tools for incident response in the form of a risk assessment model, which is based on the source-pathway-receptor model described in Chapter 2.3, and a series of checklists to facilitate the public health decision-making process.
4.1 Incident Timelines

All chemical incidents are different in terms of complexity and the hazard they present to the health of the public and the environment. Nevertheless a number of common features can be identified including how and when incidents present, the agencies involved and how incidents evolve. In developing resources for public health response to chemical incidents, it is important therefore to recognise that the management process can be broken down into a number of stages or phases and that the public health role and level of involvement will not be the same throughout each phase.

In this section the concept of incident timelines to illustrate and describe how incidents evolve and are currently managed is presented. This is a further development of the ‘event evolution’ concept introduced in Chapter 2.3 and presented in Figure 2.5. Shortcomings of the ‘linear’ incident timeline are addressed leading to an alternative cyclical model that integrates a post-incident review and feedback mechanism into the management process.

By looking at past incidents reported to the Chemical Incident Response Service (CIRS) key stages of the incident management process have been identified. In addition the opportunity to manage a number of incidents throughout the four-year duration of the research project has resulted in a much clearer understanding of incident genesis and evolution.

One way to illustrate the key phases of the incident management process is using a timeline. Figure 4.1 highlights the three main phases along the incident timeline, which are similar to those proposed by Goodfellow (2001): Acute, Post-acute and Post Incident, the main difference being that there is no set time period associated with each phase. The stages represented on the ‘event evolution’ graph in Figure 2.5 – event start and event recognition - have also been indicated. The terms used in Figure 4.1 are defined in Table 4.1.
Figure 4.1: Chemical incident timeline

Emergency services*
Local Authority
Environment Agency
Water Company

Local Authority
Environment Agency
Water Company
Health Agency
Health and Safety Executive
Environmental Consultant

Local Authority
Environment Agency
Water Company
Environmental Consultant

All agencies

Event start

Notification
Recognition

Initial response

Investigation

Clean up

Post-incident review/debrief

Post incident

Event close

Time

* Emergency Services involved in responding to acute CIs only
Table 4.1: Definitions of terms used in Figure 4.1

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event start</td>
<td>The point in time that the event that resulted in the contamination problem occurred.</td>
</tr>
<tr>
<td>Recognition</td>
<td>The point in time that the contamination problem was first recognised. Figure 4.1 indicates that there could be a time delay between the ‘Event start’ and the problem being recognised – refer to Figure 2.5.</td>
</tr>
<tr>
<td>In acute chemical incidents, local residents will generally be the first to recognise a contamination problem if it has occurred in a public or residential area, whereas the owner or an employee will be first to recognise an industrial accident such as a leak or spill in a factory. In chronic chemical incidents, recognition will either be via complaints of adverse health effects from local residents or through routine testing/environmental monitoring.</td>
<td></td>
</tr>
<tr>
<td>Notification</td>
<td>Incident notification will generally come from local residents or directly from the company in the event of an industrial accident. It is the point in time that the regulatory agency or another organisation is notified of the contamination problem. Pre-existing communication networks should ensure that all appropriate agencies are subsequently advised that an incident has occurred. There may be an interval between recognition and notification of the event. An example is illustrated in the incident timeline presented in Appendix J, which is based on Case Study 5, Appendix A.</td>
</tr>
<tr>
<td>Initial response</td>
<td>The initial response is the immediate action taken to control and manage the contamination problem. In an acute incident the primary aim of the initial response is to contain the hazard and to minimise further exposure, either through evacuation or sheltering etc., of local residents and sensitive populations acknowledged to be potentially at risk. This type of response is generally only necessary when responding to an event where adverse health effects could result from acute exposure. The initial response might involve communication with the media, in an acute incident to disseminate information to the local community and in a chronic incident to prevent adverse media attention whilst a potential problem is being investigated.</td>
</tr>
<tr>
<td>Investigation</td>
<td>Once the ‘emergency’ has been dealt with the next stage is to investigate what has happened and collect evidence on which to base subsequent management decisions.</td>
</tr>
<tr>
<td>Clean up</td>
<td>Action taken to manage and mitigate the problem. Clean up could involve removal of the contaminant source or the exposure pathway. Although receptor removal (evacuation) may be necessary in the acute phase to minimise exposure it is not a long-term solution since residents will want to return to their homes as quickly as possible.</td>
</tr>
<tr>
<td>Event close</td>
<td>The point at which the incident has been declared over by all of the agencies involved in the response, generally follows the ‘Clean up’ stage and precedes the ‘Post incident review’.</td>
</tr>
<tr>
<td>Post-incident review</td>
<td>The opportunity for agencies involved to discuss what worked well and what could be done to improve future response.</td>
</tr>
</tbody>
</table>

The scale along the time axis on the incident timeline in Figure 4.1 has intentionally been left blank so that acute and chronic incidents can be characterised on the same scale since essentially the management phases are the same even if the urgency of response is different. Across the top of the timeline, the agencies most likely to be involved at each stage have been highlighted in blue boxes. The Emergency Services
will usually take a lead role at the initial response stage in acute incidents while in chronic incidents the local authority will generally be the lead agency. In both acute and chronic incidents however if there is drinking water contamination or pollution of controlled waters either the Water Company or Environment Agency will generally be the lead agency. The exception to this is contamination of a private water supply where the local authority (as the regulator) will take the lead.

Along the timeline, the acute phase has been subdivided into three stages: recognition, notification and initial response. These stages are preceded by the ‘Event start’. Essentially the shorter the time interval between the start of the event and the problem being recognised and notified, the more effective the initial response is likely to be. It will generally be easier to contain a chemical within a few hours of the event start than after a few months by which time the chemical could have migrated a considerable distance through the ground and caused widespread contamination. This reflects the model used by Thames Water to demonstrate the ‘Golden Hour’ concept, which was presented in Figure 2.5.

Public health practitioners are unlikely to be the first organisation notified in the event of an acute chemical incident. Indeed even though they have role to play in the acute phase of the management process by identifying the population at risk and advising on immediate action to protect the health of the public, such as the need to evacuate or shelter, public health may not be informed about the incident until the investigation stage. Therefore in general, the role of public health can be more clearly defined in the post-acute phase. The post-acute phase comprises two stages - incident investigation and clean up. The purpose of the incident investigation stage is twofold, firstly to establish what has happened and secondly to collect evidence on which to base decisions about the most appropriate action to manage and mitigate the problem. This process could take between a few hours if the incident is ‘insignificant’ or ‘minor’ (refer to Chapter 3 for definitions), or up to several years if for example investigating a disease cluster associated with an industrial process. Key responsibilities for public health practitioners are identifying the population that has actually or potentially been exposed and determining the most appropriate action to minimise the long-term health impact. Biological samples might also be requested.
Information from the incident investigation is used as evidence on which to base decisions about the action required to return the area to a condition that is deemed acceptable or, in the case of land contamination incidents, ensure that it is ‘suitable for use’ (explained in Chapter 2.3). Results of any environmental samples taken will be used to determine the level of clean up required. From a public health perspective, practitioners need to be satisfied that appropriate action has been taken to minimise exposure, either by eliminating the source of contamination or removing the exposure pathway, such as advising not to drink contaminated drinking water or to eat vegetables grown in contaminated soil. In some cases, no clean up will be required although it may be necessary to initiate an environmental monitoring programme.

Public health practitioners will also use information from the incident investigation stage to determine if long-term follow up of exposed individuals is necessary.

The third phase of the incident management process illustrated on the timeline in Figure 4.1 is labelled as post-incident. For all ‘serious’ and perhaps a few ‘moderate’ incidents (refer to Chapter 3 for definitions), once the incident has been declared over by all agencies involved in the response, referred to as ‘event close’, a post incident review or debrief will be carried out. This provides the opportunity for the agencies involved to discuss what worked well and what could be done to improve future response. These suggestions may or may not be incorporated in local plans and furthermore, recommendations are unlikely to be disseminated beyond the local area. An incident debrief is unlikely to take place following an ‘insignificant’ or ‘minor’ incident, since the management of such an event will probably be less complicated with fewer agencies involved in the response. Obviously there will be exceptions to this if there are particular concerns that need to be examined.

4.1.1 Closing the Loop

The importance of analysing possible disaster scenarios in depth as a means of gaining a better understanding of the potential impact of an event is recognised by Jenkins (1999). Furthermore Heathcote (1996) advocates the dissemination of
important recommendations from incident inquiries to prevent recurrence of the same event. It is as important to learn what worked well to establish ‘best practice’ as well as what went wrong. It is suggested that there is a need for a clear mechanism whereby mistakes can be brought to the attention of others (Heathcote, 1996) to ensure that lessons learned from past incidents are not lost when the incident report is consigned to the filing cabinet.

Lessons learned by looking at the response to previous emergencies and reviewing how past incidents have been managed can be used to gauge our scientific understanding of a particular set of circumstances as well as to assess the effectiveness of incident management procedures currently in place and to identify ‘best practice’. Additional benefits of learning from actions taken in responding to past incidents include better understanding of incident genesis to improve early problem recognition, development of plans based on real events and not theoretical situations, a clearer definition of the public health function in the management of chemical incidents and also prevention of incidents occurring through enhanced awareness of potential hazards.

Yet in spite of the obvious benefits of looking at the response to previous emergencies, there is currently no formal procedure for writing up and reporting incidents and identifying lessons learned. Very few incident reports are published in journals, the main exception being those reported in in-house publications produced by the Regional Service Provider Units (RSPUs). For example, CIRS produces a quarterly newsletter, ‘The Chemical Incident Report’, which includes incident summaries as well as information to support the public health response to chemical incidents such as environmental legislation and tools for response (including the checklists discussed later in this chapter).

Consequently one of the flaws in the timeline concept presented in Figure 4.1 is that it is very linear and there is no provision to identify ‘best practice’ and suggest improvements to incorporate in future response procedures. One suggestion to promote a more proactive approach to chemical incident response and management is to ‘close the loop’ by introducing a feedback mechanism into the process so that
best practice is identified and used to shape plans for managing events in the future. The proposed framework is illustrated in Figure 4.2.

Figure 4.2: Chemical incident management – closing the loop

4.2 What do Public Health Practitioners Want/Need?

An important step in the process of developing tools and resources to facilitate the public health response to chemical incidents was consultation with public health practitioners since professional acceptance and ‘ownership’ is key to the successful implementation of tools to assist in performing a job function. Two main sources of information were used. The first was the results of a questionnaire undertaken by ALPHA (Access to Learning for the Public Health Agenda) in July 2002, to assess the learning needs of Consultants in Communicable Disease Control (CsCDC). Additionally feedback from CIRS training days and obtained through working with
public health practitioners over the four years of the project has generated a better understanding of public health requirements.

4.2.1 Conclusions From Questionnaire

Although a full survey was not undertaken as part of this research project, the results from a questionnaire sent to all 133 Consultants in Communicable Disease Control (CsCDC) in England, Wales and Northern Ireland in July 2002 provides useful evidence highlighting the key learning needs of those public health practitioners.

The aim of the questionnaire was to assess the learning needs of CsCDC in respect of the possible deliberate release of specifically biological agents. However, responses drew attention to gaps in knowledge about chemical, radiological and nuclear releases and 88% of respondents felt that training should address chemical, radiological and nuclear threats. Therefore it is likely that the responses are also indicative of the learning needs for responding to chemical incidents.

Overall, protecting the environment was identified as the top priority of those wanting more skills/knowledge. This demonstrates that public health practitioners are very aware of the negative consequences that environmental contamination can have on human health. It also supports the view that procedures for responding to chemical incidents should be integrated and that health and environmental impacts should be assessed and managed concurrently.

Of most interest was the response to the question that asked ‘how would you prefer to learn about the skills and knowledge identified as gaps?’ which revealed that there was a clear preference for practical scenarios and that discussions/lectures were least favoured. Taking past incidents and using these to create interactive exercises that can then be used as tools for training is a concept that has been adopted by the staff at CIRS. Feedback from CIRS training days where the exercises have been used confirms that using real examples to illustrate ‘best practice’ is beneficial and provides the opportunity to ask questions, develop ideas and learn from mistakes.
When the CsCDC were asked 'which of the following resources would be useful to support your learning?' a small majority (83%) favoured an information web site, 78% wanted nationally agreed guidance and 73% wanted a manual in electronic format. The advantage of having a single national source of electronic guidance is that it could be updated regularly was identified. The downside however is that information presented in this form might not be easily accessible in the field.

4.2.2 Summary of Public Health Requirements

Discussion with public health practitioners also identified a number of requirements:

- practical guidance is needed to facilitate public health response and decision-making which should provide an indication of how to do things and not simply a list of what should be done
- a tool is needed to facilitate rapid decision making at an early stage following notification of a chemical incident, even if limited information is available.

The purpose of the tool should be to:

- identify what action should be taken to minimise harm
- recognise significant gaps in the information available, either in terms of quality or quantity
- allow for refinement once more information becomes available

The need for tools and guidance to reflect the differences between acute and chronic chemical incidents was also raised and was perceived to be important in terms of resource availability as well as training. Guidance for responding to and managing acute chemical incidents was considered to be a priority; in contrast for land contamination incidents, chronic problems were considered to present the greatest knowledge gap from a public health perspective. As a result the remainder of this chapter will look at chemical incident procedures in general and land contamination incidents will be addressed separately in Chapter 5.

In the next section a methodology for developing a decision support tool to facilitate the public health response to a chemical incident is presented. Based on the
requirements identified earlier in this chapter, the tool aims to include the components summarised in Box 4.1.

Box 4.1: Summary of requirements to support the public health risk assessment process for chemical incidents

- A risk assessment model which considers both the health and environmental impacts
- A list of actions to be considered at each phase of the incident management process
- Information structured and sequenced so it is easy to find and use
- Integration with the incident categorisation scale
- Training resources which comprise incident scenarios and practical exercises

4.3 Developing Resources for Incident Response

Essentially the key decision that public health practitioners need to make when responding to any chemical incident is whether there is a significant risk of harm to human and environmental health (although the latter has received little attention from public health practitioners until recently). This approach, introduced in Section 2.3, most typically reflects the requirements of Part IIA of the Environmental Protection Act for the management of contaminated land (Section 2.3), although additionally it provides a good starting point from which to develop a useable risk assessment tool for all chemical incidents. Therefore the aim of this risk assessment model is to assist in determining the actual or potential impact of a chemical incident on the health of the public. There are essentially two possible incident management responses:

1. There is a significant or potentially significant health impact; therefore an appropriate action to contain and cleanup the chemical to minimise harm is required OR
2. There is no significant impact therefore no further action is required.
It may be necessary to include a third ‘maybe’ option if limited or unsuitable evidence on which to base a decision is available. In this situation the precautionary principle should be adopted until sufficient information to carry out a complete risk assessment has been obtained.

The proposed methodology for developing the tool is outlined in the form of a flow diagram (Figure 4.3) and is based on the source-pathway-receptor linkage.

Figure 4.3: Methodology for developing public health risk assessment tool

One of the key steps in developing a risk assessment tool is to establish the minimum data set necessary to inform the decisions regarding what action should be taken, by whom and at what time. By identifying key criteria or parameters and the interactions between them, patterns in the nature and urgency of the response required to manage the problem effectively can be recognised. The essential information to apply this approach to a chemical incident risk assessment is summarised in Figure 4.4 and discussed in more detail below. Implementation of the methodology outlined should result in an effective risk management strategy including the identification of sensitive human and environmental receptors and, if necessary, the development of procedure for further action such as a strategy for environmental sampling and long-term monitoring.
Figure 4.4: Criteria for Risk Assessment

**Characterise site**
- site history
- land use
- CIMA/COMAH
- geology
- subsurface features
- meteorology
- topography

**Identify contaminant**
- name of chemical
- source (drum, tank etc.)
- amount/volume
- chemical state
  - solid/liquid/vapour
- chemistry
  - boiling point/density
- location
- bioavailability

**Identify affected environmental media**
- air
- soil
- sediment
- surface water
- ground water
- drinking water

**Identify receptors**
- human
- food
- environmental
  - plants
  - ecological systems
  - water

**Identify exposure pathways**
- dermal contact incl eye
- inhalation of vapour/dust
- ingestion of soil
- ingestion of foodstuffs grown in contaminated soil
- ingestion of drinking water
- ingestion of meat, fish or dairy products (indirect exposure)
- plant uptake
- leaching

**Information collected should enable:**
- **identification** of sensitive human and environmental receptors
- **development** of procedure for further action (if necessary)
  - strategy for environmental sampling
  - decision on most appropriate clean up
  - follow-up/long-term monitoring
- **implementation** of an effective risk management strategy

**Any AHE reported?**
- acute
- delayed
- chronic
- teratogenic

**What are the effects of exposure?**

**Are there any guideline values?**

**What is the release mechanism(s)?**
- leak/spill
- leaching
- fire
- volatilisation
- dust
- runoff
- plant uptake
- transport

Key:
AHE = adverse health effects
The main elements of the methodology are discussed below.

**Characterise site.**
An initial assessment will involve the collection and assessment of existing information about the site and the surrounding area, for example maps, plans, photographs, geological and hydrogeological records and local records. For an acute incident, such as a fire or leak, the meteorological conditions can be useful in determining the population at risk.

**Identify contaminant.**
The actual chemical or chemicals involved in an incident may not be known immediately although the state of the chemical is usually known (i.e. whether solid, liquid or gaseous) and an estimate of the volume of chemical that has been released may be available. The latter is particularly important as for some chemicals only minimal quantities are required to cause an adverse health or environmental effect. If more than one chemical is involved a reaction may occur and generate by-products, which may be more or less harmful than the individual chemicals.

Goodfellow (2001) proposed a method whereby various properties or characteristics and sources of information can be used in identifying an unknown chemical. This was modified in August 2002 as part of the London-based CBRN project, described in Section 2.2 and in Appendix D, so that it could be used in identifying an unknown chemical, biological, radiological or nuclear agent. It is presented in Figure 4.5.

**Release mechanisms.**
How the chemical(s) was released will influence the options available for containment and management of the hazard. Mechanisms by which chemicals are released into the environment can be natural or anthropogenic and include fires, leaks, leaching, runoff and dust.
Identify affected environmental media.

Chemical incidents may result in direct or indirect contamination of one or more environmental medium. Water is subdivided into three categories: drinking water, groundwater and surface water and this is reflected in the differing exposure pathways associated with each (see ‘exposure pathways’ below). If environmental sampling has been undertaken and results are available, these should be compared to the most appropriate guidelines or standards available.

Care should be taken when using environmental standards. Before any standard or guideline is applied, it is vital that the original basis for its derivation is understood.
Standards may not necessarily be health based, and are often determined for a number of alternative reasons, for example:

- broader environmental reasons and the protection of ecosystems e.g. prevention of crop damage, or acidification;
- aesthetic considerations e.g. limiting iron in water to prevent staining of laundry and sanitary ware;
- operational reasons e.g. use of aluminium in the treatment of drinking water; or technical reasons e.g. using the lowest possible limit of detection for current analytical methods (Eagles et al, 2002).

**Identify receptors.**
This includes all potential 'endpoints' for the contamination for example humans, animals, buildings, plants, ecosystems and water. For the purposes of this research project, only human and environmental receptors will be considered. Impacts on human and environmental receptors can be measured using the chemical incident impact scale (CIIS) presented in Chapter 3, in particular Tables 3.7 and 3.8.

**Identify exposure pathways.**
This should be regarded as the most important stage in the risk assessment process, as accurately establishing the existence of pathways can confirm or disprove the likelihood of exposure and subsequently the adverse impact on human and environmental health. The effects of exposure can then be considered and compared to any reports of adverse health effects in the local population. It may be necessary to confirm the existence of possible exposure pathways by undertaking environmental sampling. Exposure pathways may be direct, for example inhalation of smoke from a fire or ingestion of contaminated drinking water, or indirect such as the ingestion of vegetables grown in contaminated soil.

Once all of the information has been collected it should be possible to identify sources of contamination, human and environmental receptors and any actual or potential exposure pathways. If an exposure-effect relationship is established or considered to be likely, it may be necessary to develop a procedure for further action.
This might involve further environmental and/or biological sampling. The results of this will influence the decision on the most appropriate clean up to minimise exposure and finally determine what follow-up or long-term monitoring is required.

To aid in the collection of the information summarised above, a series of interactive checklists is proposed.

### 4.4 Checklists

Checklists are regarded as a form of 'job aid', tools to support work and activity and direct, guide and enlighten performance (Kanse, 1997; Embrey & Richardson, 1998). They are particularly useful when performance is infrequent, the situation is complex, the consequences of error are high and there are not sufficient resources to support training (Kanse, 1997). All of these are valid when describing the role and experience of public health practitioners in chemical incident management.

Prior to deciding which questions to include in the checklist to yield the required information, a review of the checklists currently available and used by CIRS for managing incidents was undertaken. These include a checklist for water incidents presented as part of a research project completed at CIRS last year (Goodfellow, 2001) and a generic checklist for all acute incidents as well as a number of event-specific checklists, for example for flooding and non-domestic fires. The majority of these have been published in the Chemical Incident Report. A guide to resources available from CIRS for chemical incident response, including all of the checklists was presented in the April 2002 issue (Harrison, 2002).

Besides detailed analysis of the checklist content, the review of checklists involved discussion with public health practitioners, some of whom were familiar with the checklists and had used them in chemical incident response and others who had less experience. This review included consultation with individual practitioners as well as more structured group discussions. In general the checklists were considered to provide a useful aide memoir for managing a chemical incident although a number of issues were raised, including:
• duplication of questions between checklists;
• event specific questions on the acute incident checklist may not always be relevant;
• inconsistency in layout;
• too many checklists are confusing and represent a barrier to some users;
• density of information makes it difficult to work through quickly;
• need provision to record completed items during an incident;
• limited training in the use and applicability of the checklists.

It seemed sensible therefore to address these issues when developing a new checklist to support the proposed risk assessment methodology. The checklist should be easy to use and the information presented logically. In addition, suggested actions should reflect the perceived seriousness of the incident, which could be determined using the Chemical Incident Impact Scale (CIIS). It might be inappropriate however to carry out a full-scale risk assessment for a ‘minor’ incident in terms of time and resource limitations yet it would perhaps be necessary for a moderate ‘incident’. Nevertheless, always using the same basic process should improve familiarity and understanding of the proposed risk assessment methodology and subsequently afford a more effective response.

4.4.1 Basic Acute Incident Checklist

Initially the common features or actions to be considered at the initial response phase for all incidents, regardless of the cause or type of event, were identified and are listed in Box 4.2. Further similarities between the individual event checklists were then identified and combined with the criteria listed in Box 4.1 to create a basic checklist for all acute chemical incidents (Appendix K).

The structure of the checklist is intended to reflect the risk assessment process thereby providing a clear and consistent approach to incident management. A further inclusion in the basic acute checklist is an assessment of the seriousness of the incident based on the CIIS, with grade/category specific actions where appropriate.
Box 4.2: Initial response questions for all incidents

- Identify contaminant(s)
- Ensure chemical contained & fire/explosion hazard mitigated
- Identify major pathways between contaminants & receptors
- Undertake assessment of impact on health of the public
- Restrict access to contaminated area
- Ensure all appropriate organisations are aware of incident

4.4.2 Event-specific Checklists

In addition to the basic checklist, a number of supplementary event-specific checklists with a uniform layout have been created and are presented in Appendix K. More detail about the land incident specific checklists is presented in Chapter 5.

Although it is generally straightforward and apparent to decide which of the supplementary checklists to use when responding to a particular incident a user guide, comprising a series of questions to ascertain the nature of the problem, has been developed to assist in identifying the most appropriate event specific checklist(s). This is presented in Appendix K. Public health practitioners based at CIRS have tested the decision tree and feedback suggests that although it is very ‘busy’, the process is logical and can be used to quickly identify which checklist to refer to.

One of the main features of the event-specific checklists is the separation of general management activities from the more specific actions to protect the health of the public. There were a number of reasons for doing this. Firstly, it is necessary to ensure that public health decisions are based on complete information. As highlighted previously in this chapter, public health will not be directly involved in certain activities yet may need information from other agencies to carry out a detailed risk assessment. The checklists therefore provide a prompt to aid the collection of this additional information. Finally the checklists can be used to record progress and information about a particular event thus providing a suitable tool for incident reporting and feedback.
The checklists presented are not intended to provide a comprehensive set of resources but suggest a template on which further checklists, or other tools, can be based. The use of a standard layout, including font, use of bullets and numbering etc, increases familiarity and hence will mean that the tools are easier to use particularly if opportunities for training are limited.

Development of the checklists has been a dynamic and iterative process over the four-year period of the research project. There has been no formal assessment period or rigid framework against which to test the effectiveness of the tools although evaluation of the content and layout has been undertaken at regular intervals, through use in training exercises (see below) based on incident scenarios in addition to ‘real’ events. Checklists have subsequently been updated as necessary to reflect current ‘best practice’ as well as a result of feedback from the public health practitioners actually using them.

4.5 Training Resources

Training is essential in ensuring that public health practitioners and other key agencies involved in incident response are familiar with response procedures and are not accessing plans and resources for the first time during an actual incident. To substantiate this, research undertaken by Goodfellow et al (2001) demonstrated the benefit of previous training in chemical incident management in improving response performance. As a result it is suggested that training should be an integral part of the incident management process.

Earlier in this chapter it was highlighted that public health practitioners expressed a clear preference for practical scenarios and exercises to test current knowledge and to learn new skills. There are four basic types of exercise (Home Office, 1998) listed in Table 4.2 the most commonly applied of which are seminar and tabletop exercises. Therefore to assist with training in the use of the checklists, a mixture of seminar and tabletop exercises resources have been developed and used at CIRS training days, which are run at approximately monthly intervals throughout the year.
<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Details</th>
</tr>
</thead>
</table>
| Seminar exercises | • workshops or discussion based exercises  
                    • low cost activities that inform participants about the organisation and procedures that would be invoked to respond to an incident  
                    • emphasis on problem identification and solution rather than decision making |
| Tabletop exercises | • cost effective and efficient way to test plans, procedures and people |
| Control post exercises | • team leaders and communication teams positioned at control rooms they would use during an incident  
                        • aim is to test communication arrangements and information flows |
| Live exercises | • scale is very variable  
                     • provide best means of confirming the satisfactory operation of emergency communications |

Examples of the training resources produced as part of this research project are presented in Appendix L. These comprise one long exercise based on an acute chemical incident involving fuel and several short ‘buzby box’ exercises based on past events and fictional problems. All exercises have been run at CIRS training days in part to test the practical application of the checklists but also to test plans and procedures and for teaching purposes to illustrate ‘best practice’.

CIRS training days range in topic from ‘How to Respond’ days, which provide junior public health staff on the on-call rota with a basic understanding of chemical incident response, to more specialist events including ‘Environmental Management’, ‘Transport Incidents’ and ‘Environmental Epidemiology’. In addition, an annual ‘Land Contamination Incidents’ training day has been designed and co-ordinated by the Research Engineer. This event has been held annually since 1999 and aims to provide delegates with the tools and information required to facilitate a prepared and timely response to land contamination incidents. The training days have consisted of a series of presentations provided by CIRS staff and external speakers, interactive discussions and group exercises, which encouraged the use of the checklists and requested feedback on their usefulness as tools to support the public health response to land contamination incidents. Reaction to the checklists from delegates, which have included CsCDC, Specialist Registrars in Public Health, Infection Control Nurses, Local Authority Environmental Health Practitioners, has been extremely positive and the subsequent inclusion in a number of public health on-call packs
endorses their value as tools to support and facilitate the public health response to chemical incidents.

4.6 Conclusions

The aim of this chapter was to propose a methodology to support the public health decision-making process in chemical incident response and management. This has resulted in the development of a methodology for public health risk assessment, which considers both the health and environmental impacts of the incident and a list of actions to be considered at each phase of the incident management process, which are presented in the form of a basic checklist for acute chemical incidents and supplementary event-specific checklists. The layout of the checklists has been designed to ensure that information is easy to find and use. Colleagues working in public health and emergency planning have reviewed the checklists presented in this chapter and in addition they have been tested at CIRS training days. Feedback has confirmed the effectiveness of the checklists as tools to support public health practitioners in responding to chemical incidents and to facilitate the decision-making process to determine whether an incident presents a significant risk to human and environmental health.

The basic checklist includes an assessment of the seriousness of the incident in terms of the potential impact on human and environmental health based on the CIIS presented in Chapter 3. Where appropriate, suggested actions to protect the health of the public reflect the incident grade/category, which could be beneficial in terms of resource allocation for example. The supplementary checklists contain event-specific information to guide actions to protect the health of the public and to aid the collection of data needed to undertake a more detailed risk assessment.

The checklists have an additional use as a reporting tool to improve feedback of lessons learned and to shape future response plans. They are intended to be dynamic tools that should be modified and updated to reflect current best practice and the preferences of the public health practitioners who use them.
Now that the basic incident management framework and chemical incident risk assessment methodology have been developed, the approach is available for other agencies involved in incident response, including local authority environmental health practitioners and the emergency services to use and refine further to suit their respective needs. The advantages of all agencies using the same basic framework include improved communication, minimised use of agency-specific jargon, better understanding of roles and responsibilities and ultimately a more coherent and effective response.
5. TOOLS FOR LAND CONTAMINATION INCIDENTS

Land contamination incidents present an interesting challenge for public health practitioners compared to a fire or an explosion since the potential impact on the health of the public may not be immediately apparent. Indeed it may take some time to recognise that land is contaminated and that there is an exposure pathway between the source of contamination and human receptors. As with all chemical incidents, every land contamination problem is different and each one should be dealt with on a case-by-case basis. Nevertheless there are number of steps and management activities that tend to be common to all incidents and one of the major aims of this research project has been to consider whether incident management and response could be improved by a standardised approach.

The first part of this chapter summarises the results of a review of all land contamination incidents reported to the Chemical Incident Response Service (CIRS) between February 1996 and October 2001. Subsequently a categorisation system based on observed patterns in how land incidents present and evolve is proposed and tools for response developed.

5.1 Review of Land Chemical Incidents

Important issues that need to be considered when managing land contamination incidents can only really be identified though experience and by looking at past incidents. Hence a review of all land incidents reported to CIRS over a five-year period was undertaken. In particular the review aimed to find out whether:

- patterns exist in the way incidents present, evolve and can subsequently be managed
- the majority of land contamination incidents can be grouped into a limited number of categories
- patterns identified can be used to develop general guidance for the management of land contamination incidents in each category.
A search on the CIRS database indicated that there were 279 land contamination incidents reported to CIRS between February 1996 and September 2001. A number of these were operating landfill sites where there had been complaints about odour, which, for the purpose of this investigation, was considered to have little to do with soil. Therefore it was decided not to include ‘waste’ incidents for the following reasons. Landfilling involves intentional contamination of land and this project has been concerned with acute or chronic land contamination incidents (such as historic sites where the consequences of spilling chemicals onto the land were not fully understood at the time and accidental releases). From a legislative viewpoint ‘new’ landfills are managed very differently to land contamination.

It was realised prior to data collection that the amount of information collected and available for each incident would differ because the level of CIRS and public health involvement varied (refer to Chapter 2.3). However since there are typically around 1000 incidents of all types reported to CIRS each year it was considered that there should be sufficient information available to collect a reasonable sample size to enable useful statistical analysis. Also the CIRS chemical incident database represents the largest dataset that has been collated by any single organisation in the UK, other than the National Focus (described in Chapter 1). The usefulness of the surveillance data collated by the National Focus is quite limited however because the Regional Service Provider Units (RSPUs) report incidents differently. So whilst there are inconsistencies in the CIRS database due to the fact that people have reported incidents disparately, these differences would be more pronounced should one attempt to collate chemical incident data from all RSPUs.

To aid collection of information, a structured evaluation form to enable the analysis and classification of incidents was designed and used; a copy is included in Appendix G. The evaluation form contains 28 questions, of which 26 are closed questions, and aims to collect quite general information, including how the was problem identified (presentation), the incident type (acute/chronic) and known contaminants. A pilot study on ten past incidents was also carried out to refine the evaluation form before use.
The data was coded and entered in SPSS, a powerful computer software package for statistical analysis. It was necessary to have a ‘no response’ option as some of the incident information was missing from the files or had not been recorded. Of the 279 land contamination incidents recorded, 217 were identified as being actual land incidents. The remaining 62 incidents were either operating landfill sites or had been wrongly categorised. Of these 217 incidents, 16 were duplicate incidents and 16 were missing from the files thereby making the total number of incidents analysed 185. Suggested reasons for why incidents may be missing from the files includes misfiling (there are over 10,000 incident reports filed chronologically hence there is a high probability that one or more file might have been removed and replaced to the wrong location) or that the incident had been removed as part of a detailed study and not replaced at all.

For the remainder of incidents (185), the ‘completeness of information’ on which the investigation is based was assessed. Incident reports were categorised as:

**Good**
- detailed or very detailed information
- able to build up clear picture of incident
- incident report in file (either CIRS site visit report or site investigation report)
- able to respond to most (if not all) questions in questionnaire

**Average**
- some information / limited information
- able to develop reasonable understanding of incident
- able to answer at least half of questions in questionnaire

**Poor**
- little or no information on incident form
- only able to answer a few questions in questionnaire

Overall 68% of the 185 incident reports were classified as ‘average’ or ‘good’. This provides therefore a reasonable data set from which conclusions about land contamination incidents in general can be drawn. The categorisation scheme, which enabled judgement of the completeness of the information available, might be regarded as somewhat subjective. Yet it was considered necessary to provide a
distinction between incidents for which there was little or no information available (other than, for example, the chemical involved) and incidents for which a full, detailed site investigation report was available.

The data revealed that land contamination incidents have been discovered most frequently through 'complaints' and acute events (leaks, spills etc.) but that historic land is the most frequent cause of the problem (Figure 5.1).

Figure 5.1: The cause of the problem

![Figure 5.1: The cause of the problem](image)

Interestingly leaks and spills do not appear to have been a problem until 1998, although this is more likely to be due to changes in reporting and categorising incidents than anything more sinister. The results also indicated that land contamination incidents present in a number of areas of different current land use (Figure 5.2) although residential housing accounted for more than a third.

Data was also collected about the different agencies involved in managing land contamination incidents. The agency that most frequently informed public health of a land contamination incident was the local authority environmental health department (43%). In 35% of the incidents reported the environmental health department was the lead agency although this information was only available for 46% of incidents. A number of different groups and organisations were involved in the management of the incidents including Water Companies, the Environment Agency, emergency
services and the Health and Safety Executive (HSE) as well as local action groups and non-governmental organisations (NGOs) (Figure 5.3). The management of the majority of incidents (69%) involved more than one agency with the mean being 2.45.

Figure 5.2: Location of land contamination incidents – current land use

Figure 5.3: Agencies involved in the management of land contamination incidents

When considering the duration of the problem, it was observed that of those that had existed for less than 6 months, 89% involved organic chemicals compared to 60% of the incidents that had been ongoing for 24 months or more (chi²=11.92, p=0.003).
However, of those incidents that had been ongoing for 24 months or more, 61% involved heavy metals compared to 10% of the incidents that were concluded within 6 months ($\chi^2 = 35.32, p=0.000$) (Figures 5.4 and 5.5).

**Figure 5.4: Organic chemicals and duration of incident**

<table>
<thead>
<tr>
<th>Duration of problem</th>
<th>Less than 6 months</th>
<th>More than 24 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>60</td>
<td>50</td>
</tr>
</tbody>
</table>

**Figure 5.5: Heavy metals and duration of incident**

<table>
<thead>
<tr>
<th>Duration of problem</th>
<th>Less than 6 months</th>
<th>More than 24 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>60</td>
<td>50</td>
</tr>
</tbody>
</table>

Also the absence of data in the ‘between 6 months and 24 months’ category further substantiates the proposal in Chapter 2 that land contamination either results from acute events/accidents or is a chronic (historic) problem and that incidents are either **acute** OR **chronic**.

Furthermore the chemicals involved in each of the two incident categories tend to be different. For example, 97% of leaks and 96% of spills involved organic chemicals compared to 54% of historic land problems ($\chi^2 = 33.42, p=0.000$). In contrast, 86% of historic land problems involved heavy metals compared to 3% and 6% for leaks and spills respectively ($\chi^2 = 49.12, p=0.000$).

These observations confirm that it is possible to divide land incidents into two categories - acute and chronic - that have similar characteristics and this information can be used to characterise land contamination incidents more effectively. This distinction was first introduced in Chapter 2.3. On the basis of this classification
approach the data was recoded and indicates that 33% of incidents could be categorised as acute and 67% as chronic.

43% of land contamination incidents involve two or more different chemicals (mean = 2.5) and Figure 5.6 indicates the ‘top ten’ chemicals most frequently concerned. There were no significant changes in the top ten from one year to the next over the period of the study.

Figure 5.6: Top ten chemicals most frequently involved in land contamination incidents

![Bar chart showing top ten chemicals]

Figure 5.7 highlights the chemicals most frequently involved in acute land contamination incidents (only seven) and Figure 5.8 the top ten chemicals most frequently involved in chronic land contamination incidents.

Figure 5.7: Chemicals involved in acute land contamination incidents

![Bar chart showing chemicals in acute incidents]
Results substantiate the distinction that acute land contamination incidents usually involve organic chemicals whereas heavy metals are most frequently encountered in chronic land contamination incidents.

It is interesting to note that this list of the top ten chemicals involved in land contamination incidents reported to CIRS is not dissimilar to the top ten chemicals in the CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) priority list published every two years by the Environmental Protection Agency (EPA) in the United States (ATSDR, 2001) – Table 5.1. The CERCLA priority list is not a list of "most toxic" substances, but rather a prioritisation of substances based on a combination of their frequency of release, toxicity, and potential for human exposure at facilities on the national priority list (NPL). The objective of this priority list is to rank substances across all hazardous waste sites to provide guidance in selecting the substances for which toxicological profiles will be prepared by ATSDR. Those chemicals found at three or more NPL sites were considered for the CERCLA priority list, which amounted to 840 hazardous substances (ATSDR, 2001). The notable omission from the list is substances of petroleum origin, which do not appear because they are regulated by legislation other than CERCLA.
The similarity between the two lists is unsurprising since the majority of land contamination incidents reported to CIRS are chronic problems as are those sites on the NPL in the US. Similar industrial processes and substances are used in both the UK and US and indeed throughout the developed world. Therefore this suggests that the top ten list of priority substances and their relative ranking are likely to be applicable across the majority of industrialised countries although this would need to be confirmed through further research.

Table 5.1: CERCLA Top Ten Priority List

<table>
<thead>
<tr>
<th>Order</th>
<th>Substance Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lead</td>
</tr>
<tr>
<td>2</td>
<td>Trichloroethylene</td>
</tr>
<tr>
<td>3</td>
<td>Arsenic</td>
</tr>
<tr>
<td>4</td>
<td>Tetrachloroethylene</td>
</tr>
<tr>
<td>5</td>
<td>Cadmium</td>
</tr>
<tr>
<td>6</td>
<td>Benzene</td>
</tr>
<tr>
<td>7</td>
<td>Chromium</td>
</tr>
<tr>
<td>8</td>
<td>Volatile Organic Compounds (VOCs)</td>
</tr>
<tr>
<td>9</td>
<td>Polychlorinated Biphenyls (PCBs)</td>
</tr>
<tr>
<td>10</td>
<td>Mercury</td>
</tr>
</tbody>
</table>

5.2 Land Incident Categories and Tools for Response

The benefits of categorising incidents have been discussed in some detail in Chapter 3 and a scale for communicating the potential impact of a chemical incident on the health of the public developed. However this scale is primarily for acute incidents and is not really appropriate for categorising land contamination incidents, particularly chronic problems. As a result a separate system to identify and manage these incidents from a public health perspective is required. Effectively categorising land incidents will enable the most appropriate tools for responding to be quickly identified. Additionally, if used to record information about an incident, a limited number of incident categories will reduce variability in incident reporting thus improving efficiency of information retrieval.
It was suggested in Chapter 2.2.3 that land contamination incidents can be divided into two quite distinct categories - acute and chronic - based on incident duration and cause of contamination - and this observation has been confirmed in the previous section. Definitions for acute and chronic incidents have also been proposed (Chapter 2). By considering the data collected on the evaluation form a number of subcategories of land contamination incidents, or ‘incident types’, that share common features can be established. These are summarised in Table 5.2 and discussed in Sections 5.1.1 and 5.1.2 below.

Using the land incident data from 1999 presented in Chapter 2.2, the incidents listed in Table 2.5 have been re-classified using the proposed definitions. The suitability of the proposed classification system is confirmed since 96% of incidents can be categorised (Figure 5.9) with only 4% described as ‘other’.

**Figure 5.9: Land incidents reported in 1999 classified using proposed categories**
<table>
<thead>
<tr>
<th>PRINCIPAL CATEGORY</th>
<th>TYPE</th>
<th>PRINCIPAL FEATURES</th>
<th>TYPICAL SPECIES</th>
</tr>
</thead>
</table>
| Acute              | Direct contamination e.g. leaks or spills | Single chemical rather than mixture of chemicals  
Chemical mixtures e.g. leak of effluent or from drum of mixed chemical waste  
If identified quickly can be contained to minimise further contamination  
Leachable and non-leachable substances  
Casualties more likely to present themselves | Frequently organic chemicals  
E.g. solvents, fuels (petrol, diesel, kerosene)  
Less frequently inorganic chemicals (e.g. heavy metals) |
|                    | Indirect contamination | Via (contaminated) air  
e.g. dust/particulates from fire, asbestos fibres, gases  
Via (contaminated) water  
e.g. flood water, fire-water runoff, leachate | Frequently inorganic chemicals  
Less frequently organic chemicals |
| Chronic            | Part II A investigation | Probably more than one chemical  
Most commonly inorganic chemicals  
Organic chemicals may have been broken down by microbial action over time thereby giving rise to secondary rather than primary contamination | Frequently inorganic chemicals |
|                    | Planning investigation | Contamination may be widespread across the site  
Use historic maps to locate potential hotspots of contamination  
Important to understand site hydrogeology so that movement of water and hence chemicals in the soil can be more accurately predicted  
Issues of bioaccumulation from long-term exposure | Less frequently organic chemicals |
|                    | Routine testing | Allotments are a particular concern if soil is contaminated with heavy metals because of potential for plant uptake | |
|                    | Accidental discovery | Probably more than one chemical  
Potential problems off-site due to odour and leachate | Usually mixtures of organic and inorganic chemicals; many odours |
5.2.1 Acute incident categories

For acute incidents two subcategories have been suggested - direct contamination such as a leak or spill and indirect or secondary contamination. These reflect the cause of the problem or the event since this information is rapidly available in the early stages following incident notification (Chapter 4.1). Direct contamination of land is likely to involve a single chemical rather a mixture of chemicals. The main exception to this is a leak of effluent or from a drum of mixed chemical waste. The substance may be leachable or non-leachable, which will affect behaviour in the subsurface (Chapter 6). If the problem is recognised and notified quickly, the chemical can be contained to minimise further contamination. Organic substances including petrol, diesel kerosene and solvents are the chemicals most frequently involved.

Indirect contamination accounts for a small proportion (~5%) of land contamination incidents reported to CIRS and may be via air or water. For example particles, including asbestos fibres, and dust from fires, may be deposited onto land, and firewater runoff and floodwater may also give rise to land contamination problems.

Casualties are more likely to present themselves in an acute land contamination incident because of concerns about adverse health effects resulting from an acute exposure. Therefore it is imperative that procedures are in place to enable a rapid assessment of the potential health impact, to communicate the risk and to ensure that appropriate resources are available to manage the problem. The chemical incident impact scale (CIIS) proposed in Chapter 3 would be a suitable tool to use for this. The acute chemical incident checklist developed in Chapter 4 and presented in Appendix K is also considered appropriate to use in responding to acute land contamination incidents since the majority of these have been shown to result from leaks or spills (acute chemical incidents). Also this limits the number of event-specific checklists, minimising both duplication of information and confusion over which tools to use. The main exception is acute chemical incidents involving fuel since they present an interesting problem in terms of the potential human and environmental health impact. As a result a detailed study of fuel incidents has been
undertaken as part of this research project and is presented in the following chapter (Chapter 6).

5.2.2 Chronic incident categories

In contrast to acute incidents, the chronic incident subcategories reflect how the problem was discovered since it is unlikely that the event that caused the contamination would be easily identifiable. Four subcategories are proposed: Part IIA investigation, planning investigation, routine testing and accidental discovery. Waste disposal has also been included as a subcategory of chronic incidents.

*Part IIA investigation* is used to describe investigation undertaken to identify whether land is ‘contaminated land’ in accordance with the definition proposed in the Environment Act 1995 and quoted in Chapter 2.3. These incidents account for a relatively small number of problems reported to CIRS since many of the local authority strategies to identify contaminated land have yet to be implemented (Chapter 2.3). However, it is anticipated that the number of incidents in this category will increase significantly as more sites are identified as contaminated land.

*Planning investigation* is used to describe contamination identified during a site investigation prior to redevelopment. Very detailed information may be available about the site history, including historic maps to locate potential hotspots since contamination may be widespread across the site. There may also be details about the site hydrogeology so that movement of water and hence chemicals in the soil can be more accurately predicted.

25% of the chronic land contamination incidents reported to CIRS were categorised as *accidental discovery* (Figure 5.9), which describes land contamination incidents that are identified either through a complaint about adverse health effects and which is subsequently traced back to exposure to contaminated soil or to problems identified during construction (see Case Study 2, Appendix A).
In order to confirm the suitability of a site for its current use *routine testing* is often undertaken. The best example is allotment soil. Allotments are a particular concern if soil is contaminated with heavy metals because of the potential for plant uptake (see Case Study 3, Appendix A). The review of incidents reported to CIRS revealed that 80% of land contamination on allotment sites had resulted from historic contamination, suggesting inadequate sampling at the time when the land was designated for that use.

With all chronic land contamination problems there is usually more than one chemical involved and these are most commonly inorganic substances, particularly heavy metals such as mercury and lead. When organic chemicals are present, they may have been broken down by microbial action over time thereby giving rise to secondary rather than primary contamination. In these situations, if the land is disturbed either during sampling or redevelopment, an acute exposure can result. It is therefore necessary to ensure that tools for responding to chronic land contamination incidents are flexible enough to recognise the urgency of the response required in such situations.

The acute checklist developed in Chapter 4, which is appropriate for use in responding to acute land contamination incidents, is not applicable for chronic problems. The main reason being that the emphasis is on the initial response to contain the hazard and minimise exposure rather than incident investigation, which was highlighted as the key factor in successful chronic incident management (Chapter 2.2). As a result, tools specifically for managing chronic land contamination incidents are required.

### 5.2.2.1 Model and checklist for chronic land contamination

The incident timeline presented in Figure 4.1, Chapter 4 can be used to describe how both acute and chronic land contamination incidents evolve. However, for chronic problems, the incident management process is focused on three main stages - initial response, incident investigation and clean up. These have been illustrated in Figure 5.10 and the key points summarised below.
Stage 1: Initial response

The initial response, which usually involves the local authority, has the primary aim of determining the source of contamination, identifying any sensitive receptors that have potentially been or are likely to be exposed and ultimately ascertaining whether a pathway exists between the two. Action may be required to protect the health of the public, for example minimising exposure through hand-washing etc, and ensuring that any food produce that has been grown in potentially contaminated soil has been washed thoroughly prior to consumption.

Stage 2: Incident Investigation

The incident investigation stage involves undertaking a site assessment and confirming exposure pathways so that appropriate actions can be taken to minimise harm to sensitive receptors. A conceptual site model may be developed based on the preliminary site assessment, maps and knowledge of the local area (type of soil, topography, underground utility pipes etc.). Following the results of the preliminary investigation a more detailed site assessment may then be required which could involve extensive environmental sampling and a site visit. This work may attract attention from local media and therefore it is imperative to have a well-prepared communication strategy. From a public health perspective, it may be necessary to
develop a health questionnaire to circulate to those residents that have been potentially exposed and to ensure that appropriate advice and information is made available.

**Stage 3: Clean up**

A review of options available for removal of the contaminant from the site or to block the exposure pathways is undertaken to determine the most appropriate action required to make the site ‘suitable for use’. There is unlikely to be extensive public health involvement in the decision making process at this stage although advice on long-term monitoring and following up of individuals that have been exposed may be required.

The chronic land incident model presented in Figure 5.10 has been used as the basic framework for planning and developing a checklist for responding to chronic land incidents. The chronic land checklist is presented in Appendix K and additionally two ‘event specific’ checklists for land contamination problems have been developed for allotments and construction sites (or sites being redeveloped). These problems have been selected since they require collaboration with the Food Standards Agency (FSA) and the Health and Safety Executive (HSE) respectively as well as the collection of extra information on which to base the risk assessment and subsequent management decisions. For allotments this includes the type of food grown in the soil, how much produce is consumed and by whom and for construction sites information about the use of personal protective equipment (PPE) is needed to assess exposure.

In order that the layout of the chronic land contamination incident checklist is consistent with the checklist for acute chemical incident response, general management actions are separated from specific actions to protect the health of the public, which should encourage wider use of the tools since uniformity in content and presentation will enhance familiarity and accessibility.
As with the acute chemical incident checklist, the chronic land contamination incident checklist is not meant to provide an exhaustive list of actions but be a practical and pragmatically applied tool to guide the public health response and to help ensure complete, appropriate investigation and successful management and through these means to represent current ‘best practice’. Again it serves as an aide memoir of the major actions needed at each stage of the incident management process but can also be used to record progress and information about a particular event with the check boxes indicating when an action has been completed.

5.3 Conclusions

Since the relationship between humans and soil is less direct than with air or water i.e. we are far less likely to ingest or inhale soil, the link between exposure to contaminated soil and adverse human health effects is never easy to establish. As a result, land contamination incidents present an interesting challenge for public health professionals particularly since experience in managing these problems is usually limited.

In order to develop tools and resources to support the public health response to land incidents, patterns in the way incidents present and evolve have been established. Firstly, it has been demonstrated that land incidents can be divided into two quite distinct categories - acute and chronic - based on incident duration and cause of contamination. Each of these principle categories has then been divided into a number of subcategories or ‘incident types’. For acute incidents the incident types are based on the event that resulted in contamination, for example a leak or spill. In contrast the chronic incident type categories reflect the way in which the problem was discovered. For each incident type, principal features and typical contaminant species have been identified.

It was considered appropriate to use the acute chemical incident checklist presented in Chapter 4 for managing acute land incidents with the exception of those involving fuel. However, it is not applicable for chronic problems since the main emphasis is not on incidents investigation, which was highlighted as the key factor in successful
chronic incident management (Chapter 2.2) but on the initial response to contain the
hazard and minimise exposure. As a result, tools specifically for managing chronic
land contamination incidents have been developed. This includes a generic model to
illustrate the key stages in chronic land contamination incident response, which has
provided the basis for the development of a checklist to guide and support the public
health response to this category of land incident. Additionally two event specific
checklists for allotments and construction sites have been developed. The former has
been published in the Chemical Incident Report (October 2002) and feedback
requested.

Although these resources have been developed with public health practitioners in
mind, it is anticipated that they would be useful to all agencies, in particular local
authority environmental health and planning departments, who are involved in
investigating and managing chronic land contamination problems.
6. ACUTE INCIDENTS INVOLVING FUEL

The retrospective review of past incidents reported to CIRS revealed that around one third of land contamination incidents are acute incidents, and of these over 70% involved fuel oils\(^1\) or chemicals that are used fuel additives, including petrol, diesel, kerosene and heating oil.

Fuel leaks and spills at petrol stations are relatively common, which is consistent with the large number of fuel storage sites in the UK. The latest Institute of Petroleum retail marketing survey identified 13,065 petrol stations across the country (Skrebowski, 2001). Other fuel storage sites and depots include Ministry of Defence sites and pipelines and heating oil storage tanks on housing estates or individual properties. In addition fuel oil is transported around the country primarily in tankers and through a network of underground pipes. This highlights the potential for acute chemical incidents involving leaks and spills of fuel (Harris, 1994).

Fuel that is spilt onto an impermeable surface either outside or indoors may not pose a significant risk to health since it can easily be cleaned and the area decontaminated at relatively low cost and the impact on indoor air can be ameliorated through adequate ventilation (Grant, 2002). An example of such an incident was reported in The Independent (2000) following a leak of 1000 litres of diesel onto the floor of a generator room at Charing Cross Hospital after a pump had broken down. Even though a large amount of fuel was involved in the incident, it was adequately contained and cleaned up by the emergency services with no long-term impact on human health or the environment.

In contrast, once fuel is released into the environment onto a permeable surface it can be difficult to manage and presents a much more complex problem in terms of

---

\(^1\) The term ‘fuel oils’ is used to describe a range of petroleum based products that are refined from crude oil and which contain mixtures of aliphatic and aromatic hydrocarbons as well as other chemical additives. They are distinguished from one another primarily by their boiling point ranges, chemical additives and uses (Grant, 2002). Consequently all fuels have chemical ‘fingerprints’.
containment, clean up and decontamination. Vapours may accumulate under the floorboards of residential properties and contaminate the indoor air as well as presenting a fire and explosion hazard. Additionally fuel migrates readily through the subsurface, channelling along pre-existing underground features such as land drains or service pipe trenches travelling a significant distance from the site of the leak or spill. Low molecular weight hydrocarbons such as those present in fuel are able to permeate through plastic water supply pipes and contaminate drinking water. As a result inadequate planning and tactical decision making with regard to fuel spill events is likely to result in inefficient cleanup efforts with high operating and cleanup costs (Iakovou et al, 1996).

From a human health perspective, exposure to low levels of the volatile components in fuel, which often includes benzene, toluene, ethylbenzene, xylene and naphthalene at varying concentrations as well as other additives, can give rise to a number of acute and chronic adverse health effects. For example, acute exposure to these chemicals can cause respiratory tract irritation and pulmonary oedema whereas chronic exposure may result in blurred vision, visual disturbance and delirium (Farrow et al, 2000).

A study was undertaken to review in detail this category of acute land contamination incidents and included a review of fuel incidents reported in the literature. This is presented in Appendix M and the key points summarised below. Subsequently a more detailed evaluation of some of the incidents reported to CIRS from which ‘best practice’ for managing fuel incidents is identified and used in developing a checklist to facilitate the public health response to this type of event.

6.1 Key Points from Literature Review

The literature review highlighted the increasing percentage of acute incidents that involve fuel and the huge potential for further incidents, which emphasises the importance of developing a structured approach to the management of such events to minimise long-term harm human and environmental health.
The incidents reported demonstrate some of the distinguishing features that make acute incidents involving fuel unique in terms of the management response required. This includes the likelihood of explosion if vapours accumulate within a confined area and the subsequent need to evacuate residents and other property owners, the potential to affect water either through the direct contamination of groundwater aquifers used for drinking water abstraction or the permeation of low molecular weight hydrocarbons from the soil through plastic drinking water supply pipes and also the difficulty in remediating soil and groundwater once contaminated.

6.2 Incidents Reported to CIRS

Incidents reported in the literature highlight that leaks and spills occur relatively frequently although additional information obtained from the Environment Agency and CIRS data suggest that many more problems occur than are published. As a result more detailed analysis of all incidents reported to CIRS between January 1997 and December 2000 was carried out in order to identify acute incidents that involved fuel.

The number of incidents reported involving fuel increased from 18 in 1997 to 45 in 2000 (Figure 6.1). Overall there were 149 acute fuel incidents reported in this four-year period. These ranged from an accidental leak of heating oil from a broken storage tank to a spill of crude oil at sea leading to deposition of contaminated seaweed and other debris on gardens of sea front properties during high winds.

Figure 6.1: Incidents involving fuel reported to CIRS by year
Petrol and kerosene were involved in 63% of the total number of incidents involving fuel reported which perhaps reflects the underlying frequency of their usage and storage in relation to other fuels.

It was considered that the increasing number of fuel incidents reported is more likely to be due to a greater awareness of the potential for environmental contamination to result in adverse health effects rather than an actual increase in the number of incidents occurring. Consequently the number of fuel incidents as a proportion of the total number of incidents was calculated and, using Epi-info, a chi-squared test for linear trend was used to compare changes in this proportion over the four-year period. Over the same time period, the total number of incidents reported to CIRS has remained fairly constant indicating that fuel incidents are accounting for an increasing proportion of the total (Table 6.1) ($\chi^2=10.24$, $p=0.001$).

Table 6.1: Incidents reported to CIRS January 1997 - December 2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of incidents reported</th>
<th>Number of fuel incidents reported</th>
<th>Fuel incidents as a percentage of all incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>885</td>
<td>18</td>
<td>2.0%</td>
</tr>
<tr>
<td>1998</td>
<td>887</td>
<td>40</td>
<td>4.5%</td>
</tr>
<tr>
<td>1999</td>
<td>934</td>
<td>46</td>
<td>4.9%</td>
</tr>
<tr>
<td>2000</td>
<td>885</td>
<td>45</td>
<td>5.1%</td>
</tr>
</tbody>
</table>

* This total does not include incidents involving CS spray

Three recent fuel incidents that resulted in an actual or potential threat to the health of the public were reviewed in detail. These incidents were selected to highlight the diversity of fuel incidents and on the basis that they clearly illustrate specific aspects of incident response and management and present key lessons in terms of best practice. The research engineer has been involved in the management of all three incidents, which also makes it easier to identify what worked well and what improvements could be made.

The review of cases sought to identify both positive and negative aspects of incident management, the agencies involved and how each was notified, whether incident control meetings were held, the investigations undertaken, any delayed or omitted
investigations and the timeliness of action taken to protect the health of the public. These are presented in Appendix N.

6.3 Key Issues and Project Contributions for More Effective Management of Acute Fuel Incidents

The incidents described in Appendices M and N illustrate the complexity of acute fuel incidents and also the financial burden in terms of remediation costs and fines that may be imposed as the result of successful prosecution. Therefore the aim of this next section is to identify similarities in the way these acute fuel incidents evolve and should subsequently be investigated and managed. Features addressed include roles and responsibilities of key agencies, potential for secondary contamination, common contaminant pathways and 'environmental' parameters.

6.3.1 Roles and Responsibilities of Key Agencies

One of the most difficult features in any incident is the contact and communication between agencies. A number of different agencies were involved in each of the incidents described including the local authority, emergency services, water companies, the Environment Agency and the Health and Safety Executive. Therefore the need to carefully co-ordinate actions is paramount. In the first study, the local authority were fairly prompt in contacting public health, an incident control meeting was held approximately 10 days after the incident was reported and used to bring key agencies together and establish clear lines of responsibility. In the other two case studies, public health involvement was delayed. In the second case this led to the failure to consider the possibility of water contamination and delayed investigation. In the third case, public health was not involved in an incident control meeting until the 5th day following the event. However, the local authority in this case had evacuated any properties exhibiting elevated levels of petrol, as well as neighbouring premises that were not contaminated. This action eliminated any immediate potential risk to the health of the public.
Overall it is apparent that the roles and responsibilities need to be more clearly defined and that guidance should reflect the multi-disciplinary nature of incident management, even if its main purpose is to facilitate the public health response.

### 6.3.2 Contaminant Pathways and Potential for Secondary Contamination

The incident investigation involves undertaking a detailed site assessment and determining potential and actual contaminant pathways. A contaminant pathway is the link between the source of contamination and the receptor – human or environmental (see Chapter 2.2).

In managing any chemical incident, the development of a conceptual site model based on the preliminary site assessment, maps and knowledge of the local area (type of soil, topography, underground utility pipes etc.) is important since from this, all potential contaminant pathways can be identified (see Chapter 4). These potential pathways are then used to direct the investigation process and ensure that all appropriate environmental samples are collected. This type of approach is considered to represent current ‘best practice’ since it follows the methodology recommended in the contaminated land guidance for applying the CLEA model.

Whilst it is important to consider all potential exposure pathways, experience suggests that in an acute fuel incident two key exposure pathways can be identified. They are:

- water contamination (ingestion) either through permeation of fuel through plastic water supply pipes or direct contamination of a borehole. Additionally the potential for groundwater contamination if the problem is not quickly identified and contained is a concern.

- indoor air (inhalation) through vapour migration into the property. Fuel will migrate through the subsurface along the easiest possible route.

Failure to consider all such contaminant pathways can lead to delayed or omitted investigations hence potentially unnecessary exposure and subsequently negative health and environmental impacts.
6.3.3 ‘Environmental’ Parameters

The way in which chemicals move through the ground is influenced by the soil structure and the chemical composition of the soil including soil moisture content, redox condition (the oxygen availability in the soil) the pH (the acidity of the soil) (Van Wensem, 1998), and also the physical and chemical properties of the contaminant including concentration.

If a hydrocarbon (such as petrol or kerosene) or contaminated water is spilled onto the surface of the soil, it will initially migrate downwards under the action of gravity. It may also begin to spread horizontally. Not all of the liquid will continue to flow through the soil - some of it will be adsorbed onto the particles of the soil through which it has moved. Some of the contaminant may evaporate into the soil gases and be transported through the soil air. When the contaminant reaches the zone where all of the soil is completely saturated with water (saturated zone):

- if the contaminated liquid has a density that is lower than the groundwater, it will float like a lens on the water table and will spread horizontally. These contaminants are often referred to as light non-aqueous phase liquids – LNAPLS - and include kerosene and petrol.

- if the contaminated liquid has a density that is equal to the groundwater, it will accumulate at the capillary fringe until enough pressure has been built up for it to enter the groundwater. It will then sink into the groundwater and move through the aquifer in the direction of the groundwater flow.

- if the contaminated liquid has a density greater than the groundwater, again it will accumulate at the capillary fringe until enough pressure has been built up for it to enter the groundwater. It will move through the groundwater to greater depths under the action of gravity until it reaches a layer of low permeability. It may then migrate horizontally along the upper surface of the low permeability layer. These contaminants are often referred to as dense non-aqueous phase liquids – DNAPLS – and include chlorinated hydrocarbons such as trichloroethylene.

Other parameters that have been identified as having an important influence over chemical spreading and migration through the subsurface include (Scott, 1998):
- **weather** precipitation and strong winds can increase spreading; higher air temperature can increase evaporation
- **reactivity** some chemicals react with water and form products that may be harder to decontaminate/remediate
- **volatility** a chemical with high volatility will evaporate and be spread by air; a chemical of low volatility is likely to migrate through land or water

However, if there are any ‘obstructions’ in the topsoil or subsoil such as service pipes or land drains, liquid contaminants will preferentially migrate along these. This is also true for any geological features, such as an impermeable rock. Therefore determining how and to where liquid contaminants have migrated in the subsurface may require extensive sampling and detailed knowledge of the underlying geology and any underground pipelines or other buried objects. There are a number of mathematical models and associated software packages that seek to model the behaviour of contaminants in the subsurface, based on the fundamental adsorption-convection-diffusion equations describing contaminant distributions and fluxes. However, consideration of these is beyond the scope of this project.

Given these common features, the frequency of acute fuel incidents and the potential impact of such events on the health of the public, guidance for the management of acute fuel incidents has been developed in the form of a checklist of actions to facilitate the public health response.

### 6.3.4 Checklist for Acute Fuel Incident Response and Management

A detailed checklist of actions has been developed for responding to and managing acute fuel incidents (Figure 6.2). The same methodology used in compiling both the acute chemical incident checklist and chronic land contamination checklist has been applied.
Figure 6.2: Checklist for public health response to acute incidents involving fuel

<table>
<thead>
<tr>
<th>Emergency response</th>
</tr>
</thead>
<tbody>
<tr>
<td>• identify contaminant(s) involved.</td>
</tr>
<tr>
<td>• ensure contaminant has been contained.</td>
</tr>
<tr>
<td>• ensure all appropriate organisations are aware of the incident</td>
</tr>
<tr>
<td>- consider incident control meeting.</td>
</tr>
<tr>
<td>- establish clear lines of responsibility &amp; communication.</td>
</tr>
<tr>
<td>- consider contacting the media (press statement).</td>
</tr>
<tr>
<td>• restrict access to the site.</td>
</tr>
</tbody>
</table>

**Action to protect the health of the public:**
- identify population at risk.
- consider if evacuation/sheltering of residents is necessary.
- provide information to the public as needed.

<table>
<thead>
<tr>
<th>Incident investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• identify source-pathway-receptor</td>
</tr>
<tr>
<td>- confirm source of contamination &amp; estimate volume of chemical released.</td>
</tr>
<tr>
<td>- identify all potential pathways between the source of contamination &amp; receptors (human &amp; environmental)</td>
</tr>
<tr>
<td>- is there an aquifer used for drinking water abstraction?</td>
</tr>
<tr>
<td>- are there plastic water supply pipes?</td>
</tr>
<tr>
<td>- is there a river or stream used for recreational purposes?</td>
</tr>
<tr>
<td>- is the land used to grow food?</td>
</tr>
<tr>
<td>- are there other pathways that would transport the contaminants elsewhere?</td>
</tr>
<tr>
<td>• undertake detailed site assessment if necessary</td>
</tr>
<tr>
<td>- collect maps &amp; plans of the area to show geology, hydrogeology, any underground features, utility trenches, land drains, historical land use etc.</td>
</tr>
<tr>
<td>- determine direction of groundwater flow.</td>
</tr>
<tr>
<td>• undertake appropriate environmental sampling.</td>
</tr>
<tr>
<td>• maintain clear lines of communication with all agencies including the media.</td>
</tr>
</tbody>
</table>

**Action to protect the health of the public:**
- undertake assessment of public health impact of event |
  - determine exposure amongst local residents. |
  - has the wider population been potentially exposed? |
  - have appropriate actions to protect the public health been taken. |
- confirm that appropriate environmental samples have been taken |
  - drinking water samples will be required if there are plastic water supply pipes. |
  - air samples will be required if vapour migration into property is suspected. |
- consider whether biological sampling of exposed population is necessary. |
- provide information to the public as needed. |
- if necessary, initiate study (e.g. case control study) to assess health impacts.

<table>
<thead>
<tr>
<th>Remedial action</th>
</tr>
</thead>
<tbody>
<tr>
<td>• review options available for removal of contamination from site</td>
</tr>
<tr>
<td>- select &amp; apply most appropriate option.</td>
</tr>
<tr>
<td>- make provisions for long-term monitoring.</td>
</tr>
<tr>
<td>- ensure involvement of all stakeholders in decision making process.</td>
</tr>
<tr>
<td>- ensure good risk communication to stakeholders.</td>
</tr>
</tbody>
</table>

**Action to protect the health of the public:**
- consider long-term follow up & monitoring of exposed population.
It is likely that use of the fuel checklist in the three cases studies presented would have resulted in a more structured approach to their management, helped ensure appropriate investigations were undertaken and a more timely response provided. For example, in cases one and two it would have confirmed the presence of plastic water supply pipes at an earlier stage in the investigations and hence confirmed this as a potential exposure pathway to human receptors. In case three the checklist could have been used as an aide memoir by the health agency in undertaking a complete assessment of the exposed population.

6.3.5 Checklist Validation

Two options were considered for testing the checklist. The first was to wait for an appropriate incident to occur; the alternative was to write an exercise and test the checklist in that way. The latter option was selected because it allowed feedback from a greater number of people and also it was not certain that an appropriate incident would occur or that testing the checklist for one incident would provide adequate feedback. The disadvantage of using an exercise was that the checklist was not tested in real circumstances.

If the decision to wait for a 'real' incident had been adopted, it would have taken longer than the timescale of the project to collect the necessary data. However, a decision was made to forward the checklist to public health practitioners for any actual incidents reported and request feedback on presentation and usefulness. Results are summarised below.

The checklist was also presented at the 6th South West Conference in May 2002 and received feedback from participants.

6.3.5.1 Incident exercise

An exercise based on Case Study 1 (a leaking fuel pipeline) was written, a copy of which is included in Appendix L. It was tested at a training day for Specialist Registrars in Public Health, which was attended by thirty delegates. Delegates were aware that a series of checklists for managing chemical incidents existed but the checklist for fuel incidents was not introduced formally. Therefore prior to taking
part in the exercise, none of the delegates had seen the checklist or had had an opportunity to review the content. However, the format of the checklist had been discussed with CIRS, Health Emergency Planning and public health colleagues so it had undergone some peer review.

A short questionnaire was designed to gauge the delegates' thoughts on the usefulness and presentation of the checklist. A copy can be found in Appendix G.

**6.3.5.2 Results**

Verbal and written comments from delegates indicated that they all found the checklist useful for managing the incident in the exercise and would consider using it for responding to similar incidents in the future. Also, all indicated that they considered checklists to be either useful or very useful for responding to and managing chemical incidents.

In response to the two open questions, which recorded thoughts and opinions about the checklist and invited suggestions for improvements, delegates provided some useful ideas.

Positive comments included 'helped to make things systematic', 'helps prompt questions to agencies' and 'headings helpful'. Suggested improvements included giving a prompt as to which organisations to get involved at which stage and when to involve the media. The former is addressed to some extent in the incident model on which the checklist is based. The checklist has been updated to include the latter.

Over the review period (a month), three acute fuel incidents were reported to CIRS and the checklist forwarded to public health in each case.

Two of the three incidents were reports of elevated levels of hydrocarbons in drinking water thought to have resulted from past spills. These were both very minor incidents and if categorised on the Chemical Incident Impact Scale (CIIS) presented in Chapter 3, they would be 'insignificant' with less than 10 people exposed to the chemical hazard and little or no impact on the health of the public or the
environment. Yet in both cases the checklist was requested and used as a post incident audit tool to confirm that appropriate action had been taken rather than as a prompt in dealing with the problem. It was suggested previously that the checklist could be used record progress and information about a particular event, but this feedback highlights a further use for the tool.

The third incident was more serious. A leak of heating oil had resulted in contamination of a pond (fish had been killed) and elevated vapour levels inside a property. Residents, including two small children had complained of headaches and insomnia. Thus this incident was categorised as 'moderate' because of the 'significant' environmental impact and 'minor' health impact.

Since public health were not informed immediately of the incident, the initial response section of the checklist was used to confirm that appropriate action had been taken to minimise exposure and contain the problem at the time rather than to guide the public health response. However, the incident investigation section was used to collect general information on which to base the public health risk assessment and to guide the response. In particular questions to identify all of the contaminant pathways ensured that all possible exposure routes were considered, including the presence of plastic water supply pipes although drinking water supplies were unaffected by the spill.

Feedback from the public health practitioner involved in managing the incident confirmed that the checklist had been useful and that similar tools for responding to specific types of chemical incident would be welcomed. It was considered to have provided a useful guide to the general management approach whilst highlighting more specific actions to protect the health of the public. Specifically the straightforward layout of the checklist with clear subsections that reflected the logical evolution of the incident was described as particularly constructive.
6.4 Conclusions

A review of past incidents reported to CIRS and in the wider literature revealed the increasing percentage of acute incidents that involve fuel and the huge potential for further incidents. Incidents reported demonstrated some of the distinguishing features that make incidents involving fuel unique in terms of the management response required, including the likelihood of explosion, the potential to affect water and the difficulty in cleaning up soil and groundwater once contaminated. This warranted the development of a structured approach to the management of acute fuel incidents to minimise long-term harm to human and environmental health.

The fuel model and checklist was a first attempt at compiling a list of the key actions to protect the health of the public that need to be addressed at each stage of the management process for a very specific type of acute chemical incident. The tool also endeavoured to integrate the actions of other agencies involved in managing the event into a concise checklist; the benefits of doing so were outlined in Chapter 4.

Testing and validating the model reinforced the observation that until now appropriate tools and guidance for the public health management of chemical incidents has been quite limited. In addition feedback confirmed that public health practitioners welcome a standardised approach to incident management and resources to support this idea.

The checklist has been included in a number of local authority and public health chemical incident on-call packs thus providing practical evidence of the perceived usefulness of the tool for responding to this type of problem.
7. THESIS OVERVIEW AND CONCLUSIONS

The work presented in this thesis demonstrates the contributions that the research project has made towards improving the public health response to chemical incidents and their effective integration within the wider principles of environmental technology and sustainability. These contributions were made possible through the unique position of the Chemical Incident Response Service (CIRS), the project sponsor, within the NHS. CIRS has provided the opportunity to spend time with public health practitioners to identify more precisely their resource needs and to test and explore proposed solutions in 'real' situations, thus ensuring that project outputs are both pragmatic and functional.

The overall aim of the project has been to develop a methodology for public health, which could also be adapted by other agencies involved in emergency response to support and facilitate their role in managing chemical incidents. This objective has been met through developing a greater understanding of incident genesis and evolution and subsequently preparing and disseminating resources based on identifying best practice from past events.

Such resources include the co-authorship and overall editing of a Stationery Office publication entitled 'The Environment and Public Health' which is to be published by the end of 2002. The book covers all types of chemical incident, but is primarily intended for use in responding to minor incidents rather than catastrophic or disaster events. Its main objective is to provide an operational tool that can be used in the emergency response to all types of chemical incident. The primary audience is expected to be public health practitioners, although much of the information is applicable to others involved in the management of chemical incidents, including the emergency services and local authority environmental health practitioners.

This concluding chapter begins with an overview of the project aims and objectives, including identification of current gaps in knowledge and an outline of the salient research questions. Significant project outputs may be categorised broadly as ideas and concepts which provide the philosophical overarching framework and the more
practical tools and resources which have been created around it. Suggestions for further work, to complement and enhance the contributions that this project has made towards improving chemical incident response and management, are then summarised.

7.1 Project overview

Incidents involving chemicals, whether deliberate or accidental, can have far reaching implications in terms of the potential impact on human and environmental health. Following the events of September 11th 2001 and the subsequent anthrax outbreaks across the US a drive has been instigated in the UK to enhance the skills and knowledge of public health practitioners and to improve how information is cascaded to other medical professionals.

Preventing incidents from occurring in the first place is the most desirable option. However, it is important to recognise that in an increasingly industrialised society, accidents are to some extent inevitable. In addition, the potential for deliberate releases can never be ruled out and whilst the emphasis throughout this project has been on accidents, it is suggested that the tools and guidance proposed could also be applied to deliberate ‘incidents’.

The need exists therefore for a structured approach to the management of incidents and this has been widely acknowledged. Such an approach needs to include the provision of appropriate resources to be able to respond effectively to any potential or confirmed problem. Many agencies are involved in chemical incident response including the emergency services, the Environment Agency, the local authority and the local public health department so clearly defined roles and responsibilities, good communication and effective co-ordination of activities is fundamental to achieving a successful outcome. The work in this project has focussed on the role of the public health practitioner in responding to chemical incidents since limited experience, combined with a lack of suitable guidance, has resulted in the public health aspects of these incidents being managed on an ad hoc basis. This has tended to mean that
the lessons learned from the management of past incidents have not been acted upon in the most effective manner.

Identification of the limitations of current resources for the management of chemical incidents (Chapter 2) has highlighted in particular the inadequacies of current risk assessment methodologies that consider the health and environmental impacts of an incident, project or planning proposal where they are usually considered separately. An unquestionable link is demonstrated between human health and the quality of the environment (Chapter 1). Throughout the project, attention has been drawn to the interactions that exist between human and environmental health and the need for a framework, tools and resources, which take account of these interactions by considering simultaneously, has been established. The importance of ensuring that pollution streams are not diverted from humans to the environment or from one environmental medium to another, possibly more sensitive, medium has also been emphasised.

A particular focus of the project has been chemical incidents that result in land contamination since although air, land (soil) and water are interlinked, until recently, soil has not been granted the same level of protection as air or water. Additionally, land contamination incidents present an interesting challenge from a management viewpoint. This is in part due to limited experience of public health practitioners in dealing with such problems. Furthermore, unusual features such as indirect exposure pathways combined with insufficient understanding of chemical behaviour in the subsurface, mean that establishing a relationship between the presence of contaminants in the soil and reported adverse health effects is not always straightforward.

The need to improve procedures for responding to and managing chemical incidents and in particular land contamination incidents, prompted discussion that resulted in the generation of a number of different ideas and a series of research questions (Chapter 2) that provided a foundation for the project work undertaken.
7.2 Project contributions

These may be divided broadly speaking into five separate but interlinked categories, each of which is reviewed in turn below.

*A system for categorising chemical incidents*

In general, chemical incidents are currently managed on an ad hoc basis, either because of limited experience or lack of appropriate resources. Therefore one of the key aims of this project has been to consider whether developing a standardised approach to chemical incident management results in a more effective and consistent response. Since all incidents are different, tools need to be flexible enough to ensure that all possible outcomes are considered and allowances are made for situations where a decision is required even if limited information is available. Experience gained whilst working at CIRS over the past four years has indicated that it may be possible to group incidents effectively into a finite number of categories.

Scales and systems for categorisation were acknowledged to have many potential uses, which could broadly be divided into three categories - tools for planning, tools for describing events and tools for response and communication. Categories currently used either reflect the impact of the incident and hence the level of response required or the type of incident, such as those currently used by CIRS and the National Focus for surveillance purposes.

To date, however, a review of existing literature revealed that a practically applicable rapid response tool to measure the potential public health impact of a chemical incident does not currently exist. Therefore, following a review of a number of existing scales to identify useful features and to generate ideas, a scale for incident categorisation has been proposed; this has been subsequently referred to as the chemical incident impact scale (CIIS). A further aim has been to define and describe a ‘major incident’ (subsequently changed to ‘serious incident’) from a public health perspective.
Five categories ranging from ‘insignificant incident’ to ‘catastrophic incident’ have been defined and illustrated with examples selected from past incidents. The categories on the chemical incident impact scale (CIIS) are based on two parameters – the number of people potentially exposed and the severity of the health impact. These parameters were selected since the information is likely to available soon after an incident has occurred. Incident categorisation is expected to be an iterative process, which will continue until the incident is declared over. Therefore as time passes and more information becomes available, it is possible that the grading of an incident might be reduced increased.

Subsequently the possibility of merging the chemical incident scale with the Environment Agency’s pollution incident scale as a means of integrating human health and environmental impact assessment was considered. The integrated scale was tested retrospectively using data reported to the Chemical Incident Response Service in June 2002. Results demonstrated its usefulness in categorising chemical incidents from a public health perspective but that due to limitations in the usefulness of environmental information currently collected it was not possible to gauge the usefulness of the CIIS as a tool for assessing health and environmental impact simultaneously. Therefore, this represents an area for further work.

_A generic framework for chemical incident management_

The second project output is the proposal of a generic framework for the management of chemical incidents. This recognises that although all incidents are different, clear patterns in the way events present and progress can be identified and used in creating guidance, including tools for planning and response, to all chemical incidents.

The current incident management process was broken down into three key phases – acute, post-acute and post-incident - and illustrated using an ‘incident timeline’. The phases along the timeline, which were further divided into sub-stages, were positioned to reflect the time lapse between when the incident occurred and the management actions taken. By considering the management process in this way, it became apparent that there was no formal mechanism for reviewing how an incident
is managed, including what works well in addition to suggestions for improvements and identifying key lessons learned. This resulted in the proposal of a cyclical or 'closed-loop' framework for incident management, a dynamic process incorporating a feedback mechanism, which recognises the importance of updating emergency plans with observations and improvements from past incidents. Through these means it should be ensured that management plans reflect current 'best practice'.

**Tools for planning and response**

The number of incidents reported to the CIRS as well as recent reports from the Department of Health (DH) and the British Medical Association (BMA) clearly illustrated that public health have an important role in responding to and managing chemical incidents. However, it was recognised that there were limited resources specifically for public health response to these types of event. The role of public health at each stage of the management process was considered and a methodology to support the public health decision-making process in chemical incident response and management proposed. Prior to developing guidance, identifying the wants and needs of public health practitioners was considered to be important since professional acceptance and 'ownership' are key to the successful implementation of tools to assist in performing a job function.

This resulted in the development of a methodology for public health risk assessment, which considers both the health and environmental impacts of the incident. A list of actions to be considered at each phase of the incident management process has been presented in the form of a basic acute incident checklist and supplementary event specific checklists. Suggested actions also reflect the seriousness of the incident measured on the CIIS. By this means it should be ensured that appropriate actions are taken and that resources are allocated effectively. The checklists can be used additionally as reporting tools to collect information during an incident, facilitate the feedback of lessons learned and subsequently shape future response plans. The layout of the checklists has been designed to ensure that information is easy to find and use, though they are dynamic tools that can be modified and updated to reflect current 'best practice' and the preferences of the public health practitioners who use them.
As well as a better understanding of incident genesis, utilising the incident timeline concept to advocate a standard framework for incident response has resulted in a more thorough understanding of the key agencies that are likely to be involved in incident response. Although this project has focussed on the needs of public health practitioners in the development of tools and guidance, the generic framework and risk assessment methodology is available for other agencies involved in incident response to use and to refine further to suit their respective needs. The advantages of all agencies using the same guidance in responding to incidents would be expected to include improved communication, minimisation of the use of agency-specific jargon and as a result a better understanding of roles and responsibilities.

*Tools for land contamination incidents*

After looking generally at chemical incidents, the project focussed on land contamination incidents. The link between exposure to contaminated soil and adverse human health effects is never easy to substantiate since it may take some time to establish that land is contaminated and that there is an exposure pathway between the source of contamination and human receptors. As a result, land contamination incidents present an interesting challenge for public health professionals compared to a fire or an explosion, since the potential impact on the health of the public may not be apparent immediately and experience in managing these problems is usually limited.

Land contamination has a proven potential to impact on human health and the environment, which justifies the need to develop a response tool for public health practitioners to minimise such impacts and to prevent long-term contamination, which could continue to give rise to impacts into the future. As with all chemical incidents, every land contamination incident is different and each problem needs therefore to be dealt with on a case-by-case basis. However, an aim of this research project was to consider whether incident management and response could be improved by a standardised approach. It was recognised that any such approach would need to reflect the fact that incidents are dynamic. Patterns in land
contamination incident evolution were therefore used to develop both a categorisation scheme for such incidents and guidance for managing future incidents.

Two distinct categories of land contamination incidents have been defined — *acute* and *chronic* - and subsequently referred to as ‘principal categories’. The term *acute* has been used to describe land contamination that results from a sudden one-off release of a chemical either directly to the soil, such as leak or spill from a tank, or indirectly via aerial deposition or firewater runoff. In contrast, *chronic* describes land contamination that has resulted from a continued or repeated release of chemical substances over a period of time. Response time was identified as the key parameter that determines the effectiveness of response for *acute* land contamination incidents, whereas for *chronic* land contamination incidents success is more likely to be determined by accurately establishing the most significant exposure pathways between the source of contamination and sensitive receptors. Further, differences between *acute* and *chronic* incidents were identified and discussed, including legislation, the roles and responsibilities of organisations involved in response and management, the requirements of an effective risk communication strategy and the chemicals typically involved.

It was appropriate that the research project concentrated on developing procedures for managing acute land contamination incidents since the review of tools and guidance (Chapter 2) revealed current resources were limited. Also there was already a significant amount of research into the management and remediation of *chronic* land contamination and hence limited original work that could be added. The main exception was that much of the published information was not available in a form that public health practitioners could use in the event of an incident to determine the potential adverse health effects following exposure to chemically contaminated soil. This justified a need for further work.

Detailed consideration showed that the chemical incident impact scale (CIIS) for acute chemical incidents (Chapter 3) could be used to categorise acute land contamination incidents since the majority of these problems result from leaks and spills i.e. acute chemical incidents. However, it was not appropriate for categorising
chronic land contamination problems and therefore a separate system to identify and manage these incidents from a public health perspective was required.

Following a review of all land incidents reported to CIRS between February 1996 and October 2001, within the two principal categories a number of incident subcategories that share common features were established. For example, for acute incidents there are two categories, which reflect the cause of the problem or the event - direct contamination such as a leak or spill, and indirect or secondary contamination. For chronic incidents four incident types are proposed: Part IIA investigation, planning investigation, routine testing and accidental discovery. Waste disposal has also been included as a subcategory of chronic incidents. In contrast to acute incidents, the chronic incident categories reflect how the problem was discovered since it is unlikely that the event that caused the contamination would easily be identifiable. In this way the categories reflect the taxonomy for acute and chronic incidents presented in Chapter 2.2. The principal features and typical contaminant species have also been highlighted for each of the incident types.

A generic incident management model for chronic land contamination incidents was developed and provided the basis for a checklist to guide and support the public health response to this category of land incident. However, in order to limit the number of checklists used by public health practitioners, the acute chemical incident checklist presented in Chapter 4 was considered acceptable to use in responding to acute land contamination. The benefits of this were minimising duplication of information and confusion over which tools to use. The main exception to this was acute chemical incidents involving fuel since they present an interesting problem in terms of potential human and environmental health impacts. As a result a detailed study of fuel incidents was undertaken as part of this research project.

Fuel incidents

The retrospective review of past incidents reported to CIRS revealed that around one third of all land contamination incidents are acute incidents, and of these over 70% involved fuel oils or chemicals used as fuel additives, including petrol, diesel, kerosene and heating oil. A review of reported incidents highlighted some of the
distinguishing features that make acute incidents involving fuel unique in terms of the management response required; for example, once fuel is released into the environment it can be difficult to manage. Thus fuel presents a complex problem in terms of containment, clean up and decontamination. Vapours may also accumulate under the floorboards of residential properties and contaminate the indoor air as well as presenting a fire and explosion hazard. Additionally, fuel migrates readily through the subsurface, channelling along pre-existing underground features such as land drains or service pipe trenches, travelling a significant distance from the site of the leak or spill. Low molecular weight hydrocarbons such as those present in fuel are able to permeate through plastic water supply pipes and contaminate drinking water.

Given these common features, the frequency of acute fuel incidents and the potential impact of such events on the health of the public, it was realised that there was an urgent need for guidance for the management of acute fuel incidents. This has therefore been developed and is in the form of a checklist of actions to facilitate the public health response. It is recognised that this is a first attempt at compiling a list of the key public health actions that need to be addressed at each stage of the management process for a very specific type of acute chemical incident. However, the checklist will need to be further developed through iterative feedback. The tool also endeavoured to integrate the actions of other agencies involved in managing the event into a concise checklist. Feedback from public health practitioners who used the checklist in responding to exercises as well as ‘real’ incidents confirmed that the straightforward layout of the checklist, with clear subsections that reflected the logical evolution of the incident, was particularly constructive.

Testing and validating the model also reinforced the observation that appropriate tools and guidance for the public health management of chemical incidents had been quite limited and that practitioners welcomed the standard approach to incident management proposed in this project and the associated tools and resources.
7.3 Recommendations for Future Work

*Improved incident surveillance*

Enhanced surveillance would facilitate a greater understanding of when and where incidents are occurring thus ensuring that resources, including further research, are allocated appropriately.

There are several suggestions to improve collection and dissemination of chemical incident information. In general, it has been identified that clear and consistent definitions agreed by all agencies involved in managing incidents would have several advantages, not least by improving communication in an acute incident. It would also make sharing of information between agencies for surveillance purposes more straightforward. The standard framework for incident management proposed in this project would also provide a good starting point from which to develop these definitions since it takes into consideration the actions of all agencies involved in the process.

It was also recognised that within CIRS it would be beneficial to collect information in a more structured way including details of environmental impacts and actions taken. As the proposed checklists aim to integrate health and environmental information, it is suggested that these could be used as a basis for recording information.

*Incident impact scale*

Since the environmental information collected by CIRS was not sufficient to test the CIIS retrospectively, it would be interesting to use the scale to categorise incidents as they are reported. The required health and environmental information could be requested. This would provide the opportunity to test the scale in more realistic circumstances and to ascertain whether it is easy to use in the early stages following incident notification to determine the potential health and environmental impact. Subsequently the capabilities of the tool for inter-agency risk communication could then be tested, though this would require prior training in the use of the scale. The
development of inter-agency training resources to facilitate linking to existing emergency plans would also be beneficial.

It was also suggested in Chapter 3 that the CIIS could be expanded and used to communicate the severity of all CBRN incidents. Since there is a move towards developing integrated CBRN plans it would also seem sensible to expand the definitions in the scale to take account of biological, radiological and nuclear incidents. Since the CIIS is has been developed from the International Nuclear Scale, this should not present too big a challenge.

Formal testing of resources

As a suggestion for further research in this area, it would be interesting to undertake extensive testing to assess whether using the checklists results in a significantly improved public health response to chemical incidents and whether more directed training might also achieve the same goal. Whilst this would be time consuming and developing a suitable testing methodology would be difficult since accurately simulating incidents is not straightforward and public health practitioners may not respond as if they were dealing with a ‘real’ incident, it would be a useful exercise to carry out.

Interactive resources

It would be interesting to explore the possibility of creating an interactive computer tool for public health, based on the proposed incident management framework and risk assessment methodology. Information from past incidents could also be used in establishing a comprehensive ‘knowledge base’ and responses to the questions, such as those used in the checklists, could be used in generating a list of public health actions. In this way, a site-specific action plan based on ‘best practice’ can be instigated.
PERSONAL CLOSING STATEMENT

The contributions set out in this thesis provide an improved understanding of chemical incident genesis and evolution and have been used as a basis for the development of tools and resources to improve the management of chemical incidents. A more effective approach to incident management is less wasteful in terms of resource use both now and in the future thus providing a more sustainable environmental solution.

We live in a society where so much is taken for granted, so much energy consumed and so much waste generated but even implementing the small changes proposed by this work could cumulatively contribute to making a difference in the way we interact with the world around us.

“What is needed is a fundamental transformation of people’s attitudes and practices (...) Only a new world view and mortality can change this basic relation of people to the earth. People’s behaviour is a matter of choice based upon values (...) The need for a world ethic of sustainability – an ethic that helps people co-operate with one another and nature for the survival and well-being for all individuals and the biosphere – could not be greater.” Fien (1993).
8. REFERENCES


Agency for Toxic Substances and Disease Registry (ATSDR) (2001). 2001 CERCLA priority list of hazardous substances that will be the subject of toxicological profiles and support document. Division of Toxicology – ATSDR. USA.


American Society for Testing and Materials (1996), Standard guide for risk-based corrective action at petroleum release sites (E-1739-95), ASTM


2000.


Coleman G (2002). In Chemical terrorism alert system to be set up. WHO (2002).


Heathcote D (1996), ‘To err is human, to repent is divine but to persist is diabolical’. Industrial Emergency Journal 1(2):34.

exposure to the public to toxic substances'. *NHS Management Executive.*


Murray V (2001). ‘Responding to chemical and biological terrorism: Do we have sufficient technical resources and skills?’ *Public health Medicine* 3(3):84-85. Rila Publications Ltd.


National Health Service Management Executive (1993). Health Service Arrangements for Dealing with Chemical Incidents (HSG(93)38), London: NHSME.


Royal Commission on Environmental Pollution (1996). Nineteenth Report: Sustainable Use of Soil. HMSO.


Thames Water (2001). Notes from MSc Emergency Planning and Disaster Management, University of Hertfordshire, April 2001


Websites:
http://www.atsdr.cdc.gov/clist.html
http://www.cen.bris.ac.uk/civil/students/eqteach97/earth5.htm
http://www.doh.gov.uk/shiftingthebalance/index.htm
http://www.environment.detr.gov.uk/contaminated/land/1.htm
http://www.environment-agency.gov.uk
http://www.fphm.org.uk
http://www.g7.utoronto.ca/g7/what_is_g7.html
http://www.hampshire.org/
http://impact.arc.nasa.gov/torino/
http://www.natfocus.uwic.ac.uk/
http://www.nao.gov.uk
http://www.risc-site.nl/ (Van Hall Instituut)
http://www.outlook.noaa.gov/tornadoes/tornfact.htm (National Oceanic and Atmospheric Administration)
APPENDIX A
A. CASE STUDIES

Case study 1: School on Contaminated Site

Summary
A primary school was built on potentially contaminated land adjacent to a former gas works site.

Presentation
During excavation of a storm water drain, two workers collapsed and reported to the local Accident and Emergency Department. It was suggested that they might have been exposed to hydrogen cyanide gas although it is unclear where this may have come from. Following this incident the HSE requested that all workers on site wore personal monitors.

Incident Investigation
Workers commented on the fact that when land had been excavated along the side of the school building for drainage pipes to be laid, an almond smell and high readings for HCN registered on their personal monitors and on monitors located within the school buildings. However, levels dropped quickly.

Prior to the construction of the school a number of site investigations had been undertaken both on the proposed school site and on the adjacent land (former gas works site). Two thirds of the school buildings were built on one, perhaps two infilled ponds that had been used to dump various waste materials including builders' rubble and other refuse. It was considered that one of them might also have been used as a vehicle inspection pit in the past. However, a number of problems were experienced when attempting to sink boreholes into the 'ponds' and consequently there are gaps in the information obtained and the extent of contamination beneath the buildings is unknown.

Raised levels of spent oxide, referred to as blue billy, were identified on the gas works site. When the land was excavated for the school to be built, the waste topsoil was dumped onto the gas works site covering the previously exposed spent oxide. It
was identified as the potential site for the development of a supermarket in the near future following sufficient remediation to remove the spent oxide and other chemicals associated with gas woks sites.

A stream running along the bottom edge of the site was monitored by the Environment Agency. Although the water was found to be slightly acidic, goldfish thrive. There were no aquifers or abstraction points in the area.

Remedial Action

A recommendation was made to not open the school until a thorough investigation of the site had been carried out.
Case study 2: New development on land contaminated with heavy metals

Summary
The planning department of the Local Authority granted planning permission to build a three-storey residential nursing home on a former factory site. The site had a long industrial history dating back to 1865 when it was used as a builders yard. By 1893 the builders yard had become a dye works and around 1900 a boiler manufacturer. In 1954 a metal plating works occupied the factory site. Heavy metals were used in a number of the processes. During operation activities carried out by the company gave rise to contamination both on the site and to some surrounding gardens. The factory closed in 1985 and had since been left derelict.

Prior to developing the site, samples were taken to determine the extent of contamination in the soil. Information about the previous site use, the contaminants likely to be present and the location of potential 'hot spots' was available. However, the depth of contamination was unknown. For this reason, a multistage sampling process was undertaken. This involved taking a series of samples in areas of known contamination and using a wide-spaced sampling strategy in other areas.

A total of approximately 4000m$^3$ of 'contaminated' soil was excavated from the site prior to the before building work commenced.

Presentation
Following reports by the local media of health concerns from local residents who had formed an action group, the CCDC contacted the Pollution Control Team at the Local Authority.

Incident Investigation
With the permission of the owners/occupiers, the Pollution Control Team undertook a programme of soil sampling in the gardens around development in collaboration with CIRS and the CCDC. Not all of the 31 gardens were accessible for sampling at that time. Many of the gardens had been paved with concrete or planted with grass. Samples were not taken from these gardens. Although contamination may be present in the soil underneath, as no pathway between the source and receptor currently
existed the likelihood of health effects resulting from exposure to the soil was greatly reduced. Ten gardens were sampled in initially and samples from the remaining gardens were collected subsequently.

Where practical, two bulk samples were taken from each garden. One of these consisted of a mixture of three samples taken from as near to the boundary wall as possible and the other a mixture of two or three samples taken about 5 metres from the wall. Further samples were taken in areas where there was known to be heavy contamination on the factory side of the wall prior to excavation.

The top layer of soil was removed using a small trowel and the sample taken at a depth of 15 – 20 centimetres. The samples were then sent to the laboratory for analysis. Analyses for copper, lead, zinc, cadmium, chromium and nickel were undertaken on all samples. The sample data was compiled in a spreadsheet and a graph showing the variation in contamination around the perimeter of the boundary wall was produced. This highlighted ‘hotspots’ and enabled the determination of patterns of contamination.

Plants are able to tolerate cadmium and lead at higher concentrations than those recommended for human consumption. Therefore, home-grown vegetables presented a potential health risk in areas with contaminated soil. Lower concentrations of zinc, copper and nickel are considered to be more toxic to plants than harmful to human health. Chromium does not pass from soil into plants too readily so is not likely to be present in foodstuffs at a level which is toxic to humans. However, the sensitivity of different plants and mammals (including humans) to heavy metal poisoning is dependent on a number of factors. These include the metal concerned, the presence of other trace elements, the pH of the soil, the uptake of the metal from the soil and the metabolic activity within the plant.

A health questionnaire was sent to local residents. No adverse health effects were reported with one exception. A pregnant lady was concerned about the risk to her unborn baby.
Remedial Action

No remedial action was taken in the gardens as there was considered to be a risk to human health.
Case study 3: Proposed allotments contaminated with heavy metals and PAH’s

Summary
Soil sampling and analysis was undertaken in order to establish the suitability of an area of grassland adjacent to a large housing estate for use as allotments.

Presentation
The Local Authority contacted the PCT as raised levels of heavy metals and polycyclic aromatic hydrocarbons (PAH’s) had been detected in the soil.

Incident Investigation
The soil on the proposed allotment site was very ashy and small pieces of coal were identified. The grass was patchy and quite straggly in places although this was unlikely to be due to contaminants in the soil. There was evidence to suggest that the site had been used for the disposal of domestic waste and bonfires.

Soil samples taken from the proposed allotment site were found to contain heavy metals (lead, zinc, copper, nickel and mercury), arsenic and Polycyclic Aromatic Hydrocarbons (PAHs) above ICRCL ‘action’ levels. Further investigation identified the former land use of the area and part of the adjacent housing estate as an ash tip. It was decided that a series of samples should be taken from gardens on the housing estate to try and determine the extent of the contamination because the exact location of the former tip was unknown.

Further sampling was undertaken in the gardens of vacant properties on the adjacent housing estate and communal open spaces to establish the extent of the contamination in the area. In total, 33 samples were taken from 15 locations on the estate including communal areas near to blocks of flats and the private gardens of vacant properties. Samples were taken at depths between 0.2m and 1m. Elevated levels of heavy metals were found in 19 of the samples (8 gardens), arsenic in 11 of the samples (6 gardens) and PAHs in 4 of the soil samples (2 gardens). In 6 of the sample locations the levels of the contaminants screened were below ICRCL action levels for domestic use. Of greatest significance from a human health viewpoint is
the level of lead present in some of the soil samples. 2170 mg/kg was measured. This greatly exceeds the ICRCL action level of 500 mg/kg.

The most likely source of the contamination was considered to be a former ash tip on which the housing estate was constructed in 1949. The extent of the former tip was unknown but it was believed that it infilled a former ‘v’ shaped valley. The trough was believed to be around 15m deep and filled with ash and colliery spoil discard. There was also a history of mining and quarrying in the area. At the bottom of one of the boreholes a black sludgy mixture containing pieces of glass and similar material was found but not identified. This suggested that domestic and other waste may have been disposed of at some time in the past.

Residents who attended a meeting of the local council to oppose the proposed relocation of the allotments commented on the fact that attempts to grow vegetables in gardens on the estate in the past had usually failed. No adverse health effects had been reported to the Environmental Health Officer or to the PCT although it was known that around 90% of the residents were smokers therefore any exposure to PAH’s from the soil would be negligible compared to the PAH’s in cigarette smoke.

Remedial Action

A number of recommendations for further investigation were made.

- To determine if any vegetables were grown in any of the gardens on the housing estate and if so, what?
- To identify whether any of the children living on the estate/playing has pica (especially repeated mouthing of soil).
- To collect further samples in order to characterise the black sludge at bottom of borehole and also to try and locate the boundary of the former ash tip.
Case study 4: Contamination of a drain with leachate from a former coal ash tip

Summary
Concerns were raised about the possibility of drainage from a former ash tip polluting an inland watercourse including a drain approximately 100m downstream of the tip.

Presentation
The Inland Drainage Board contacted the Environment Agency and later the Local Authority and PCT with two primary concerns:

- Occasionally, drainage board employees worked in the dyke usually using machinery to clear weed and sediment but sometimes by hand particularly in culverts. They wore standard protective clothing;
- In dry summers farmers with land adjacent to the drain may, under an abstraction license use the water for irrigation.

Incident Investigation
There were three consented discharges from the site. It was believed that the discharge to the drain was from 4 old lagoons buried to the middle west of the site. A significant amount of liquid was discharged from these lagoons. The leachate could be continuing to flow for a number of reasons. For example, the lagoons may have been poorly capped. This would allow water (e.g. rainwater) to penetrate through the waste material and become contaminated.

The Environment Agency had analysed the water downstream of the on a monthly basis for a number of years. Samples were screened for biological oxygen demand (BOD), chemical oxygen demand (COD), ammonia, suspended solids, thiocyanate, oil and grease, free cyanide, monohydric phenols and total iron.

Raised levels of iron were detected in the drainage water. There was not believed to have been any iron in the slurry disposed of in the lagoons although it was highlighted that iron in the form of pyrites (FeS) is present in a lot of colliery waste. The ammonia in the drainwater was considered to present the biggest problem but the levels measured were not dissimilar to those found in watercourses near to
sewage works. The levels of phenol in the drain water had been raised but were reducing gradually. In any case levels were not excessive and unlikely to increase, as the lagoons had not been used for 8-10 years. Local drinking water was unlikely to be affected as the site was located on the edge of a sandstone aquifer and not near a water abstraction point. The nearest abstraction point was 9-10 km from the site. If there were raised levels of phenol in the public water supply there would be complaints of a phenolic taste from customers.

It was considered that the nature of the crops planted should determine whether the water was suitable for irrigation. It was felt that MAFF should be contacted, advised of the analyses and asked to provide more detailed advice.

Remedial action
No further action was taken as it was therefore concluded that as long as the drain water was not directly ingested there was no risk to human health.
Case study 5: Kerosene spill

Summary
This incident involved a leak of domestic fuel oil into the ground, leading to the possible contamination of a private drinking water supply.

Presentation
A fuel leak was reported the Environmental Health Department of the Local Authority in September although the leak was believed to have occurred some time between January and June. In June the fuel supply pipe, which had cracked, had been repaired and the fuel tank refilled. Fuel was not believed to have leaked from the tank after this date. Approximately 4000 litres of the fuel oil (kerosene) were lost over the six-month period.

Incident Investigation
Some of the bricks on the driveway close to where the fuel oil was stored had been removed to reveal contaminated sand. There was a strong smell of oil and the sand and bricks were discoloured. It was unclear how the fuel oil had travelled through the soil, which was sandy silty clay above chalk, and no soil samples were taken. Consequently, there was no clear indication of the probable migration route or migration time of the fuel oil through the soil. There was the possibility that the fuel oil may have migrated through the soil to a ‘soak away’, a brick chamber (perhaps an old slurry pit) located somewhere under the driveway.

Primary concern was that the fuel oil had leached through the soil and contaminated the drinking water. Water for drinking and domestic use was pumped from a borehole in the grounds and treated with sodium hypochlorite prior to distribution. The borehole was of unknown depth and had been used to supply drinking water for a number of years. There were no records of past problems with the water supply and no unusual taste or odour had been reported.

Remedial Action
It was concluded, following laboratory analysis of water samples taken from the borehole, that contamination of the water resulting from the migration of fuel oil
from the spill was not likely although further sampling and a continual monitoring programme was recommended. Also sources drawn from the same aquifer were sampled and were not contaminated.
### B. DEFINITIONS

#### 1. National Focus definitions for incident ‘type’

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>deposit</td>
<td>Inappropriate deposit of chemical substances in non-designated location which cannot be attributed to a fire, explosion, leak or spill</td>
<td>Fly-tipping, over-chlorination of a swimming pool, inappropriate dosing of drinking water, spread of mercury from containers, pouring pesticide into a drain, acid applied to toilet seats, chemical drums on beach etc.</td>
</tr>
<tr>
<td>explosion</td>
<td>Violent release of energy resulting from rapid chemical reaction</td>
<td>Mixing of incompatible, reactive chemical substances etc.</td>
</tr>
<tr>
<td>fire</td>
<td>Combustion of a material with the production of heat, light, smoke etc.</td>
<td>Fire at factory or warehouse triggered by an electrical fault etc.</td>
</tr>
<tr>
<td>land</td>
<td>Release associated with substances in, on, or emanating from, the surface or sub-surface of previously contaminated land which cannot be attributed to a leak or spill.</td>
<td>Wind blown dust from redevelopment activities, contamination of air, surface water or groundwater etc.</td>
</tr>
<tr>
<td>leak</td>
<td>Gaseous, liquid or solid release arising from a fault in a container or pipe.</td>
<td>Release from damaged from or fractured pipe, CO exposure due to a faulty boiler or blocked flue, CS gas release due to faulty container etc.</td>
</tr>
<tr>
<td>other</td>
<td>A release of chemical substances attributed to a specific event that cannot be described as deposit, explosion, fire, land, spill, leak or release.</td>
<td>Acid thrown in a person face etc.</td>
</tr>
<tr>
<td>release</td>
<td>Inappropriate release from an identified source that cannot be attributed to other types of incident (excluding unknown and other).</td>
<td>Intentional CS gas exposure, pesticide over-spray, gas produced during inadvertent mixing of chemicals, venting including relief value discharge, operational malfunction increasing stack emissions, exposure to damp-proof agents, dust from a stockpile etc.</td>
</tr>
<tr>
<td>spill</td>
<td><strong>Unintentional</strong> gaseous, liquid or solid release from an intact container or pipe.</td>
<td>Open drum knocked over, valve on pipe opened by mistake, CS gas exposure due to unintentional depression of release valve etc.</td>
</tr>
<tr>
<td>unknown</td>
<td>A release of chemical substances that cannot be attributed to a specific event.</td>
<td>River contamination in which the contaminant source is not known etc.</td>
</tr>
</tbody>
</table>
2. Chemical Incident Response Service definitions for incident ‘event’

<table>
<thead>
<tr>
<th>Incident</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>State of combustion in which inflammable material burns, producing heat, flames and often smoke</td>
</tr>
<tr>
<td>Explosion</td>
<td>Violent release of energy resulting from a rapid chemical reaction, especially one that produces shock wave, loud noise, heat and light</td>
</tr>
<tr>
<td>Transport accident</td>
<td>Unforeseen event involving a vehicle used to transport goods or people</td>
</tr>
<tr>
<td>Spill</td>
<td>Act of disgorging contents from a container unintentionally</td>
</tr>
<tr>
<td>Leak</td>
<td>Crack, hole or fault in a container or pipe leading to a release of material. Carbon monoxide exposures from blocked flues or faulty systems can be inserted here</td>
</tr>
<tr>
<td>Malicious act</td>
<td>Act motivated by wrongful, vicious or mischievous purpose</td>
</tr>
<tr>
<td>Air</td>
<td>Contamination of the gases that we normally breathe</td>
</tr>
<tr>
<td>Water</td>
<td>Contamination of drinking water, oceans, rivers, lakes, estuaries, groundwater etc.</td>
</tr>
<tr>
<td>Food &amp; drink</td>
<td>Contamination of any substance containing nutrients, such as carbohydrates, proteins, fats that is ingested for the purpose of generating energy and body tissue</td>
</tr>
<tr>
<td>Land</td>
<td>Contamination of the land surface of the earth that is composed of disintegrated rock particles, humus, water and air</td>
</tr>
<tr>
<td>Waste</td>
<td>Inappropriate or unauthorised disposal of waste products, both domestic and industrial; seepage of waste products from waste disposal site to an adjacent site leading to contamination</td>
</tr>
<tr>
<td>Medicine</td>
<td>Contamination of substances that are used to restore or preserve health</td>
</tr>
</tbody>
</table>
Sources and types of pollution
Chapter 2 from ‘The Environment and Public Health’ (Eagles et al., 2002)

Chapter aims and content
The aim of this chapter is to provide an introduction to some of the sources and types of pollution that may result in contamination of environmental media – air, land and water. The section begins with a general introduction to sources of contamination before considering each of the environmental media in turn. Naturally occurring incidents, as well as those resulting from human (anthropogenic) activities, are included along with a number of case examples to illustrate key points.

Sources of environmental contamination
Environmental contamination may result from a number of sources including chemical incidents. A general awareness of these different sources is important so that when a problem is reported the cause of the contamination can be more easily identified. This ensures that the most appropriate way to prevent any further exposure can be determined and the best clean-up (remediation) option selected.

For many incidents the cause is obvious, so the incident can be described by what actually happened or the ‘event’, such as ‘fire’ or ‘explosion’. However, for other incidents the event may not be obvious or the contamination may be the result of more than one event. These incidents are often described according to the environmental medium affected. Environmental media are considered to be air, land (soil) and controlled waters (groundwater, surface water, freshwater and coastal water), which includes rivers, lakes, streams and aquifers. In addition sources of drinking water contamination will be included.

Contaminants that are released to the environment are controlled by a complex set of processes that include various forms of transport and cross-media uptake (Asante-Duah, 1998). So whilst environmental media may be directly contaminated, there
will always be the potential for secondary (indirect) contamination if the contaminant source is not contained and mitigated in an appropriate and timely manner. Some examples of direct and indirect cross media contamination are indicated in Figures 1 – 3.

**Figure 1: Sources of air contamination**

```
Chemical input
  /       \
/         \       
Water    Land
  |       |
  \       \     
    Air

Outdoor air

Indoor air
```

**Figure 2: Sources of land contamination**

```
Chemical input
  /       \
/         \       
Air   Water
  |       |
  \       \     
    Land
```

Figure 3: Sources of water contamination

These highlight contaminant sources (or contamination events), environmental pathways (or mechanisms) and environmental receptors. The source-pathway-receptor linkage (Figure 4) is an important concept in the investigation of both environmental contamination and chemical incidents, and will be discussed in greater detail in later chapters.

Sources of contamination that can affect all environmental media fall into one of two categories

- natural sources
- anthropogenic sources
  - historical legacies
  - contemporary issues
  - accidents/emergencies (e.g. fire, explosion, spill, leak)
Contamination sources can be described as point or non-point sources. Point sources refer to discrete, localised discharges of contaminants into the environment and include emissions from an industrial chimneystack, a leak of fuel from an underground storage tank or effluent discharge to a river. Usually the contaminant is identifiable and can often be measured. Non-point sources may be referred to as diffuse sources, which are releases of contaminants into the environment over a wider area. Examples include traffic emissions and contamination with radon gas in homes built upon granite.

Natural Sources
Many pollutants within the environment have natural as well as anthropogenic sources. For example, some natural emissions of air pollutants include:

- releases of gases such as sulphur dioxide through volcanic eruptions
- releases of hydrogen sulphide from geyser and hot spring activities and by biological decay from bogs and marshes
- increased concentration of ozone in the lower atmosphere as a result of unstable meteorological conditions such as violent thunderstorms
- emissions of a variety of smoke and particles from forest fires and storms

In addition the geology in different areas of the country will influence the background level of certain chemicals in the soil. Examples include greatly enhanced
levels of arsenic and copper in soils contaminated by drainage waters and stream sediments from mining and smelting in South West England and much higher than normal levels of copper, lead, zinc and cadmium in soils downstream from disused mines in Wales (Senesi et al, 1999).

*Anthropogenic sources*

An anthropogenic source of contamination can be defined as any process or facility that has the potential to release chemicals that may result in contamination of environmental media, for example a factory, a farm or a landfill site.

Many industrial processes have the potential to give rise to environmental contamination. As a result the Department of the Environment (DoE now DEFRA) prepared ‘industry profiles’, which are available for 47 different industrial activities and provide information on the processes, materials and wastes associated with individual industries, including information on the potential contaminants. The Industry Profiles are available from The Stationery Office.

*Sources of Air Contamination*

There are two main groups of air pollutants:

- Primary pollutants: emitted directly into the air e.g. carbon monoxide and sulphur dioxide
- Secondary pollutants: produced when primary pollutants react with other pollutants or normal atmospheric compounds e.g. ozone

Some pollutants fall into both categories, e.g. nitrogen dioxide, and some particulate matter is formed as a secondary pollutant, but may also be emitted directly.

Both indoor and outdoor air may be affected. Indoor air can be contaminated directly from another environmental medium such as water or soil, or via contamination of the outdoor air. For example, contaminated water or soil beneath a building may result in vapour entering the house directly and contaminating the indoor air.
Internal furnishings, such as carpets and upholstered furniture, as well as building materials, may have been treated with chemicals (e.g. formaldehyde), which can also give rise to direct contamination of indoor air. Alternatively, a fire outside or other outdoor/atmospheric contamination may give rise to indoor air contamination if the chemical/plume is able to enter the building through windows, doors or an air conditioning inlet. In addition, both land and water may become contaminated when pollutants from air are deposited. Some examples are presented in Boxes 1 and 2.

Box 1: A travelling chemical incident

A chemical tanker and a petrol tanker collided in the English Channel and a quantity of unleaded petrol was spilt. This evaporated and was carried several hundred kilometres in the wind across central England and Wales, resulting in widespread complaints of odour associated with streaming eyes, noses and upper respiratory tract irritation.

Box 2: A warehouse fire

A warehouse used for storing paper-based material was destroyed by fire. It was quickly confirmed that none of the contents of the warehouse would give combustion products with particular toxicological concerns, however it soon became apparent that the roof was made from asbestos cement. This disintegrated due to the heat of the fire and chunks of asbestos containing material were deposited along the path of the plume covering roads, houses and gardens.

As vehicles drove over the material, the chunks were broken up further distributed, with the potential for fibres to be released back into the air. Rain is effective at clearing asbestos fibres from air and washing them into the soil or into surface water drains.
Sources of Land Contamination

Land contamination is a widespread problem in the UK due to heavy industrial activity in the past. Many sites have been left derelict and may contain chemicals that are a potential hazard to human health and the environment. In addition, ‘new’ land contamination may result from industrial processes or acute events, including leaks, spills, fires, and explosions. These may result in direct contamination of land or indirect contamination through surface runoff or aerial deposition.

In addition to being a ‘sink’ for contaminants, soil often provides a pathway for contaminants to other environmental media: air and water (including surface water and groundwater). There is also potential for food contamination if crops are grown in contaminated soil. Some examples are presented in Boxes 3 and 4.

Box 3: The redevelopment of an inner city contaminated land site

Planning permission was granted for the redevelopment of a small brownfield site in an inner city area. The site had a long industrial history dating back to 1865 including a builder’s yard, a dye works, a boiler manufacturer, and a metal plating works. The plating works closed in 1985 and whilst most of the equipment was dismantled and chemical baths drained and removed, no further clean up of the site was undertaken and it was left derelict. Heavy metals were used in the process and spills and dumping during operation gave rise to contamination both on the site and to some of the surrounding gardens.

Sources of Water Contamination

Water can be subdivided into surface water, groundwater, marine water, or drinking water. Water contaminants may be point or non-point sources. Discharge to a river from a sewage works is an example of direct contamination from a point source. A poorly contained waste disposal site with leachate migrating through to an aquifer used for drinking water abstraction is an example of indirect contamination of drinking water from a non-point area source.
Box 4: A leak of petrol from an underground storage tank

A leak of petrol from an underground storage tank (UST) into the ground resulted in contamination of surface water drains that ran to a ditch that became contaminated. Drinking water samples were taken from a number of properties in the area and elevated levels of petroleum hydrocarbons were found in the drinking water of two neighbouring properties. The water pipes supplying the two properties were made of lead except at the point where the supply entered the properties where plastic connectors had been used so it was considered that the petrol had permeated through the plastic. Soil saturated with petrol was exposed during excavation to replace the pipes. One year later, complaints of petrol smells inside one of the properties were reported and elevated levels of petroleum hydrocarbons were detected.

The major water pollutants are

- oxygen demanding waste (BOD) for example, milk or sugar
- pathogens
- nutrients
- synthetic organic and inorganic compounds
- oil
- heavy metals
- radioactive materials
- heat
- sediment

This chapter will concentrate on those that are chemical in origin and are underlined in the list above.

Drinking Water

Drinking water may be contaminated directly via surface, ground or marine water, where these water sources are subsequently used for drinking water. Water may also become contaminated if plastic water supply pipes are used in areas of soil that are
contaminated or become contaminated with organic chemicals, as these are able to permeate through the plastic material. The treatment of wastewater may also lead to environmental contamination from sewage discharges to surface or marine waters, or by the disposal of sewage sludge to land.

In addition, drinking water can also become contaminated directly without any associated environmental contamination. There are four main stages at which water that has been abstracted for drinking water purposes can become contaminated and examples of contamination occurring at each of the stages are provided below:

Storage reservoir: the pre-treatment raw water storage reservoir is often open to the environment and vulnerable to any spills, or runoff from road drainage.

Water treatment and final storage: in the water treatment plant itself inadvertent spills or overdosing of treatment chemicals such as aluminium sulphate could occur or a fuel spill on site resulting in pollution of stored water.

Distribution system: in the distribution pipes, chemicals from the pipe itself or corrosion deposits/sediments may become dislodged and contaminate the water. Alternatively, mis-connections may lead to the backflow of chemicals used in industrial processes or heating/cooling systems directly into the drinking water supply. In addition, low molecular weight hydrocarbons, such as those in fuel, are able to permeate through plastic water pipes, which may result in contamination.

Internal premises: within buildings themselves, internal piping may have similar problems to those of the distribution system. A further source of contamination may arise from the linings of internal water storage tank.

It should be noted that, water that is polluted in a raw water storage reservoir, prior to any treatment, might be decontaminated in the water treatment process, depending on the type and quantity of the pollutant.
In most contamination incidents water is a sink for contaminants. Some examples are presented in Boxes 5 and 6.

Box 2.5: Fire at a chemical recycling plant

A site used for the storage of multiple chemicals, where many containers were in a damaged state and different chemicals were stored next to each with the potential for reaction, was destroyed by fire, causing an air pollution event. Contaminated firewater was initially contained on site, however, subsequent heavy rain led to flooding of the site when a nearby river burst its banks. The firewater then caused contamination of surrounding surface water, agricultural land and flooded into nearby homes. The resulting widespread contamination necessitated a lengthy remediation process.

Box 2.6: Long-term leakage of heating oil into soil leading to permeation of plastic water supply pipes

A small housing estate in a rural location was supplied with oil for central heating. Following the discovery of oil contamination in lake near to the site, investigations found the external oil meters outside some of the houses were leaking. The meters were replaced and no further pollution was found in the lake. However, the contaminated soil surrounding the meters subsequently caused contamination of the drinking water supply to the houses, due to permeation of organic chemicals from the oil through plastic water supply pipes.
Groundwater

Groundwater is a very important resource and in the UK almost 30% of our drinking water is abstracted from groundwater sources (Figure 5). Some potential sources of groundwater contamination are highlighted in Figure 6. Once a groundwater source becomes contaminated it is very difficult to remediate and therefore groundwater protection is vital.

Figure 5: UK drinking water supplies from groundwater
The transport of pollutants through the subsurface will be strongly influenced by the direction of groundwater flow and the nature, quality and mobility of groundwater are all dependent on the rock formations in which the water is held (Manahan, 1993).

Most groundwater was originally rainwater that has infiltrated through the ground, although some water is held by dry soil particles at the surface. The quantity of water that can be accommodated under the surface depends on the porosity of the subsurface strata (Wilson, 1990) and the ease with which the water is able to flow is influenced by the permeability of the material. Below the surface, some soil particles will be covered in water but the gaps between the soil particles are filled with air (Figure 7). This is referred to as the unsaturated zone or the aeration zone.
Further underground, all of the voids between the soil particles become filled with water. This is referred to as the saturated zone. The water table is situated at the very top of the saturated zone and may also be referred to as the phreatic surface. A perched water table is produced when there is an impervious rock in the unsaturated zone. Water is drawn above the water table by small passageways through the soil in a region called the capillary fringe (Manahan, 1993). These features are illustrated in Figure 8.

A bed or ‘stratum’ of rock below the Earth’s surface that holds water and through which water can flow is called an aquifer (Watt, 1990). Rocks that are too impermeable to allow the flow of water are referred to as aqicludes. An aquifer that has become overlain by impermeable material is called a confined aquifer.

For more information about groundwater and the UK groundwater industry refer to ‘Groundwater – Our Hidden Asset’, published on behalf of the UK Groundwater Forum by the British Geological Survey (2000).
Figure 8: Labelled diagram of subsurface*

*Figures 2.8 and 2.9 are taken from 'Fundamentals of Environmental Chemistry', Stanley E. Manahan, Lewis Publishers 1993
Risk Communication

Chapter 9 from ‘The Environment and Public Health’ (Eagles et al, 2002)

Chapter aims and content
In all chemical incidents it is important that risk is communicated and managed effectively to ensure that the public are aware of any dangers and also to minimise any inappropriate media attention. This is true for both acute incidents, such as a fire in a warehouse or a chemical leak, and long-term chronic problems, such as a landfill site or a derelict factory site that is to be redeveloped. The aim of this chapter is to provide an overview of some of the key issues that should be considered when communicating environmental risk.

Introduction
The link between the quality of the environment and human health has been recognised for centuries but recent years have seen increased interest in the interactions between human health and the environment in which we live. Environmental problems are often perceived to have a public health impact and many people now have access to the Internet and are able to obtain detailed information on the risks associated with various chemicals and industrial processes. This information has not always been peer reviewed and so may be inaccurate or misleading or perhaps require careful interpretation. Communicating risks effectively has therefore become an important issue.

It is important that all of the people who may be interested in a particular issue are identified and involved in the communication process. This group of people are collectively referred to as ‘stakeholders’ and may include local industry, lawyers and representatives of financial institutions as well as local residents and community action groups. However, it is important to realise that all stakeholders may have conflicting views and concerns and may require different information and reassurances.

Communicating with the public
The primary aims for communicating with the public are to:
• alert the affected population to the hazard;
• provide information on all actions the public should be taking to minimise adverse health effects;
• where possible, reassure the public about the level of risk in order to minimise anxiety.

Communicating about risks to the public’s health can be a difficult task. The Department of Health has produced some Pointers to Good Practice that give a good overview of the complexities of risk communication and lay down a framework for good communication (Department of Health, 1998).

The public reaction to risk may seem surprising, especially when compared with scientific estimates. The concept of ‘risk’ means different things to different people, which is why public reaction to risk can differ so much from what the evidence would suggest. Until recently the prevailing view has been that the public are simply behaving irrationally when worrying unnecessarily about low-level health risks. There is now widespread acceptance that the reaction of the public to risk is not irrational but based upon issues that relate to

• the characteristics of the risk,
• the trust they feel for the people and organisations giving them the risk message and
• the extent to which they are involved in two way communication.

The way in which the public treat and respond to risks will also depend on their perception of how the risks relate to them and things they value (Health and Safety Executive, 1999).

Certain types of risk are known to have characteristics that alarm the public. Factors that are important in understanding what triggers concern and sometimes anger have been established through many years of research. These include whether the risk is voluntary, how familiar the risk is, the apparent equity of the distribution and so on (Box 1). It appears that these characteristics reflect fundamental values and they cannot be dismissed as irrational. Box 2 presents an example which uses these ‘fright
factors’ to demonstrate why the public are so often opposed to the siting of waste disposal facilities.

Box 1: Key factors affecting the tolerability of risk by individuals and society (Adapted from Communicating about risks to public health: pointers to good practice, NHS Executive, 1998)

"FRIGHT FACTORS"
Risks are generally less acceptable if perceived to be...
1. involuntary rather than voluntary
2. inequitably distributed
3. inescapable by taking personal precautions
4. arise from an unfamiliar or novel source
5. result from manmade rather than natural sources
6. cause hidden and irreversible damage
7. pose some particular danger to future generations
8. arouse particular dread
9. damage identifiable rather than anonymous victims
10. poorly understood by science
11. subject to contradictory statements from responsible sources

Because of the factors that affect risk perception, the use of risk comparisons should be avoided (Fairman et al, 2000). Comparing the public health risks of one issue with another familiar accepted risk (such as crossing the road) may appear to put the risk into perspective, but could backfire especially if involuntary and voluntary risks are juxtaposed.

Therefore in communicating risk it is important to look at issues much wider than the preparation of messages and the release of announcements, although these are important.
Box 2: Waste disposal

Waste Disposal (Keller 1992, Sandman 1985)

In the UK we are currently facing a huge waste disposal problem which has resulted from the fact that too much waste is being produced for the current disposal facilities to deal with. A particular problem is the disposal of hazardous waste. An obvious solution to this dilemma would be to develop new disposal facilities. However, no one wants to live near to an incinerator or landfill site due to the perceived hazards associated with such facilities. These include endangering public health, air and water quality, property values, peace of mind and quality of life (the media is often responsible for providing much of this information). The principal barrier to disposal facility development is therefore considered to be community opposition.

The following points outline some of the reasons why communities fear hazardous waste disposal sites.

- The perceived risk associated with a hazardous waste facility is, in part, a reflection of its unfamiliarity.
- The risk is perceived as involuntary due to outside coercion.
- The risk is perceived to be in the control of others.
- There are undetectable risks, for example, a large part of the dread of carcinogenity is its undetectability during its inactive/dormant period.
- A substantial share of the fear of hazardous waste facilities is attributable to the fact that only a few are to be sited and therefore a few people must suffer the costs/risks to provide the benefit for many.
- The individual is unable to protect him/herself in the event of an accident.

The public places most trust in management strategies that recognise and identify risks and which provide for rapid response and implementation of corrective action (Petts, 1994). Trust is easily lost while building it is a long-term cumulative process. Short of a reputation for infallibility the single most important factor is openness. Perception of the potential hazards associated with a chemical or chemicals can provoke a great deal of anxiety. This is further amplified by speculation and rumours when appropriate information is not available. It is therefore really important that clear and appropriate information is provided and made available to the public. This
should include a candid account of the underlying evidence (Department of Health, 1998) and of any assumptions made or areas of uncertainty.

It is vital to ensure that the affected population is clearly identified and contacted to avoid causing unnecessary anxiety in areas that are not affected by the incident. The affected population can be alerted about hazard through a number of routes including:

- personal letter
- general letter
- information leaflet
- door-to-door visit
- local media (radio, newspaper, television)
- public meeting
- e-mail
- the Internet

In addition other facilities can provide information for the public seeking information. For example, it may be necessary to set up a telephone helpline/information line. For a good précis of the pros and cons of different methods of communicating risk, see Sniffer (1999).

Care should be taken to ensure that vulnerable sections of the population are able to receive and act on information, for example, the elderly or disabled, particularly those living alone and/or those who are housebound. The need to provide information in languages other than English should also be considered. Contingency plans should be made for the possibility of an electricity failure, which would limit the methods available for contacting the public.

It should not be assumed that the public will not understand complex information, and uncertainties should not be covered up as a consistent conclusion from research on the subject is that this reduces public trust. In addition, in the age of the Internet, somebody is bound to find out if information is being distorted or hidden. Refer to
Boxes 3 and 4 for checklists of Do’s and Don’ts of written and verbal risk communication.

**Box 3: Dos and Don’ts of written risk communication**

<table>
<thead>
<tr>
<th>Things to do</th>
<th>Things to avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ Be as clear as possible about the data and its meaning</td>
<td>☑ Provide conflicting information to different audiences</td>
</tr>
<tr>
<td>☑ Highlight the way decisions were made</td>
<td>☑ Make promises you cannot keep</td>
</tr>
<tr>
<td>☑ Be constructive about the way risk is being communicated</td>
<td>☑ Justify involuntary risk by pointing at higher risk acceptance at voluntary risk</td>
</tr>
<tr>
<td>☑ Emphasise areas of value judgement, uncertainties and underlying assumptions</td>
<td>☑ Assume that no response means ‘all is well’</td>
</tr>
<tr>
<td>☑ Accept the concerns and fears as legitimate and understandable sentiments</td>
<td>☑ Don’t only admit to what you know ‘the other side’ knows already</td>
</tr>
<tr>
<td>☑ Respond positively to reasonable requests</td>
<td>☑ Change your story as you go along</td>
</tr>
<tr>
<td>☑ Offer further contact points</td>
<td>☑ Hide behind legal (or any other) jargon</td>
</tr>
<tr>
<td>☑ Make the message and the programme understandable</td>
<td>☑ Become confrontational</td>
</tr>
<tr>
<td>☑ Invite key individuals to take part</td>
<td></td>
</tr>
</tbody>
</table>

**Box 4: Dos and Don’ts of verbal risk communication**

<table>
<thead>
<tr>
<th>Things to do</th>
<th>Things to avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ Be as clear as possible about the data and its meaning</td>
<td>☑ Assume the ignorance of the audience. It is condescending, hazardous and often wrong.</td>
</tr>
<tr>
<td>☑ Highlight the way decisions were made</td>
<td>☑ Talking ‘at’ people, appearing too keen to get your own message across at the expense of answering the question</td>
</tr>
<tr>
<td>☑ Emphasise areas of value judgement, uncertainties and underlying assumptions</td>
<td>☑ Make promises you cannot keep</td>
</tr>
<tr>
<td>☑ Listen!</td>
<td>☑ Justify involuntary risk by pointing at</td>
</tr>
<tr>
<td>☑ Leave contact details for follow up</td>
<td></td>
</tr>
</tbody>
</table>
© Accept the concerns and fears as legitimate and understandable sentiments  
© Be as open and honest as possible  
© Empathise with the audience – how would you react if you were in their position?  
© Make the message and the programme understandable  
© Have an interdisciplinary team preparing and presenting the communication

<table>
<thead>
<tr>
<th>higher risk acceptance at voluntary risk</th>
<th>© Surprising the audience with new insights or data they could/should have had access to in advance</th>
<th>© Change your story as you go along</th>
</tr>
</thead>
<tbody>
<tr>
<td>© Act on the feeling of threat towards you</td>
<td>© Hide behind legal (or any other) jargon</td>
<td>© Allow individuals monopolise the debate</td>
</tr>
</tbody>
</table>

Regardless of the quality of the information provided, merely making information available is not the solution to eliminating public concern, particularly when managing more complex chronic problems. Information must be communicated effectively and there should be a provision for feedback so that there is a feeling that concerns have been heard and not just dismissed. A dynamic consultation process whereby local residents are able to request information, voice concerns and be satisfied with the response is needed.

**Communicating with the media**

A possible risk to public health is more likely to become a major story if any of the ‘media triggers’ listed in Box 5 become apparent. Media interest may amplify public awareness and concern about a particular issue. The media are often accused of sensationalising stories and fabricating the truth. Because of this the media are often regarded quite negatively when considering their role in communicating risk to the general public.
Box 5: Media triggers (Adapted from Communicating about risks to public health: pointers to good practice, NHS Executive, 1998)

- Questions of blame
- Alleged secrets and attempted “cover-ups”
- “Human interest” through identifiable celebrities, heroes, villains, dupes, etc. (as well as victims)
- Links with existing high-profile issues or personalities
- Conflict
- Signal value: the story as a portent of further ills
- Many people exposed to the risk, even if at low levels
- Strong visual impact
- Links to sex and/or crime

It is important to consider communications with the media at a very early stage of the incident because:

- the media can provide valuable assistance in providing information to the public on any precautionary action that should be taken to minimise adverse health effects.
- you can have a much greater influence over the information that is released to the public and reduce any unnecessary anxiety from inaccurate reports and ‘scare’ stories. If you do not provide information then the media will be compelled to obtain details from other potentially less reliable sources.
- the media may be a useful source of information.

When communicating with the media it is important to be very clear about the message you wish to convey. Consider putting your local press first as this will foster goodwill. It is usually from there that local TV and radio and the national media pick up stories to gain wider attention where this is appropriate. Using the media both to disseminate information to the public is considered to be of major value in the United States hence the development of the SOCHO (single over-riding communication health objective) sheet (Figure 1). This is a very practical and easy
to use tool that can be used in preparing a press statement or for a television or radio interview (Latham, 2000).

The aim of the SOCHO sheet is to put the onus on the interviewee to state the issue accurately and concisely and to give advice – not to elicit a sound bite or to ‘dumb down’ the information.

Releasing a joint press statement that has been agreed by all of the agencies involved in managing the incident is considered to be the most appropriate course of action. This ensures that all agencies involved are sharing the same information.
In one brief paragraph, please state the key point or objective of your (media/press story) submission. This statement should resemble what you, the writer, would like to see as the lead paragraph in a newspaper story or in a broadcast news report about your submission.

What are the three facts or statistics you would like the public to remember as a result of reading, or hearing about your story?

1.
2.
3.

What is the main audience or population segment that you would like this to reach?

Primary

Secondary

What is the one message the audience needs to take from this article?

Name:

Telephone number:
Site Investigation and Remediation

Chapter 11 from ‘The Environment and Public Health’ (Eagles et al., 2002)

Chapter aims and content

This chapter looks at the on-site response that may be required to manage an incident. The information will be most relevant for those dealing with historic (chronic) land contamination problems although more general topics include carrying out a site visit, identifying an unknown chemical, decontamination and personal protective equipment (PPE).

Introduction

Chemical incident management can broadly be divided into three stages as highlighted in Figure 1.

Figure 1- Three stages of chemical incident response and management

<table>
<thead>
<tr>
<th>STAGE 1: Emergency response</th>
<th>STAGE 2: Incident investigation</th>
<th>STAGE 3: Remedial action</th>
</tr>
</thead>
<tbody>
<tr>
<td>• usually involves the emergency services</td>
<td>• address health and environmental impact of event</td>
<td>• review options available for removal of contamination or inhibiting exposure pathways</td>
</tr>
<tr>
<td>• primary aim is to remove risk of explosion or fire</td>
<td>• identify source-pathway-receptor</td>
<td>• select and apply most appropriate option based on suitable for use approach</td>
</tr>
<tr>
<td>• chemical contained to prevent further contamination and migration</td>
<td>• undertake detailed site assessment if necessary</td>
<td>• continue care of affected individuals</td>
</tr>
<tr>
<td>• take immediate action to protect public health (shelter/evacuate)</td>
<td>• identify any affected individuals</td>
<td>• determine if long term environmental monitoring or epidemiological investigation is required</td>
</tr>
</tbody>
</table>

Emergency response

The immediate or emergency response to many chemical incidents involves the emergency services and often the Fire Service will take a lead role. When dealing with incidents that involve hazardous materials, frequently referred to as HAZMATS, the primary aim is to remove the risk of explosion and prevent pollution of controlled waters – surface water, such as rivers and streams, freshwater lakes and groundwater. Local residents may need to be evacuated largely, at this stage, due to risk of fire or explosion. Once this hazard has been mitigated, the contaminant needs
to be contained as far as possible to prevent wider migration of the chemical and
minimise further contamination. Control of the incident is then passed to the
appropriate regulatory authority for further investigation and management. This is
usually the local authority or the Environment Agency.

Also at this stage any immediate action required to protect public health, and in
particular any individuals that have been exposed, should be taken. Casualties may
require decontamination before further medical treatment. It is also imperative that
those managing the incident have appropriate personal protective equipment (PPE)
so that exposure is minimised. Further information about decontamination and PPE
is outlined in Box.1.

Box 1 - Personal decontamination and personal protective equipment

The NHS guidance on planning for major incidents issued in 1998, states that:
Health authorities must ensure that appropriate health care measures are being provided by acute
hospital trusts, ambulance trusts and other providers to (a) guard the health, safety and welfare of their
own employees and (b) assist and treat those people who have or may have been exposed to a
chemical incident, including:

- provision of protective clothing for those administering care either at the scene of the
  incident or at the receiving hospital(s); and
- availability of facilities for the decontamination of casualties, staff and equipment, either at
  the scene of the incident or at the receiving hospital(s).

Advice on decontamination and personal protective equipment (PPE) may be available from the
regional health emergency planning advisor (HEPA) or from relevant occupational health
professionals. The National Focus is currently reviewing guidance for decontamination/PPE on behalf
of the Department of Health.

Incident Investigation

The incident investigation stage addresses the health and environmental impact of the
event. It involves undertaking a detailed assessment and determining potential and
actual contaminant pathways. A contaminant pathway is the path taken by the
chemical between the source of contamination and the receptor (the person, product
or part of the environment that will potentially be affected by the chemical).
A site investigation may be carried out in order to identify and assess any hazards that may be present on a site. This information can then be used to determine whether any remedial action is required and what measures or controls need to be put in place in order to protect human health and the environment.

It is generally considered that a site investigation can be divided into two phases.

The initial assessment involves the collection and assessment of existing information about the site and the surrounding area, for example:

- maps
- plans
- photographs
- geological and hydrogeological records
- local records (for land contamination problems, information about the past industrial use of the site may be used to identify the contaminants likely to be present).

Once the information has been analysed a site visit is often carried out [refer to Box 2]. A site visit can help you to visualise the problem and enable a more informed assessment of the on-site and off-site risk. Site visits usually require collaboration between public health and other agencies that may be involved in the management of the incident, such as environmental health officers and pollution control officers as well as inspectors from the Environment Agency and the Health and Safety Executive.
Site visits and data collected for the subsequent report should aim to address, where relevant, the following issues.

Site identifiers
- Site name, i.e. address and location
- Site type (e.g. mine, landfill, spill etc.)
- Site status and description in terms of registration/official listing e.g. CIMAH, Integrated Pollution Prevention and Control (IPPC)
- EA/EHO contact name, phone number and fax number. Also names and grades of those who accompanied you on the site visit
- Description of problems/concerns. This may include perceived concerns of the referring authority and the real/actual concerns after assessment.

Site History
- Current and past uses of the site including buildings and areas where workers members of the public may be exposed to contaminants
- Dates of significant events (e.g. fires, changes in use etc.)
- Descriptions of any previous history of contamination on the site and any remedial action taken
- Information on the process of treatment, storage and disposal of hazardous waste on the site both currently and in the past
- Description of number and location of service pipes and utilities on the site, under the site or through the site and of over-head power lines, if present.

Recent meteorology and description of weather conditions during the site visit (if appropriate)

Geographic and demographic data
- Ordnance survey map co-ordinates of the site, the scale of the map used
Distance for the site to closest residence

Approximate population size residing within one mile radius of the site or within the potentially affected area, whichever is greater

Uses of the land in the surrounding area including schools, hospitals, residential care etc., in addition to features such as streams, agricultural land, water reservoirs, other industrial sites etc.

Topographic features of the land and description, where available, of geology of the region.

Location and relation ship to surroundings

On-site activities and estimated number of people involved in these activities

Barriers and fencing enclosing the site and preventing, where appropriate, public access

Security on site

Estimated frequency of on-site activities

The methods of transporting hazardous material to the site and off-site

Number of other potential sources of environmental contamination in the surrounding area

Description of safety procedure, if any, in place to limit exposure off-site

List of substances identified

List of chemical names and CAS numbers if known

Estimate of the quantities of contaminants released into each medium (soil, air, surface water, ground water)

Maximum concentration, range and extent of contamination of each medium, including where possible peak and trough concentrations

Potential or actual movement of the chemical by dispersion, diffusion etc.

Identification of waste materials and their quantities

Documentation of any chemical, mechanical, meteorological or other phenomenon that might rapidly alter the current physical state of the chemicals present or the general condition of the site (e.g. fire, tidal zone, rain earthquake etc.)

Documentation of potential toxicity to humans of each of the substances identified and any mixtures or compounds that might be formed, for example, as a result of combustion or atmospheric conditions.

Health Assessment

Documentation of any adverse health reports among the workers at the site; these may be categorised as acute, acute-on-chronic and chronic health effects

Ascertainment of any health complaints among the emergency services or those working on
the clean-up process
Documentation of safety measures being taken to contain the hazard - both occupational and public safety
Ascertainment of those with increased susceptibility to adverse health effects
Documentation of any reports of health complaints as a result of the incident among the local population; these may be categorised as acute, acute-on-chronic and chronic health effects
Plans for follow-up of those exposed.

Analytical information for biological and environmental sampling
Name and contact number of the laboratory conducting the analysis of samples
Description of the methods of sampling used
Detection and quantification limits for analytical data
Sample storage protocol and holding times
Number and location of all samples taken and date and time of sampling; reference to peak and trough samples should also be indicated where necessary
Assurance of care with sampling equipment and protective clothing to prevent cross-contamination of samples
Description of the level of quality assurance/ quality control guidance for the analytical process
Evidence of ‘chain of custody’, if necessary, for samples.

A meeting prior to the site visit will allow for agreement between agencies about the purpose of the visit and will provide the opportunity to raise any specific issues and concerns. It is important to ensure that all personnel visiting a potentially contaminated area wear appropriate personal protective equipment (PPE). At the end of the visit a further meeting to agree further actions and request additional information is invaluable. The public health practitioner should write a report of the site visit, so it might be useful to take a camera and a site visit report form (Form 1) to record incident details for future reference.

The results of this first phase of the site investigation will lead to one of the following conclusions:
- the site is free from contamination and that risk from exposure is negligible
- the site is contaminated and further investigation is required to determine the exact nature and extent of the contamination.
In the latter situation, further investigation is undertaken in order to:

- determine the distribution of contaminants (where and how much)
- identify possible hazards and potential exposure pathways
- determine the most appropriate clean-up option for the site

One of the most important stages of the site investigation process is sampling and analysis of the environmental media that may have been affected. Information from sampling points can be used to determine the distribution of contaminants and the volume of contaminated material. This can be done using calculations or computer models but these will not be discussed in any further detail at this stage.

Soil samples

This section will focus on soil sampling patterns although a more detailed discussion of collecting and analysing environmental samples is provided in Chapter 10 of ‘The Environment and Public Health’ (Eagles et al, 2002). In contaminated land investigation, a sampling programme is designed to establish the spatial distribution as well as the concentration of contaminants present. The sampling programme could be single or multistage. The extent of knowledge of where contaminant ‘hotspots’ or plumes are located within the soil will influence the sampling pattern selected. In practice, the information collected during the initial phase of the site investigation should provide a strong indication of the location of potential hotspots so a sampling pattern can be selected and modified accordingly. The obvious advantage of using a multistage sampling programme is that it is more flexible, but it is more expensive and time consuming. So if there is no indication of the spatial distribution of the contaminants, a multistage sampling programme should be undertaken with a series of wide-spaced samples taken initially to search for areas of significant contamination. Subsequent samples can then be taken from areas where contamination has been detected. Some sampling patterns are shown in Figure 2.
Figure 2 – Soil sampling patterns

1. X-pattern
2. W-pattern
3. Transects
4. Square grid
5. Rectangular grid
6. Diamond grid
7. Grid samples plus hotspots
8. Random
9. Stratified random
10. Herringbone
A review of the effectiveness of some of the patterns for locating elongate areas of contamination was carried out by Ferguson (1992). He concluded that
(a) the square grid sampling pattern is efficient for locating elongate hotspots but can suffer from severe loss of performance for elongate hotspots lying parallel to the grid direction;
(b) the stratified random pattern is a relatively poor performer and the simple random pattern is worst of all;
(c) the herringbone pattern is the best performer and is only very weakly influenced by the orientation of the hotspot.

In order to establish the vertical extent of the contamination, a series of samples are taken across the site. The depth of contamination can be determined by taking a series of samples from the same hole at different depths. Great care should be taken to collect representative samples and maintain sample integrity; for many contaminants the concentration sufficient to present a hazard is very low. This is especially true in the case of some Polycyclic Aromatic Hydrocarbons (PAHs).

Samples of contaminated soil may be obtained by excavation of trial pits or from boreholes. Manual sampling is only really practical to depths of <1m and the samples obtained are not always very representative.

Remedial Action
Once a site investigation has been undertaken, the nature and extent of contamination will have been assessed. This information can then be used to determine what level of clean up or 'remediation', if any, is required.

The aim of remedial action is to achieve one or possibly more of the following:
• remove or remediate the source of contamination;
• remove the pathway of exposure between the source and the receptor;
• remove the receptor from the location of the contamination.

Source removal
Examples of source removal are:
• extinguishing fires;
• clean up of spills;
• removing or remediating contaminated soil;
• flushing water pipes of contaminated drinking water;
• fitting a filter to an industrial facility to remove particulates.

Secondary contamination sources may also require removal or remediation. For example, mercury can be carried on clothing into homes and contaminate furnishings, and attempts at decontamination by occupants may result in further contamination of vacuum cleaners and washing machines.

With all removal techniques the contaminant still has to be disposed of somewhere. The aim, however, is to either render the chemical harmless or to keep it in a more appropriate location, away from populations and/or under conditions which prevent its escape. Some remedial options have the potential to remove the source of contamination completely, rather than just moving it somewhere else. Some examples for land contamination are discussed later in this chapter.

Pathway removal
Removing the pathway involves making the chemical unavailable to the receptor, which, in terms of risks to public health, is usually humans, but may also be animals, plants or buildings. For example, pathway removal may occur in contaminated land by stopping people eating plants grown in contaminated soil, or providing plastic coated metal pipes to prevent chemical contamination of water supplies through permeation. Alternatively, chemicals could be solidified so they can no longer move and therefore cannot be taken up by plants for human consumption or contaminate water sources. In an incident of drinking water contamination, the pathway between the contaminant and the population at risk could be removed by preventing the population from drinking or using the water. In an incident of acute outdoor air contamination, for example as the result of a fire, the pathway can be removed by advising those at risk to remain indoors with windows and doors shut to prevent or reduce ingress of the contaminants into the house (sheltering). Obviously some
pathway removal measures can only be temporary and some sort of source removal or remediation will be required in the long-term.

**Receptor removal**

Focusing on human populations, the most common method for removing the receptor would be the evacuation of the population at risk away from sources or pathways of contamination and chemical exposure. Such action may be most appropriate in circumstances of significant environmental contamination, for example the Love Canal hazardous waste incident.

Figure 3 illustrates a more detailed version of the source-pathway-receptor model introduced in Chapter 2 of ‘The Environment and Public Health’ (Eagles et al, 2002). It outlines the information required to describe each stage and the methods that can be implemented in order to minimise exposure.

**Remediation options for contaminated land**

In the UK, the level of remediation undertaken on a particular site is based on a ‘suitable for use’ approach. This means that risks to human health and the environment are assessed based on the current or intended future land use and any remedial action undertaken should ensure that those risks are mitigated. It is considered that risks from contaminated land can be satisfactorily assessed only in the context of specific uses of the land (whether current or proposed), and that any attempt to guess what might be needed at some time in the future for other uses is likely to result either in premature work (thereby distorting social, economic and environmental priorities) or in unnecessary work (thereby wasting resources) (DETR).

Options for the remedial treatment of contaminated land can broadly be divided into three categories:

- excavation and disposal
- containment
- treatment
Figure 3 - Source-pathway-receptor model and remediation

- **Chemical Source**
  - **what is the chemical/mixture of chemicals?**
  - **where is the chemical located?**
  - **how much of the chemical is**

- **Exposure Pathway**
  - **what is the pathway?**
  - **how are people being exposed, ingestion, inhalation contact with skin, eye, mucous membranes?**

- **Human Receptor**
  - **how many people are exposed?**
  - **who has been exposed, e.g. young, old?**
  - **what is the exposure, concentration and duration?**

- **Health Impact**

---

**Remove the chemical from:**
- air
- water
- land

Fire service extinguish fires and contain/clean-up hazardous substances

Consider shut-down of hazardous/polluting facilities
- where necessary contact
- local authority
- Environment Agency
- specialist waste company
- to clean up and safely dispose of chemicals

**Remove the pathway**
- shut windows/doors and air conditioning inlets to keep out polluted air
- drinking water
- stop consumers drinking/using water
- stop manufacturers using water
- surface/ground/marine water
- stop abstractions for drinking water, industry and agriculture
- stop recreational uses of the water
- stop physical contact with or growing food on contaminated land
- stop consumption of contaminated food

**Remove people from the contamination and/or monitor health impact**
- questionnaire – identify exposure and symptoms
- biological sampling to assess level of exposure and health impact
- ask GPs, hospitals, etc. for reports of adverse health effects
- consult disease registers for unexpectedly high rates of disease
- epidemiological study
- establish cause and effect
- long term follow up of disease outcomes

---

C-36
The most important factors to take into consideration when deciding what remediation technique to employ to clean up a particular site are:

- What is the land currently used for and what will it be used for in the future?
- What type of contamination is present, e.g. solid, liquid, gaseous?
- What is the cost of carrying out each of the appropriate remedial methods?
- What are the geological conditions, e.g. soil type, porosity, water levels in the soil?

In addition, it is important to consider how reactive (physically, chemically or biologically) and how mobile the chemicals are.

Until recently in the UK, the first choice of remedial solution has been to excavate the soil and transport it to a licensed landfill site (this is an example of source removal). This option has a comparatively low cost and the 'process' is well understood. Other methods used are capping or covering and containment (this is an example of pathway removal). However, in light of the introduction of landfill tax, disposal to landfill has become an increasingly expensive option and resulted the need to explore alternative solutions for cleaning up contaminated soil. These broadly fit into two categories – insitu (no excavation of soil material is required) and exsitu (soil is removed from the site and treated elsewhere). A number of the options that have been explored are outlined in Figure 4. Those underlined are summarized below.

**Vitrification**

This involves raising the temperature of contaminated soil to a high enough level to cause it to melt. The organic compounds are then driven off or oxidised into simpler compounds. On cooling, the soil solidifies into a glass like material, which contains the inorganic contaminants. These contaminants are then stabilised in the vitrified soil, which is impermeable and has very low leaching characteristics. This is an insitu process. This process has also been used for the containment of radioactive waste.
Figure 4 - Remediation Options (Taken from ‘Remedial Processes for Contaminated Land’, edited by Malcolm Pratt, IChemE 1993)

Stabilisation & Solidification
Stabilisation involves mixing reagents, such as cement, lime or others, with contaminated soil or sediment in order to minimise the mobility of contaminants and reduce the toxicity of the media. Solidification involves mixing additives with the soil to improve the engineering properties (for example, compressive strength, permeability etc.). These two processes are often used together in many remediation applications and can take place insitu or exsitu.

Biological treatment
Bioremediation is a destructive remediation technique that uses microbial processes to break down contaminants in the soil. The technique is used mostly for organic compounds for example, petroleum hydrocarbons, pesticides and solvents and takes advantage of the natural ability of living things to remove hazards that threaten humans and animals. The process may be aerobic (in the presence of oxygen) or anaerobic (in the absence of oxygen).
Microbial breakdown usually occurs naturally in contaminated soil, but the process is often very slow and incomplete. Circulating nutrients and oxygen through the soil and optimising the temperature and pH can be used to modify and enhance the process. This is referred to as biostimulation.

Sometimes the organisms that are able to utilise the contaminant are poor competitors and so specially bred micro-organisms or pre adapted cultures are added to the soil. This is called bioaugmentation.

Problems may occur if contaminants are broken down into intermediate products that are equally or more harmful than the original, for example, trichloroethylene anaerobically degrades to vinyl chloride.

Bioventing is a process in which air is either injected or extracted to force air movement in the contaminated soil – increasing oxygen levels in the soil enhances natural degradation processes.

**Vacuum extraction**

This is a common technique for the removal of volatile organic compounds (VOCs) from contaminated land. A vacuum is applied through extraction wells to create a pressure gradient. The reduced vapour pressure in the wells causes air and VOCs to flow out through the extraction wells.
Form 1: Site visit report form

**Site**

**Date** 

**Time**

**Who visited**

**Incident summary**

---

### FURTHER INFORMATION

1. Who has identified the issue to the health agency?

<table>
<thead>
<tr>
<th>Local Authority</th>
<th>Local Residents</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment Agency</td>
<td>Emergency Services</td>
<td></td>
</tr>
</tbody>
</table>

2. How was the issue discovered?

<table>
<thead>
<tr>
<th>Spill, leak, explosion etc*</th>
<th>Planning application</th>
<th>Complaint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine testing **</td>
<td>Change of land use</td>
<td>Other:</td>
</tr>
</tbody>
</table>

* or other acute incident  
** planned by the Environmental Health Department of the Local Authority

3. How long has there been a problem?
4. Who is currently involved in the incident including the incident investigation?

SITE SPECIFIC INFORMATION

5. Where is the site? (Postcode if possible)
6. How big is the site (acres/hectares)?
7. Is the area predominantly rural or urban?

8. What is known about the history of the site and the adjacent land?

9. What is the site currently used for?

<table>
<thead>
<tr>
<th>Parkland</th>
<th>Light Commercial</th>
<th>Allotments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>Heavy Industry</td>
<td>Farming</td>
</tr>
<tr>
<td>Derelict &amp; abandoned site</td>
<td>Other:</td>
<td></td>
</tr>
</tbody>
</table>

10. What is the soil type?

<table>
<thead>
<tr>
<th>Sand</th>
<th>Clay</th>
<th>Mixed</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt</td>
<td>Loam</td>
<td>Mixed waste material</td>
<td></td>
</tr>
</tbody>
</table>

11. What is the underlying geology/hydrology?  

(A) Is the site on/near an aquifer?  
(B) Is there an abstraction point on or near to the site?  
(C) Do any (plastic) water pipes run through the ground?  
(D) Other

Yes No
12. Does a stream/river flow through or near to the site?

13. What is the topography?

14. What is the prevailing wind direction?

15. How close is the nearest property to the site?

**CONTAMINANTS IN THE SOIL**

16. What chemical(s) is present?

17. What form is the chemical(s) in?

18. What levels of chemicals have been detected in the soil?

19. How many samples have been taken?

20. Who has taken the samples?

21. How were the samples taken? (Sampling strategy?)

22. Where have the samples been sent for analysis? (UKAS accredited laboratory?)

**INITIAL HAZARD & RISK ASSESSMENT**

23. Have there been any complaints of health problems that may be associated with exposure to the chemical(s)?
24. Is there a pathway between the source of the contamination and any potential targets (human, animal etc.)?

25. Is further sampling, environmental or biological, required?

26. What (if any) immediate action is required? (evacuation etc.)

27. Can the chemical be controlled/contained immediately?

28. What steps need to be taken to prevent further contamination? (Short and long term considerations)

**ACTIONS**

Site visit report written by
Date
APPENDIX D
D. LONDON SECTOR CBRN PROJECT GROUP MEETING

The aim of the project group meeting in July 2002 was to discuss and scope the possibility of developing a support structure and the implementation of a common framework for the public health (PH) response to hazardous incidents, to include accidental and deliberate chemical, biological, radiological and nuclear incidents (CBRN).

A template plan for PCTs had already been developed and circulated, which comprises a framework addressing their core services but not addressing either the public health response or the health economy co-ordination function. This is now required urgently for the five sectors upon which those functions are now focused, co-terminal with the health protection units, new health authorities and NHS Direct boundaries. This needs to be complemented by regional and hopefully national structures.

It was understood that there are a number of groups and individuals undergoing similar work, with varied timelines to completion. Maximum use should be made of such activity, while not hindering a rapid outcome to support the development of London arrangements.

It was felt that there was a need to streamline public health emergency response and bring CBRN incident management alongside other emergency response structures within the NHS. This would need to ensure that clinical response issues as well as the management response of the NHS to support this are fully integrated. All incidents, whether public health emergencies or not within the sector should be supported by a joint PH and NHS management response team.

The project team are a Regional HEPA (David Donegan), a CIRS representative (Emma Eagles) and 2 SPRs in public health (Abdu Mohidden SE Sector) and (Anita Roche SW Sector).
Notes from meeting:

**Defining the role of public health**

The role of public health in responding to and managing CBRN incidents needed to be more clearly defined, since the role was quite vague and the expectations of other agencies that may also be involved in managing incidents varied. In particular we needed to think about:

- does the role of PH differs in CBRN incidents...what are the similarities/differences?
- where does PH fit in within the NHS and with other agencies?
- defining the public health function as well as the role of individuals
- obtaining clear expectations and role endorsement from DH and other stakeholders

It was agreed that professional acceptance and ‘ownership’ were key to the success of the strategy, thus highlighting the need for involvement and consultation of public health practitioners.

**Actions:**

- define role of PH and PH functions
- identify and review all of the guidance which currently exists
- identify and review UK legislation as it reflects guidance
- establish expectations and role endorsement (consultation)

**CBRN incidents – Common Features & Notable Variance**

Some guidance and legislation for the management of CBRN incidents already existed but this was not generic. Therefore we needed to consider C,B,R, and N incidents separately and then compare and contrast:

- legislation
- guidance
- definitions of role (see above)
functions, actions and services provided in each scenario

It was anticipated that there would be much commonality between conventional outbreak management, chemical incident management, nuclear weapon incident management and terrorism responses to deliberate release and that it would subsequently be possible to identify common features, in particular triggers and timescales that can be used to outline actions, functions and services of public health.

Actions:
- compare and contrast CBRN models used to respond to incidents
  - what is common?
  - what is different?
- agencies and structures

Identifying ‘best practice’
The new framework should reflect current best practice. We needed to identify what this was although it was agreed that there was limited reporting of lessons learned from past incidents, especially in the biological field and hence incomplete evidence on which to base any conclusions.

It was also considered useful to obtain copies of some (good) on-call packs and to find out if there is a pro-forma for reporting incidents exists.

Actions:
- establish evidence
- literature review – published guidance/Internet
- incidents – professional and peer consultation
- what we/they like and identify as ‘best practice’
- identify gaps in research and other evidence
Anticipated project outcome

- clear definition of role and function of both individuals and the public health response
- decision support tool for incident and risk assessment
- reflective escalation pathway indicating required actions at each level
- model within which this structure was best supported at each level
- practical guide to ‘making’ it happen (control room etc.)
- public health management guide
- integrated management response guide

Actions:

- build risk assessment and filter action tool
- develop model for response
  - evidence
  - escalation
  - team response
  - plan – on-call pack
- review supporting system and links required to effect the desired outcome.

Synopsis

It was realised that a thorough appraisal of the subject as outlined and the activity to address the task was a significant resource undertaking. Against the short time scale for the consultation draft, it was realised that the likely outcome would be an informed ‘best’ guess. While the skeleton framework was being consulted and implemented, the more detailed material to support that structure could be built in to the system as key targets completed by individuals and the team.

A first draft of the proposed framework was released for consultation in September 2002 and it was anticipated that the final version would be completed by November 2002.
E. LAND CONTAMINATION AND HUMAN HEALTH

The link between the quality of the environment and human health has been recognised for centuries but recent years have seen increasing interest in the interactions between humans and the environment within which they live. Environmental problems are often perceived to have a potential public health impact. Yet it is only in the past twenty years following incidents such as Love Canal in New York State (Johnson & Covello (eds.), 1987; Jackson, 1996) that soil has been identified as an important exposure route to potentially toxic substances (Hynes, 1997; RCEP, 1996). Indeed, Abrahams (2001) believes that the association between the health of humans and the quality of the world’s soils has been ‘under appreciated and under reported’.

There are a number of reasons why this may be. Firstly soil is perceived to be dirty - we often refer to it as ‘dirt’ - so contamination may be less obvious than contaminated air or water that may have a strange taste or odour. Secondly human interaction with soil is less frequent than with the other environmental media. Contaminants do not disperse as far or as quickly in soil as they do through air and water so any adverse health effects may be very localised and also exposure may occur several years after the initial pollution incident. Nevertheless, it is now believed that soil pollution should be given the same priority as pollution of air or water (RCEP, 1996; Sims et al, 1997) and Senesi et al (1999) describe soils as the most important environmental compartment functioning as a sink for trace elements released by human activities.

Soil can affect human health in several ways leading either to specific diseases or to more general ill health (Oliver, 1997). However, direct links between soil quality and human health are often difficult to establish and many of the examples that do exist have not been quantified (Abrahams, 2001; Oliver, 1997; Thornton, (1987)). A number of reasons for this are delineated in the literature. For example most trace elements tend to accumulate in mammalian tissues, even at low exposure doses, representing a subtle environmental health hazard (Senesi et al, 1999).
Exposure to elevated levels of chemical substances in soil may occur through eating vegetables that have been grown in contaminated soil, inhalation of soil vapour or dust, dermal contact or through direct ingestion of the soil. Paustenbach et al (1992) outline the most significant exposure routes that need to be considered for different land use scenarios (Table 1).

Table 1: Most significant exposure pathways for different land use scenarios

<table>
<thead>
<tr>
<th>Residential</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil/dust ingestion</td>
<td></td>
</tr>
<tr>
<td>Dermal uptake</td>
<td></td>
</tr>
<tr>
<td>Garden vegetable ingestion</td>
<td></td>
</tr>
<tr>
<td>Dermatitis hazard</td>
<td></td>
</tr>
<tr>
<td>Recreational</td>
<td></td>
</tr>
<tr>
<td>Soil ingestion</td>
<td></td>
</tr>
<tr>
<td>Dermal contact</td>
<td></td>
</tr>
<tr>
<td>Runoff</td>
<td></td>
</tr>
<tr>
<td>Agricultural</td>
<td></td>
</tr>
<tr>
<td>Uptake via crops</td>
<td></td>
</tr>
<tr>
<td>Uptake by grazing animals</td>
<td></td>
</tr>
<tr>
<td>Runoff</td>
<td></td>
</tr>
<tr>
<td>Groundwater hazard</td>
<td></td>
</tr>
<tr>
<td>Fugitive dust</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
</tr>
<tr>
<td>Soil ingestion</td>
<td></td>
</tr>
<tr>
<td>Dermal uptake</td>
<td></td>
</tr>
<tr>
<td>Inhalation of fugitive dust</td>
<td></td>
</tr>
<tr>
<td>Groundwater/runoff</td>
<td></td>
</tr>
<tr>
<td>Wildlife</td>
<td></td>
</tr>
<tr>
<td>Uptake by birds</td>
<td></td>
</tr>
<tr>
<td>Adverse effects of predator food chain</td>
<td></td>
</tr>
<tr>
<td>Effects on development and reproduction</td>
<td></td>
</tr>
</tbody>
</table>

As soil ingestion is highlighted as the most significant exposure pathway in most settings, this will be considered in more detail.

Ingestion
All members of an exposed population will inadvertently ingest small quantities of soil (Ferguson & Marsh, 1993). The majority of soil ingested by adults is thought to occur through hand to mouth contact and soil on produce (Paustenbach et al, 1992). However, some people, especially young children who are exploring their surroundings, may deliberately eat small quantities of soil. Ingestion of substances
that are not normally regarded as edible is referred to as pica; more specifically the deliberate ingestion of soil is referred to as geophagia (Abrahams, 2001).

Most studies have investigated children because of their vulnerability to soil ingestion (Abrahams, 2001). An example is presented by Calabrese et al (1997), who discuss the possibility for child soil pica episodes to result in acute intoxication in cases where contaminant concentrations in the soil are considered to be below health based guideline levels set by the United States Environmental Protection Agency (US EPA). US EPA exposure assessments and guidelines derived from these are based on the premise that 95% of children ingest 200 mg soil/day. However, findings indicate that during an acute soil pica episode, a child may ingest up to 50g of soil. There have been many more studies and reports published on childhood pica and assessing risk to human health due to the deliberate ingestion of contaminated soil. However, a detailed investigation of these is considered to be beyond the scope of this literature review.

As a point of interest, in an agricultural setting where animals will consume crops grown in contaminated soil, they may also ingest considerable quantities of soil (cattle ingest an average of 0.9kg soil a day). Lipophilic chemicals accumulate in beef tissue and fat, which then provide humans who eat the meat with a significant dose.

Some trace elements including arsenic, cadmium, lead and mercury, are known to be harmful to human health in excessive quantities. These elements naturally exist at elevated levels in some soils because of the parent rock from which they were broken down. Therefore an addition of these elements through anthropogenic activity, such as mining or smelting, may result in very high levels of the chemical in the soil. Examples include greatly enhanced levels of arsenic and copper in soils contaminated by drainage waters and stream sediments from mining and smelting in South West England and much higher than normal levels of copper, lead, zinc and cadmium in soils downstream from disused mines in Wales (Senesi et al, 1999).
In addition, some elements are antagonists - one blocks the toxic effects of the other. Other elements are synergistic and enhance each other's effect, for example lead and cadmium. This means that even small doses can have an adverse impact on health (Oliver, 1997)

**Lead**

Most of the research into toxicity of elements via soil ingestion has concerned lead (Abrahams, 2001). A summary of lead toxicity is presented in Box 1.

Box 1: A summary of lead toxicity (Farrow et al, 2000)

<table>
<thead>
<tr>
<th>How is lead absorbed into the body?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organic lead</strong></td>
</tr>
<tr>
<td>Inhalation is the primary route of absorption for organic lead. On inhalation organic lead can cause severe toxicity with symptoms occurring a few hours to 10 days post exposure. It can also be absorbed by ingestion and via the skin.</td>
</tr>
<tr>
<td><strong>Inorganic lead</strong></td>
</tr>
<tr>
<td>Absorption of inorganic lead by inhalation depends upon particulate size and physical state of the compound; 50 to 70% of an inhaled dose is absorbed if the particle size (&lt;1 μm) allows the material to reach the alveoli. It can also be absorbed by ingestion.</td>
</tr>
</tbody>
</table>

Absorbed lead is stored in the bone. In continued exposure, the lead, which is first only loosely deposited in bone, gradually becomes fixed to bone.

<table>
<thead>
<tr>
<th>How does lead affect the body?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acute exposure</strong></td>
</tr>
<tr>
<td>Organic Lead: Initial effects are anorexia, nausea, vomiting, insomnia, tremor, weakness, fatigue, headache, aggression, depression, irritability, restlessness, hyperactivity, confusion and memory impairment. Acute mania, convulsions, delirium, fever and coma may be delayed for hours or days. Apparent complete recovery can take 2-6 months to occur and some effects may persist for longer.</td>
</tr>
<tr>
<td>Inorganic Lead: Large amounts of inhaled or ingested lead may cause nausea, vomiting, anorexia and abdominal pain. Malaise, convulsions, encephalopathy, hepatic and renal damage, anaemia, hypertension and bradycardia may occur.</td>
</tr>
<tr>
<td><strong>Chronic exposure</strong></td>
</tr>
<tr>
<td>Chronic exposure to excessive lead in children can cause brain damage, affect growth, damage kidneys, impair hearing, and cause learning and behavioral problems. In adults, lead can increase blood pressure and can cause digestive problems, kidney damage, nerve disorders, sleep problems, muscle and joint pain, and mood changes. Foetuses, infants, and children are more vulnerable to lead exposure than adults since lead is more easily absorbed into growing bodies. Also, the tissues of small children are more sensitive to the damaging effects of lead.</td>
</tr>
</tbody>
</table>
Lead may occur naturally in the soil but it is generally present as the result of mineral and industrial waste (Oliver, 1997) and atmospheric deposition from, for example, vehicle exhaust prior to the removal of lead from petrol. The main exposure routes by which lead can enter the body are direct ingestion of the soil and inhalation of soil dust. In addition, lead uptake by vegetables grown in urban soils may be a significant exposure route particularly in areas where there is some industrial contamination (Thornton, 1993).

A number of studies were carried out by Thornton et al. (1994), which looked at lead contamination of UK dusts and soils and the implications for childhood exposure. Samples of dusts and soils were collected and analysed for 53 locations in England, Scotland and Wales, including areas that were known to be ‘geochemical hotspots’. In the UK geochemical hotspots are mostly related to widespread metal contamination of the surface environment due to historical mining and smelting activities (Thornton, 1993). Results of the studies demonstrated that concentrations of lead in dusts and soils were sufficiently large to give rise to concern that a proportion of urban children were likely to be exposed to significant amounts of lead and overall, 10% of homes had in excess of 2000 µg/g lead in house dust. 5% of garden soils were above this level.

Cadmium

Cadmium is another potentially toxic metal that occurs naturally in soil in small amounts (usually less than 1 µg/g), but which is often present at much higher levels due to anthropogenic activities. The main pathway by which cadmium enters the body is the ingestion of contaminated food (Thornton, 1992; Oliver, 1997). It has been recognised that cadmium accumulates in food plants including lettuce, spinach, celery, and cabbage, often in large amounts, without having phytotoxic effects (Oliver, 1997). This means that high levels of cadmium may be consumed unknowingly through the consumption of contaminated food produce and individuals who consume homegrown vegetables from allotments and domestic gardens with elevated soil cadmium concentrations may significantly increase their exposure (Thornton, 1992).
Cadmium can also enter the human body through inhalation but this pathway is less important except in industrially exposed workers and people living close to an emission source (Commission of the European Communities, 1978, cited by Thornton, 1992).

This next case summarises probably the most reported example of ingestion of food grown in soil contaminated with heavy metals that resulted in adverse human health effects.

Shortly after the end of the Second World War, there was a high incidence of a bone disease in Jinzu Valley, Toyoma Province, Japan. The disease, referred to as itai-itai which means ‘ouch’ in Japanese, attacks bones and causes them to become thin and break and is closely linked to exposure to heavy metals and in particular cadmium. Mining operations for lead, zinc and cadmium had taken place upstream of the affected area and mining waste had been dumped in the river. Farmers then used the river for the irrigation of crops and for drinking water.

The link between the disease and the contaminated food and water was not made until the 1960’s when samples of tissue and bones from the victims of the disease were examined and found to contain alarmingly high levels of zinc, lead and cadmium. Samples of soil collected were found to contain an average of 6 parts per million cadmium and this increased to 125 parts per million in the rice (Keller, 1992; CIRS, 1999).

Zinc

During the eighteenth and nineteenth century, zinc was mined around the village of Shipham in Somerset. A study carried out by Thornton et al (1980) highlighted that over 90% of the surface soils sampled in and around the village contained in excess of 20µg/g cadmium and 60% exceeded 60 µg/g. The highest level detected was 800 µg/g. In actual fact the levels detected in the Shipham soil were considerably higher than those detected in Japan and yet no adverse health effects have been reported. Harrison (1992?) suggested the reason for this is that although the levels were higher, the bioavailability was much lower. Potentially, the large amounts of zinc and
calcium also present in the soil had provided some degree of protection against the possible adverse effects of cadmium (Thornton, 1987). In contrast, Oliver (1997) suggested that the residents had not suffered any adverse health effects because only about half of the vegetables consumed were local and therefore only a small part of their diet was grown on polluted soil.

There has not been a considerable amount of work associated with potential adverse health effects that could result through dermal contact with contaminated soil, yet Abrahams (2001) suggests that the dermal pathway can contribute a significant or even predominant portion of the risks attributable to contaminated soils. Ferguson (1996) believes that the uncertainties associated with dermal exposure to soil contaminants may exceed those of all other pathways combined and suggests that this reflects the lack of knowledge about key exposure parameters. These include the nature, frequency and duration of contact and the area of skin exposed.

**Hazardous waste issues**

A number of examples in the literature describe circumstances where land contamination and adverse health problems have resulted from the inappropriate disposal of hazardous waste. Probably the most famous of these examples, which resulted in the declaration of a national emergency in New York State in 1978, is Love Canal. In 1896 William Love began digging a canal to serve as a water power conduit connecting Lake Ontario and Lake Erie (bypassing Niagara Falls), hence the nickname ‘Love Canal’. It was never completed. However, the Hooker Chemical Company, located west of the canal, used the site as a dumping ground for the chemical by-products of its manufacturing processes. The company dumped more than 40000 tonnes of toxic chemical waste (Jackson, 1996). Once the canal was filled with waste, the land was covered over and sold to the local education board in 1953 for $1.00. A school and later a housing estate were built on top of the waste dump.

In the early 1970s, the site was found to be leaking. Residents complained of respiratory problems and skin irritations. Samples of soil and water taken from the area of the old waste dump were heavily contaminated with a number of toxic
chemicals. After some time and a great deal of pressure from local action groups, the government declared a state of emergency and many residents were evacuated.

Another example of land contamination in the Netherlands that resulted from inappropriate disposal of waste led to the development of Target and Intervention values to assess whether a soil contaminant is likely to present a hazard to human health. The levels were developed in the 1980’s following an incident at Lekkerkerk – 1600 drums of toxic waste, which had been dumped illegally, were discovered at a site that had been redeveloped for housing. Chemicals, including toluene, seeped into groundwater and voids in the ground below the houses and resulted in clean-up costs of about £150 million.

**Conclusion**

Whilst direct links between soil quality and human health are often difficult to establish and many of the examples that do exist have not been quantified, this review has illustrated that some relationships between exposure to elevated levels of trace elements in soil and adverse health effects in humans have been recognised. There is no clear evidence to substantiate that anyone has become seriously ill as a direct result of exposure to contaminants in soil. However, recognition of the contribution from soil to the total daily intake of a substance is critical to improving our understanding of how environmental contamination can adversely impact on human health.

Smith (1991) (cited by Beckett (1993) provides a very thought provoking quote with which to conclude this review....

“*It should also be recognised that some of the possible effects of exposure of humans to chemicals are so intangible, when set against the variations in human well-being, that it will never, except in a few unfortunate cases, be possible to demonstrate a cause and effect relationship between exposure to a contaminated site and current, or more probably future, ill health....to ask to be shown a site where exposure to a particular level of contamination has caused harm is rarely a sensible question to ask. We do not generally have the tools, or the time, to be able to answer it.*”
F. THE ROLE OF THE FIRE BRIGADE IN CHEMICAL INCIDENT RESPONSE

1. Visit to London Fire Brigade Headquarters
A meeting took place at London Fire Brigade Headquarters with Dave Hanlon, Hazmat Officer with responsibility for Environmental Protection, on Monday 17th January. The aim of the meeting was to answer a number of questions that have arisen as a result of the EngD research project into emergency response to chemical spills and the management of such events. These include:

- Where does the role and responsibility of the Fire Brigade begin and end?
- Is a set protocol/procedure followed for the containment and clean up of leaks and spills?
- What materials are used in decontamination?
- What other groups/organisation are involved in the management of such events/incidents?

The Fire Brigade provides a safety critical service and therefore undertaking a risk assessment forms a key part of decision-making. An example discussed was that of a fire in a building with a settling cylinder that could potentially explode. A risk assessment would be undertaken to determine the most appropriate way to fight the fire. It would be considered wise to fight the fire from outside the building unless there were people inside in which case a rescue operation would be undertaken but with more controls (PPE etc).

The risk assessment process can be broken down into three interrelated parts.

STRATEGIC
- Primary and most important level of decision making
- Higher risk = greater input into risk reduction and control strategies
- Defines safety critical support issues for all personnel
- Ensures the provision of appropriate ‘management systems’ to achieve
- Safe systems of work
- Training
- Equipment
- Information
- Supervision
- PPE

SYSTEMATIC

- Provides a model for assessing all foreseeable hazards and risks
- Output – the development of a ‘risk inventory’
- Significant risks analysed, assessed and appropriate control measures identified and put in place
- Risk assessment divided into manageable ‘key stages’ by taking the following steps:
  - Separation of risk into three domains: Activities, Environment and Equipment
  - Domains examined and broken down into further ‘key stages’
  - ‘Risk Menu’ and ‘Activity Matrix’ generated at each key stage
  - Significant risks identified and documented for future reference
  - Significance of risk calculated (Risk = Hazard severity x Likelihood of occurrence)
  - Risks prioritised using a ‘Risk Grid’
  - Additional control measures implemented
  - Risk assessment process reviewed

DYNAMIC

Designed to support decision making when faced with unforeseen situations – reactive assessment of risk

- Divided into three stages
  - Risk analysis
  - Risk assessment Followed by post incident review
  - Risk management
Dealing with a spill

In the 1947 Fire Services Act a requirement was set to provide a Fire Brigade with facilities to mobilise personnel who would be trained to visit premises to look at hazards and risks and use equipment for other things in addition to fires, including incidents involving hazardous materials. There is no requirement to take charge in such events but this frequently happens. In addition there is currently no funding for dealing with incidents involving hazardous materials.

However, most UK fire brigades have taken the initiative and acquired appropriate equipment including ‘Grab Packs’ (which contain putty for sealing leaks, absorbent pads, a clay mat etc.) in addition to dedicated environmental protection units. The equipment carried on dedicated units is agreed between the Fire Brigade and the Environment Agency at a local level. This is principally because the nature of incidents is likely to vary. For example if the area is heavily industrialised then there is greater potential for a chemical spill than in the countryside.

When dealing with incidents that involve hazardous materials, the primary aim is to remove the risk of explosion and prevent pollution of controlled waters. There are six main concepts to consider. These are:

Ensuring a safe approach.
When approaching the site of an incident involving hazardous materials care should be taken to avoid the ‘plume’, which may be smoke or a vapour cloud. Hazardous materials are often flammable or explosive and the smoke they produce on combustion may be toxic. In addition the spilt chemical may release toxic vapours.

Accurate incident assessment.
A hazard assessment must be undertaken initially to ascertain the nature and extent of the problem. This will take into consideration such factors as wind direction, gradient and the physical properties of the hazardous material. The action taken in the event of an incident involving hazardous materials will vary according to the situation. Actions can be offensive (an active approach), defensive (not involving direct intervention) and non-interventionist.
Establishing a security perimeter.
A security perimeter controlled by the police might be necessary. The purpose of this would be to allow emergency workers to function without hindrance, maintain the safety of the general public and exclude all unauthorised personnel.

Establishing hazard control zones.
The affected area should be cordoned off and hazardous and safe zones identified. These are often categorised as:

- Hot zone – area directly affected
- Warm zone – for fire service support activity
- Cold zone – for incident management and liaison

Effective control of resources
Equipment tends to be depleted faster at incidents involving hazardous materials compared with fires. Therefore it is necessary to anticipate resource requirements to prevent incident escalation. This is especially important as it is considered that most serious chemical incidents start as small ones but may develop as a result of:

- lack of anticipation
- lack of resources
- failure to be proactive in command
- lack of understanding of the situation
- establishing a support organisation

In responding to incidents involving hazardous materials, one of the primary aims is to develop and implement a pollution control strategy. The incident commander (or HAZMAT adviser) will work in close liaison with other emergency services as well as staff from the Environment Agency.

There are considered to be seven options available for the control or containment of a serious spill. These are diversion, covering, damming, diking, dilution, absorption or dispersion. The most appropriate method of pollution control will be determined by reviewing the properties of the substance or substances involved. This will include
the strength of the solution, its miscibility in water and whether it is flammable or explosive. If the substance is flammable or produces toxic vapours then it may be necessary to cover the spill, for example with a foam blanket, to mitigate.

A leak or spill of a hazardous material (and decontamination runoff) should be contained if at all possible. If containment is not possible the substance should be diluted. However, four criteria must be met prior to diluting a spill with water. The substance should be water-soluble but it must not react with water, produce a toxic gas on water contact or form any kind of solid or precipitate.

Once the spill has been contained, advice can be sought on the most appropriate method for decontamination. Responsibility for leading the clean-up operation is then passed to the Environment Agency (or other regulatory body) although fire brigade equipment and other resources may be used.

To ensure effective co-operation between the Fire Service and the Environment Agency in dealing with incidents that involve the potential pollution of controlled waters, the disposal of waste, Part A IPC authorised sites, COMAH sites and/or the release of radioactive substances, the Local Government Association and Environment Agency have written a Protocol on fire service issues. This will replace the ‘Memorandum of Understanding’ that currently exists between the Fire Service and the Environment Agency. The purpose of the Protocol is to minimise the hazard to the environment from Fire Service activities, including fire fighting and hazardous materials incidents, and to encourage liaison and formulate preventive measures at the planning stage for special risk sites where there is the potential for pollution to occur during an incident. However, it is acknowledged that life-saving operational procedures take priority over pollution prevention in the event of a major incident.

The HAZCHEM scheme

In the early 1970’s a working group was established with members from London Fire Brigade, the Chemical Industries Association, the police and other interested groups. Their aim was to develop a scheme for providing the emergency services with the
information they would require about a hazardous material to ensure that an incident could be dealt with quickly, safely and efficiently.

A placard containing the ‘warning diamond’, a code to indicate the action to be taken in the event of a fire or spillage, the united nations number for substance identification and a telephone number to access specialist advice was produced. The scheme was piloted in Cleveland in 1974 and introduced nationally on a voluntary basis in 1975. These panels are also used on buildings in London to indicate where hazardous materials are stored. As a rule of thumb, the instructions provided by the warning panel are for use in the first seven minutes. After this time more information is required.

**Figure 1: UK Hazard Warning Panel**

<table>
<thead>
<tr>
<th>EMERGENCY ACTION CODE</th>
<th>HAZARD DIAMOND</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNITED NATIONS NUMBER</td>
<td></td>
</tr>
<tr>
<td>TELEPHONE NUMBER FOR SPECIALIST ADVICE</td>
<td></td>
</tr>
</tbody>
</table>

More detailed information on hazardous materials can be obtained through specialist databases which all UK fire brigades have access to. One of these is CHEMDATA, which contains comprehensive information on hazards, protection and procedures. The London Fire Brigade have an additional system called CIRUS (chemical information and updating system), which is continually updated. The information stored in CIRUS, which can be accessed within seconds, includes the chemical name, the emergency action code and information on personal protection and decontamination.
2. Hazardous Materials and Environmental Protection Course – Fire Service College, Moreton-in-Marsh

The aim of the Hazardous Materials and Environmental Protection (HMEP) course for fire service personnel is to prepare officers for command and specialist advisory roles at hazardous materials and/or environmentally damaging incidents. It is a six-week residential course based at the Fire Service College in Moreton-in-Marsh, Gloucestershire. Topics covered on the course include protective clothing and decontamination, legislation, risk assessment and basic toxicology.

The Research Engineer attended three days of the course including one day of practical exercises to gain a better understanding of fire service capabilities in managing chemical (or ‘HAZMAT’) incidents and some practical experience in the use of equipment for containing chemical leaks and spills. Three scenarios are presented below.

Scenario 1: A transport accident with a leaking road tanker containing beer

The hole in the drum was blocked using ‘dammit’, a ready mixed clay sealing putty, which is in the Environment Agency ‘Grab pack’.

To contain the spill a boom was inflated using water and placed on the road around the tanker.
Scenario 2: A leak into a river from a pipeline upstream of a drinking water abstraction point

As in the first scenario, the leaking pipe was sealed using dammit putty.

The river downstream was blocked using a piece of wood weighted with sand bags. It was not possible to use the boom as above because the chemical had mixed completely with the water in the river. Therefore it was necessary to construct a complete barrier.

The contaminated water was pumped out of the river and then sprayed onto an adjacent field.

This was considered appropriate because the chemical had been diluted sufficiently to present a long-term environmental hazard.
Scenario 3: A chemical leak from a drum onto land and into a lake used for fishing

The hole in the drum was blocked using ‘dammit’ and chemical that had leaked onto the ground was soaked up using absorbent pads.

The chemical that had leaked into the water was contained using a boom filled with water to aid bouancy. This was possible because the chemical was immiscible with water.

References
Hazardous Materials and Environmental Protection Course Notes, The Fire Services College
The Carriage of Dangerous Goods by Road Regulations 1996 (CDG Road), March 1998
Risk Assessment at Hazardous Materials Incidents, March 1998
Pollution Control – Techniques and Equipment, March 1998
Transportation of Hazardous Materials: Information Sources, April 1998
APPENDIX G
**G. QUESTIONNAIRES AND FORMS**

1. **Local Authority Questionnaire**

For the purpose of this questionnaire, a land contamination incident was defined as an area of land or site that contains a chemical(s) that is potentially hazardous to human health and the environment.

| 1. How many land contamination incidents have you personally been involved in managing? (Please circle) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 0                          | 1-3                         | 4-6                         | 7-9                         | 10+                         |

| Please specify: |

| 2. Did you have access to sufficient resources/information? (Please circle) |
|-----------------------------|-----------------------------|
| Yes                         | No                          |
| Don’t know                  |

Please specify (books, databases, personal contacts, organisations etc)

| 3. In general, how much time do you spend dealing with a land contamination incident? (Please estimate) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| 0.00                        | 0.50                        | 1.00                        | 5.00                        | 10.00                       |

| Please specify (hours/days/weeks/months) |

| 4. Has there been any consultation between your health authority and the local authority with regard to the new Contaminated Land Legislation? (Please circle) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Yes – extensive            | Yes – a little              | Not really                  | No                          | Don’t know                  |

<p>| 5. Do you feel the health authority role in managing land contamination has changed since the introduction of the legislation? (Please circle) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|</p>
<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
</table>

If Yes, please give details.

6. Would it be useful if health authorities had guidance specifically on the public health management of land contamination (Please circle)

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
</table>

If Yes, please give details.

7. What should the guidance contain? (Please rank in order of importance, 1=most important)

|--------------------------|-------------------------------|-----------------------|--------------------------|-------------------------------|--------------------------|----------------|------------------|---------------------|----------------|----------------|------------------------|-----|-----|

If you would be happy to discuss your answers, please provide contact details.

- Contact name: ...........................................................
- Telephone number: ...........................................................
- e-mail address: ............................................................

Thank you very much for your time and co-operation!!!
2. Fuel checklist questionnaire

I would be very grateful if you would take a couple of minutes to complete this short questionnaire to provide feedback about the presentation and usefulness of the fuel incidents checklist.

Many thanks.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Was the questionnaire useful in managing the incident in the exercise? (Please circle)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. What was good about the checklist?</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3. What improvements could be made?</td>
<td></td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Would you consider using the checklist for responding to similar incidents in the future? (Please circle)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Don’t know</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5. How useful do you consider checklists to be for responding to and managing chemical incidents? (Please circle)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very useful</td>
<td>Useful</td>
<td>Not useful</td>
<td>Don’t know</td>
</tr>
</tbody>
</table>

Any further comments?
3. Land incident evaluation form

1. Completeness of report/information (1=poor 5=good)

2. How has the incident been categorised?
   a. by CIRS
   b. by National Focus

3. Who first identified the issue to the Health Authority?
   Planning department
   Environmental Health department
   Other Local Authority department
   Environment Agency
   Water Company
   Other
   Fire brigade
   Police
   Ambulance service
   Local residents
   Hospital
   Unknown

4. Who else was involved in managing the incident?
   Planning department
   Environmental Health department
   Other Local Authority
   Environment Agency
   Water Company
   Environmental Consultant
   Fire brigade
   Police
   Ambulance
   Local residents
   Hospital
   Other

5. Which agency took the lead?
   Health Authority
   Planning department
   Environmental Health department
   Other Local Authority
   Environment Agency
   Other
   Fire brigade
   Police
   Ambulance
   Local residents
   Water Company
   Not known

6. Were the media involved?
   Yes    No    Unknown

7. How was the issue discovered?
   Spill, leak, explosion etc
   Complaint
   Routine testing
   Part of planning process
   Unknown
   Part IIA investigation
   Other site investigation
   During construction
   Other
8. Describe the cause of the problem
Spill Leak Malicious
Historic Land Waste Other
Water Fire Unknown
Transport Air

9. How long had there been a problem?
<6 m 6–24 m > 24 m Unknown

10. Was the size of the affected area known?
Yes No Unknown

11. Was the history of the site known?
Completely Partially Unknown

12. What was the site used for?
Recreational use School Light Commercial
Open space Hospital Heavy commercial
Allotments Nursery Heavy Industry
Housing Farming Derelict site
Other Not known

13. What chemical(s) was present?
Organic Heavy metals Other inorganic

Please list all:

14. Was any speciation of metals carried out?
Yes No Unknown N/A

15. Which environmental media were affected?
Air Soil Surface water Groundwater

16. Were environmental samples taken?
Air Soil Surface water Groundwater

17. Is there a copy of the site investigation/report in the file?
Yes No

18. Was an exposure pathway identified?
Yes No Unknown
19. Was food contaminated?
   Yes  No  Unknown

20. Was drinking water contaminated?
   Yes  No  Unknown
   a. Was the site on/near an aquifer?
      Yes  No  Unknown
   b. Was there an abstraction point on or near to the site?
      Yes  No  Unknown
   c. Did any (plastic) water pipes run through the ground?
      Yes  No  Unknown

21. Does a stream/river flow through or near to the site?
    Yes  No  Unknown

22. Was the location of the nearest property to the site known?
    Yes  No  Unknown

23. Were there any complaints of health effects?
    Yes  No  Unknown

24. Were any health effects identified?
    Yes  No  Unknown

25. Were any children with pica identified?
    Yes  No  Unknown

26. Was a health questionnaire sent to local residents?
    Yes  No  Unknown

27. Were any biological samples taken?
    Yes  No  Unknown

28. Were residents evacuated?
    Yes  No  Unknown

Any interesting features?
H. STANDARDS FOR CONTAMINANTS IN SOIL

The relative lack of toxicological data presents a significant problem in determining whether the level of contamination on a particular site is likely to present a threat to human health (Ferguson, 1996). The majority of available data is based on plant or animal exposures. Although there are extensive mathematical models for extrapolating this data to consider human exposure, these are based on a ‘generic human’ so models need to be adjusted for sensitive populations (Aldrich et al., 1998) e.g. children, pregnant women, the elderly, who are most at risk. Other questions that are raised as a result of these assumptions include:

- Is the metabolism of small amounts of the chemical the same as with large amounts?
- Is there actually a threshold where there are no effects?
- Is the metabolism the same for all people?

Also it is often assumed that the relationship between exposure and effect is linear and this is not necessarily true.

In addition to these problems, it is very difficult to identify soil as contaminated as there are no definitive guidelines to indicate ‘normal’ levels of substances in the ground. In addition it is known that background levels of, for example, heavy metals, are much higher in urban soils than in agricultural land. This is not to say that the land is more or less contaminated respectively as, for example, the pesticides applied to agricultural land may present a greater risk to human health. Furthermore, the form or chemical state of an element influences its bioavailability and hence its potency (Harrison (ed), 1994).

The Department of the Environment, Transport and the Regions (DETR) – now the Department for Environment, Food and Rural Affairs (DEFRA) – have been involved in the preparation of a new set of guideline values for contaminants in soil. They are to be used in establishing whether a site poses actual or potential risks to human health in the context of the existing or intended use of the site. The guideline values replace the levels developed in the 1983 by the Interdepartmental Committee
for the Redevelopment of Contaminated Land (ICRCL) (ICRCL, 1987), which were
set as guidelines for redevelopment. These introduced the concept of ‘threshold’
concentrations, which are non-legally binding values for contaminants in the soil
based on the intended land use. A second edition of the paper ‘Guidance on the
assessment and redevelopment of contaminated land’ was published in 1987.
Threshold or ‘trigger’ values were suggested for 20 substances, principally inorganic
contaminants, including heavy metals. For a number of the substances, action levels
were also suggested. It is now acknowledged that the ICRCL guidance is limiting
due the small number of contaminants that are included (Simmons, 1999), and the
fact that the levels were only ever intended for redevelopment use only and not as a
general environmental quality assessment (Beckett, 1993). In addition, the ICRCL
guidance is not mandatory and its application has led to a wide variation in the
policies and interpretation used by different local authorities (Peters & Blake, 1999).

Prior to the ICRCL guidelines being developed, the only system for assessing how
significantly a site was contaminated was that published by the Greater London
Council following a site investigation and remediation programme of gasworks sites
undertaken in the 1970’s. These are often referred to as ‘Kelly’ values. The GLC
guidelines pre-dated the ICRCL values by only two or three years yet were very
different in format (Beckett, 1993). Firstly, many more contaminants were included
and secondly the guidelines distinguished five ‘levels’ of contamination -
uncontaminated, slight contamination, contaminated, heavy contamination and
unusually heavy contamination – and for each category a range of concentration
values was quoted (Beckett, 1993). However, Beckett highlights that GLC
guidelines could not be used to determine whether a site was suitable for a given
form of development.

The ICRCL and GLC guideline values were developed for use in determining the
level of clean-up required when re-developing a contaminated site and not for use in
determining whether a site presented a hazard to human health. Nevertheless, until
recently ICRCL values have most been widely used in the UK for the assessment and
remediation of contaminated land due the absence of anything more appropriate and

H-2
as a result Beckett (1993) states that ‘evidence of continuing misuse of ICRCL trigger concentrations has been accumulating’.

Other guidelines that are used in the UK to assess whether a soil contaminant is likely to present a hazard to human health are the Dutch Target and Intervention values (originally A-B-C values) (Croner, 1996). The levels were developed in the 1980’s following an incident at Lekkerkerk – 1600 drums of toxic waste, which had been dumped illegally, were discovered at a site that had been redeveloped for housing. Chemicals, including toluene, seeped into groundwater and voids in the ground below the houses and resulted in clean-up costs of about £150 million (Croner, 1996).

The Target and Intervention values, which have been developed for about 100 chemicals, are based around two levels:

- **Target levels (T-values)** - environmental quality standards, background or normal levels for pollutants in soil
- **Intervention Levels (I-values)** - above which pollution represents an unacceptable risk to water, plants animal and human well being

The values have been calculated for a standard soil, which is defined as containing 10% organic matter and 25% clay. A correction should therefore be made to the T and I values to allow for the amount of clay and organic matter actually present in the soil being sampled. The varying ability of different soil types to absorb and stabilise metals and organic compounds can then be taken into consideration (Croner, 1996).

Where the level of contamination in the soil exceeds the I-value, it is suggested that remediation should be carried out in order to reduce the concentration of the contaminant in the soil to the T-value.

Until recently the Dutch approach was to remediate land to a state where it presented no risk to human health or the environment so that it could be used for a wide range
of future options – also referred to as multifunctionality – unless the clean-up caused environmental problems, was impossible for technical reasons or was too expensive (Ferguson, (1999)). However, this strategy was replaced in 1997 by a less rigid fitness-for-use approach.

The new soil guideline values have been derived using the Contaminated Land Exposure Assessment (CLEA) model. The model, which was released in March 2002, uses a probabilistic risk-based approach similar to that developed by the US EPA and by SNIFTER (Scotland and Northern Ireland Forum for Environmental Research) (Cragg, 2000). Guideline values have been derived for five different land use scenarios: housing with gardens, housing within a landscaped area, open spaces, allotments and industrial use. Generic assumptions are made in the scenarios, a list of which will be published. Allowances are also made for uncertainty and the model takes into consideration the bioavailability (See Box 1) of the contaminant.

The first set of guideline values covers arsenic, cadmium, chromium, cyanide, lead, mercury, nickel, phenol, polycyclic aromatic hydrocarbons (PAHs) and selenium. It is anticipated that others will be developed in the future.

Other countries have developed guidelines for contaminants in soil, including the US, Australia and Germany. These have not been discussed as they are not widely used in the UK.

Box 1: Bioavailability (Paustenbach et al, 1992)

<table>
<thead>
<tr>
<th>Environmental contaminants are able to cross biological barriers with varying degrees of efficiency but when they are bound to soil particles, the efficiency of uptake decreases. The bioavailability of a chemical is the percentage of the chemical in soil that is absorbed by humans. Factors which affect the bioavailability of a chemical are:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• the physiochemical properties of the contaminant</td>
</tr>
<tr>
<td>• the environmental matrix in which it is present</td>
</tr>
<tr>
<td>• the nature of the biological membrane</td>
</tr>
<tr>
<td>Chemicals in soil are usually absorbed to a lesser degree that chemicals in pure form.</td>
</tr>
</tbody>
</table>
I. WORLD HEALTH ORGANIZATION REGIONAL OFFICE FOR EUROPE

Press Release EURO/10/02
Copenhagen, 4 June 2002

Chemical terrorism alert system to be set up

Europe makes plans for public health preparedness and response

Representatives of Member States in the WHO European Region and international organizations have met at the WHO Regional Office for Europe to arrange to prepare for and respond to any deliberate use of chemical agents by terrorists. These plans include a chemical incident alert system.

“We do not know when or if there will be a chemical attack, but we know, from our experience in handling other crises involving chemical accidents, that preparation saves time and saves lives,” said Dr Roberto Bertollini, Director, Division of Technical Support at the WHO Regional Office for Europe. His statement reflected the views of the representatives of the Member States.

“Fighting chemical terrorism involves not only international cooperation but close collaboration, planning and integration across a host of different sectors and experts. This allows a fast and efficient response in emergencies, and it also strengthens public services overall,” noted Professor Gary Coleman, International Clearing House for Major Chemical Incidents in Cardiff, United Kingdom.

The recent three-day meeting was held in Copenhagen and organized by the Regional Office jointly with the International Programme on Chemical Safety (IPCS – a joint programme of the International Labour Organization, the United Nations Environment Programme and WHO). The participants heard evidence from officials in charge of anti-terrorist activities, poison centres, emergency preparedness units and national surveillance systems, and from the international organizations most involved in this area, such as the United Nations Office for the Coordination of Humanitarian Affairs, the Organisation for Economic Co-operation and
Development and the European Commission (EC). The decisions made build on WHO and IPCS global initiatives in this area, and support those of the Global Health Security Action Group, EC and others to ensure maximum cooperation on an agreed, coherent and streamlined response against terrorist attack. Work is already underway to devise an international incident scale that will quickly identify the severity of an incident.

Significant chemical incidents of some kind occur every month, and the events of 11 September 2001 in the United States have triggered scrutiny of the European Region’s ability to respond, particularly to transboundary threats. In the last six-month period for which figures are available, 704 chemical incidents took place in the United Kingdom, 3 of which affected over 50 people. Major incidents in Europe include the explosion in a warehouse at a fertilizer factory in Toulouse, France, in September 2001, which killed 31 people and injured over 2000, and the explosion in a fireworks factory in Enschede, Netherlands in May 2000, which killed 20 people and injured hundreds more. Terrorism involving chemicals could not only cause explosions but also affect the public through food, air and other routes.

The participants at the meeting committed themselves to establishing:

- an alert and response system for chemical incidents, utilizing as much as possible the existing mechanisms at the global, European Region and European Union levels;
- a forum for the exchange of experience between the countries to establish a strategy and programme for upgrading communication with the public; and
- an international system to classify incidents.

The participants also agreed to define the role and functions of poison control centres in preparedness and response.

Most countries have already developed key areas of their capability to respond to chemical incidents. Actions range from setting up specialized agencies, such as a health protection agency or emergency committees, to establishing a local Web site that coordinates information from the rescue services and then informs the public.
The participants agreed that, if public health is to be protected against chemical terrorism, cooperation between countries and organizations in Europe is essential to help build on existing initiatives and systems.
J. INCIDENT TIMELINES
APPENDIX K
### K. CHECKLISTS

#### Acute Chemical Incidents—Basic checklist

**Questions to Ask the Notifying Organisation**

*For all chemical incidents* request a brief summary of what is known **now** about the chemical incident.

- **What** has happened? Is it a fire, explosion, spill, leak, etc?
- **Where & when** did it happen?
- **What media** has it affected? e.g. air, water, land, food
- **What** is the **source** of contamination? Has it been safely contained/removed?
- **What** is known about the **contaminating substance**?
  - specific name(s)
  - composition
  - concentrations

**Action to protect the health of the public:**

- Categorise the human & environmental health impact of the incident on the Chemical Incident Impact Scale

**You may need the following additional information:**

- Have any adverse health effects been reported following exposure or have there been any complaints?
  - what symptoms have been reported? (may have been reported to local authority, GPs, A & E departments, water utility etc.)
- How many people have actually &/or potentially been exposed & to what contaminant concentrations?
  - has the Ambulance Service been alerted? have they received any casualties?
  - have local hospitals been alerted? have they received any casualties?
  - do A&E departments have adequate PPE & decontamination facilities?
  - do A&E departments have appropriate antidotes & an adequate supply?
**Recommendations for acute phase response**

**Information to obtain/confirm from other agencies**

**Grades 0-4**

- Ensure appropriate agencies are taking steps to prevent further contamination
- Ensure access to affected area is restricted to minimise exposure
- Ensure relevant Local Authority, Environment Agency & water company (if appropriate) personnel are informed; take contact details
- Establish clear lines of responsibility & communication
- Establish whether any environmental samples been taken?
  - what sampling strategy has been used, e.g. sampling frequency, priority analyses? (if possible identify peaks & troughs in the analytical results)

**Grades 2-4**

- Consider convening a multi-agency incident control meeting
- Consider issuing a press release to local press & media – remember to have alternative versions in appropriate language

**Action to protect the health of the public:**

**Grades 0-4**

- Alert CIRS as soon as you are aware of the incident; pass on as many details as possible
- Define affected population, & monitor symptoms & disease levels – mark on a map or geographical information system
  - are any additional populations at risk?
  - have appropriate actions to protect public health been taken?
  - consider sheltering (‘go in, stay in, tune in’) versus evacuation (consider & advise on risks of evacuation)
- Review potential adverse health effects of the chemical & methods of control
- Provide information to the public as needed
- Consider setting up a help line to provide assistance

**Grades 2-4**

- Consider referring to health emergency plan & ensure key staff members are notified
- Consider alerting GPs, NHS Direct, NHS & private hospitals, neighbouring CsCDC & other medical professionals
- Consider informing Food Standards Agency/DEFRA if there is a threat to food or agriculture
- Consider informing the National Focus, Department of Health or Chief Medical Officer
Recommendations for incident investigation (post-acute phase response)

Information to obtain/confirm from other agencies

Grades 0-4
- Confirm that the chemical hazard initially identified is the actual chemical hazard
- Identify source-pathway-receptor linkages
  - is there an aquifer used for drinking water abstraction?
  - are there plastic water supply pipes?
  - is there a river or stream used for recreational purposes?
  - is the land used to grow food?
  - are there other contaminant transport pathways?
- Obtain notification for each organisation involved on when incident is declared over and when they are standing down

Grades 2-4
- Obtain updates on incident evolution and any secondary contamination
- Undertake detailed site assessment
  - collect maps and plans of the area
  - establish topography and direction of groundwater flow
  - collect further environmental samples
  - compare any measured concentrations with regulatory standards and any past sample results, e.g. from routine sampling
- Obtain any plume modelling (real time or after event) data

Action to protect the health of the public:
- Re-evaluate incident category

Grades 0-1
- Ensure appropriate remedial action has been undertaken to remove source of contamination or exposure pathway
  - once confirmed, no further action required
  - go to ‘post incident questions’

Grades 2-4
- Consider conducting a site visit
- Undertake further assessment of health impact
  - consider whether biological sampling of sentinel cases and other exposed individuals is necessary
  - consider carrying out a questionnaire survey of all those exposed to identify any adverse health effects
  - if necessary, initiate a case control study to assess health impacts
  - consider long-term follow up and monitoring of the exposed population
### Post incident questions for public health

**Grades 0-4**

- Has the incident been declared over for each organisation involved and are they standing down?
  - o have all those affected been informed of the end of the incident?
  - o have all those involved in incident management been advised of event close?
- Have all those with adverse health effects fully recovered?
  - o do any patients need long term follow up?
  - o consider longer-term epidemiological surveillance
- Are all records of the incident complete & up to date?
- Conduct an audit of the management of the incident
  - o identify lessons learnt
  - o identify necessary modifications to emergency and/or incident plans
- Provide final media briefing with details of how incident has been managed, any remaining adverse health impact & any preventative actions to be taken.
Event specific checklists
Water Section 1 - Drinking water supplies

Recommendations for questions to ask the Water Utility

Exposure

- Have “at risk” groups been identified and alerted including: home and hospital renal dialysis patients, bottle fed infants, residential and nursing homes, schools, etc.?
- Have all affected drinking water consumers been informed, including food and drink manufacturers, who may be using potentially contaminated water?
- What quantities of water are likely to have been consumed?
- Have alternative drinking water supplies been arranged, are alternative bathing and laundry facilities required?
  - if yes, have consumers been notified not to drink, cook with or use tap water?
  - are bowser water supplies safe to drink?
  - have the elderly and disabled access to alternative supplies?
  - are large alternative supplies available for critical users?
  - have supplies been cut off?
- What samples are being taken and analysed?
  - who is taking the samples?
  - is there appropriate quality control?
  - are duplicate samples being taken and analysed by an independent organisation?
  - are samples being tested for taste and odour?
- Is there a possibility of microbiological contamination as well as chemical?

Water supply

- What is the source of drinking water currently in supply and the treatment processes used?
  - have there been any changes in supply or treatment?
  - have there been any previous problems?
  - is water from different sources mixed in supply?
- Have drinking water abstractions been closed?
  - when will they be re-opened?
  - how much water is in storage reservoirs
- Have sewage treatment works been taken offline?
  - what impact will this have?
- Have water treatment works been taken offline?
  - what impact will this have?
  - is disinfection still effective?
- Could drinking water storage reservoirs have been affected?
- What action for remediation/decontamination is taking place?
  - are water pipes being flushed to remove contaminated water?
  - can water supply areas be re-zoned to limit the area affected?
  - are there any processes available to remove contaminants, e.g. activated carbon?
  - what is the expected time frame for remediation/decontamination?
Post Incident Questions

- Does the drinking water now meet required standards for drinking water quality?
- Have water utility drinking water pipes and domestic water pipes, tanks and plumbing fittings been adequately decontaminated?
- If permanent new water pipes have been installed, have these been verified to be uncontaminated?
- Is a report to the Drinking Water Inspectorate required?
- Consider compiling a list of renal patients with routine updating for easy reference in the event of future incidents

Water Section 2 – Private drinking water supplies

Recommendations for questions to ask Environmental Health Officers

- Have alternative drinking water supplies been arranged. Are bowser water supplies safe to drink?
- Are there hospital, drinking water, or food and drink processor or manufacturer abstractions in the area? Should they be closed?

Recommendations for questions to ask the Water Utility

- Inform water utility of the contamination, even if it is a private supply, may be a public water abstraction from the same aquifer.

Post Incident Questions

- Does the drinking water now meet required standards for drinking water quality?
- Have drinking water supply pipes, tanks and plumbing fittings been adequately decontaminated?
- If permanent new water supply pipes have been installed, have these been verified to be uncontaminated?
- Is a report to the Drinking Water Inspectorate required?
Water Section 3 - Surface water

Recommendation for questions to ask the Environmental Health Officer

- Is the area used for water sports, swimming, fishing, etc.? -
- Are there any other uses of the water resource, e.g. abstraction for drinking water or food and drink processing or manufacturing, fishing or agricultural usage for irrigation or livestock watering? -
- Consider advising the public of contamination and controlling access to the affected area by people and animals (N.B. policing controls may be difficult) -
- Will the area of contamination change over time, e.g. movement down a river? -
- Could drinking water storage reservoirs have been affected? -
- Is long term monitoring of the affected, or potentially affected area necessary? -

Water Section 4 - Marine or coastal water

Recommendations for questions to ask the Environment Agency/Maritime Coastguard Agency

- Is the area used for water sports, swimming, etc.? -
- Is there any recreational or commercial fishing, or collection of other marine wildlife for food in the area?
  - Are aquatic organisms being sampled, for example by CEFAS? -
- Consider advising the public of contamination and controlling access to the affected area?
Chronic land contamination incidents – basic checklist

Recommendations for initial response

- Identify contaminant(s) involved
- Identify major pathways between contaminants & receptors (human & environmental)
- Ensure all appropriate organisations are aware of the incident  
  - consider holding an incident control meeting
  - establish clear lines of responsibility and communication
- Restrict access to the site if appropriate

Action to protect the health of the public:

- Identify population at risk
- Consider if evacuation/sheltering of residents is necessary
- Provide information to the public as needed

Recommendations for incident investigation

Initial investigation

- Identify source of contamination
- Identify all potential pathways between contaminants & receptors  
  - is there an aquifer used for drinking water abstraction
  - are there plastic water supply pipes?
  - is there a river or stream used for recreational purposes?
  - is the land used to grow food?
  - are there other pathways that would transport the contaminants elsewhere?
- Undertake preliminary desk study  
  - determine current past & future land use
  - collect maps & plans of the area to show geology, hydrogeology etc.
- Consider carrying out a site visit (refer to site visit checklist & report form)

Action to protect the health of the public:

- Undertake full assessment of public health impact  
  - determine exposure among local residents & users of the site
  - has the wider population potentially been exposed?
  - have appropriate actions to protect public health been taken?
- Continue to provide information to the public
### Detailed investigation
- Undertake further sampling to determine extent of contamination on/off site including control samples to determine ‘background’ levels
- Develop detailed conceptual site model
- Determine if it is ‘**contaminated land**’
- Prepare media statement
- Consider holding a public meeting

### Public health action
- Develop health questionnaire to assess exposure & health effects
- Consider whether biological sampling of exposed population is necessary
- Assist in preparation of media statement

### Recommendations for remedial action
- **If ‘contaminated land’**
  - review options available for removal of contamination from site
  - select and apply most appropriate option
  - make provisions for long term monitoring
  - ensure involvement of all stake holders in decision making
- **If not ‘contaminated land’**
  - consider if remedial action is required & options available
  - decide whether to take action or to make provisions for long-term monitoring
  - communicate decision (with reasons) to stakeholders, incl. local residents

### Public health action
- Consider long-term follow up & monitoring of exposed population

### Post incident questions for public health
- Has the incident been declared over for each organisation involved and are they standing down?
  - have all those affected been informed of the end of the incident?
  - have all those involved in managing the incident been advised of event close?
- Have all those with adverse health effects fully recovered?
  - do any patients need long term follow up?
  - consider longer-term epidemiological surveillance
- Are all records of the incident complete and up to date?
- Conduct an audit of the management of the incident
  - identify lessons learnt
  - identify necessary modifications to emergency and/or incident plans
- Provide final media briefing with details of how incident has been managed, any remaining adverse health impact & any preventative actions to be taken
### Land Section 1 – Allotment sites (Land used for growing food)

#### Recommendations for initial investigation

- Identify source of contamination
  - **for acute events:** source of contamination should be easily identifiable (refer to **basic acute checklist**)
  - **for chronic problems:** refer to historical maps/information about past activities on the site (refer to **chronic land checklist**)
- Identify all potential pathways between contaminants & receptors (human & environmental)
  - what types of food are grown in the soil?
  - are there other pathways that would transport the contaminants elsewhere?
- Undertake preliminary desk study
  - collect maps & plans of the area to show geology, hydrogeology, any underground features, utility trenches, land drains, historical land use etc
  - determine direction of groundwater flow to help predict movement of chemicals through ground
- Consider carrying out a site visit (refer to site visit checklist & report form)

#### Action to protect the health of the public:

- Undertake assessment of public health impact
  - determine exposure amongst local residents & users of the site
  - has the wider population been potentially exposed?
  - have appropriate actions to protect the public health been taken?
- Confirm that appropriate environmental samples have been taken
  - control samples to determine ‘background’ levels
- Continue to provide information to the public
  - advise not to eat food grown in contaminated soil or encourage thorough washing of food prior to consumption
  - encourage thorough washing of hands following contact with the soil

#### Recommendations for detailed investigation

- Undertake appropriate environmental sampling to determine extent of contamination on/off site
- Sample & analyse food grown in contaminated soil (consider contacting FSA)
- Develop detailed conceptual site model
- Prepare media statement
- Consider holding a public meeting

#### Action to protect the health of the public:

- Develop health questionnaire to assess exposure & health impacts
- Consider whether biological sampling of exposed population is necessary
- Assist in preparation of media statement
**Land Section 2 – Sites being redeveloped**

**Recommendations from initial investigation**

- Has a detailed site investigation already been carried out?
  - If yes:
    - Are results of environmental sampling available?
    - Is further environmental sampling required?
  - If no:
    - Consider implementing a sampling programme
    - Undertake preliminary desk study
      - Collect maps & plans of the area to show geology, hydrogeology, any underground features, utility trenches, land drains etc
      - Identify past, current & proposed use of the site
      - Identify contaminant and source of contamination
      - Identify all potential pathways between contaminants & receptors (human & environmental)
    - Is there an aquifer used for drinking water abstraction?
    - Are there plastic water supply pipes?
    - Is there a river or stream used for recreational purposes?
    - Is the land used to grow food?
    - Are there other pathways that would transport the contaminants elsewhere?

- Develop a conceptual site model
- Has land been identified as ‘contaminated land’?
- Consider carrying out a site visit (refer to site visit checklist & report form)

**Action to protect the health of the public:**

- Undertake assessment of public health impact
  - Determine exposure amongst local residents & users of the site
  - Has the wider population been potentially exposed?
  - Have appropriate actions to protect the public health been taken?
  - Provide information to the public as needed
- If workers have been exposed:
  - Consider whether appropriate PPE has been used.
  - Consider whether biological sampling of exposed population is necessary.
  - Ensure HSE have been informed.
- Confirm that appropriate environmental samples have been taken
  - Drinking water samples if there are organic chemicals & plastic water pipes
  - Control samples to determine ‘background’ levels
- Consider developing health questionnaire to assess exposure & health impacts
Non-domestic fires

Recommendations for questions to ask about fire

- Where is the fire?
  - Is the area urban, residential or industrial or rural?
    - Any motorways or major transport routes?
    - Any susceptible populations e.g. hospitals, schools, nursing homes?
    - Any caravan parks?
- When did the fire start?
- What is burning?
  - What are the potential health effects from the products of combustion?
  - What information is known about chemicals and their storage or building materials?
- Is there a risk of significant spread or of explosion?
- How big is the fire? (How many fire tenders are in attendance?)
- How hot is the fire i.e. over 1,000°C or less than 1,000°C?
- How is the fire being managed?
- What are the local weather conditions?
  - Identify plume pathway, range and possible particulate deposition
  - Consider informing neighbouring CsCDC and any local hospitals and GPs under or near to plume need to include advice about turning off air conditioning intakes
  - Is a CHEMET available? If yes ask for a copy

Recommendations for questions to ask other agencies

- Consider requesting environmental sampling to confirm contents of building or plume and for any particulate or building debris including asbestos
- Check Environment Agency and/or Water Company has been contacted to warn of potentially contaminated run-off water entering drains or sensitive watercourses
- Check MAFF has been contacted to warn of any secondary contamination to food sources from plume deposition

Action to protect the health of the public:

- Limit public exposure to hazards, consider advising on evacuation or sheltering until fire is out
- Identify all casualties
- Consider taking biological samples from any sentinel cases
- Ensure all those attending the site use appropriate PPE (including EHOs and PH)
- Ensure no further contamination is likely to spread from site when fire contained - consider recommending use of water or tarpaulins to maintain dust and debris control
- Depending on the reported health effects and the products of combustion, it may be appropriate to consider advising local inhabitants on issues including
  - Preventing children playing with any debris
  - Consider keeping pets indoors until clean up complete
  - Do not mow lawns until clean up complete
- Depending on safety consider asking adults to wear thick plastic gloves and collect debris in gardens, etc. and place in clearly marked containers
### Sheltering or evacuation

#### Questions to facilitate the evacuation/sheltering decision

- **Is the substance harmful to the public?**
  - highly toxic/toxic/irritant/non-irritant
  - short-term/long-term effects
  - explosive/non explosive
- **Will the public be exposed?**
  - substance contained/Potential for release
  - capable of dispersal via wind, rain, etc.
  - public in path of projected route
  - distance, plume height, meteorological conditions, stability of weather conditions
- **Will dilution factors minimise risk?**
- **When will the public be exposed (time of day)?**
  - already exposed
  - imminently
  - not for a few hours
- **How long could the exposure last?**
  - few minutes
  - hours
  - days
  - months
  - years

#### Sheltering in a chemical incident – Action to protect the health of the public:

- Provide a help-line number, consider using NHS Direct
- Ensure effective forms of communication with other emergency services
- Ensure effective communication systems with the public, especially to ensure sheltering is in place as quickly as necessary
- Provide post sheltering advice on airing houses
- Provide medical assistance post sheltering, especially to those incapacitated

#### Specific instances where evacuation may be appropriate

- **Before an incident (precautionary)**
  - risk of imminent explosion (e.g. defusing a bomb/making safe an explosive hazard)
  - small leak likely to escalate sharply
  - release/threatened release of radioactive materials
- **During an incident**
  - spread of fire to members of the public
  - continuing release of hazard over a prolonged period of time
  - after an incident
  - gross environmental contamination
Considerations on whether to evacuate or not

- Is there sufficient time to evacuate?
- How long will decision process take?
  - the emergency services' response time
  - Public health response time
- Method being chosen to co-ordinate and inform the public?
  - door-to-door
  - via loudhailers
  - radio/TV networks
  - language barriers, the need for translators
- The time of day (it is more difficult to warn people effectively at 4 a.m. than at 8 p.m.)
- Time to prepare the public
  - to collect clothes, medication, baby supplies, pets, cheque books, credit cards etc
  - and to secure their homes
- Time required for the public to move
- The population profile:
  - number of elderly, handicapped and immobile
  - are any residential homes/nursing homes in the affected area?
  - any people on dialysis machines, or others at special risk?
- The extent of the road network
  - transport availability – private and public
  - blockage of roads – e.g. flooding or snow
  - hazardous travel conditions – e.g. fog, snow, sleet, ice etc.
- Consideration of the effects on the evacuees of:
  - outside temperature
  - psychological trauma/medical risk
  - cost
  - how large a zone is to be evacuated
- Possible health risk to the police cordon

Criteria for returning home

- Incident is under control and not expected to escalate
- The residential premises are considered safe
- Environmental sampling and analyses to provide risk assessment information in residential premises has been completed and discussed with medical toxicologist, where necessary
- Leaflet has been provided to explain the situation and actions that should be taken on returning to the premises, such as opening windows and doors to ventilate the premises for appropriate period of time
- Advice about whom to contact if any ill health effects develop, such as NHS Direct, General Practitioner, local accident and emergency department etc.
L. INCIDENT EXERCISES

1. Fuel exercise (including facilitator notes)

This exercise was written to test the usefulness of the fuel incident checklist presented in Chapter 5. Delegates were divided into groups of five or six and presented with the information in the boxes and were able to request additional information. A CIRS representative facilitated discussion.

Day 1

You receive a call from the Local Authority. The son of an elderly lady is concerned about a longstanding smell of fuel inside her property. There has been a problem for the past five years but recently the smell has been a lot worse.

- Do you consider there to be a risk to public health?
- If so, what action would you take?
- What further information would be useful?

Facilitator notes (allow 15 minutes for discussion):

If delegates ask appropriate questions, the following additional information is available:

- map of the area
- summary of site history/identification of potential sources
- results from air samples collected by the Local Authority
- fuel checklist
- kerosene fact sheet

Further information about the incident at this stage:

- no adverse health effects have been reported
- although there has only been one complaint, the extent of contamination is unknown
• the source of fuel is unknown although the most likely source has been
  identified (underground pipes from original central heating system)
• there have been reports of incidents involving fuel on the estate previously
• evacuation question raised
• Environment Agency was informed.

*If delegates have not asked about environmental (air samples) after 5 minutes, present them with the information

Facilitator notes for air sample results (allow 5 – 10 minutes for discussion):
As fuel migrates readily through the subsurface, it is important to determine how widespread the contamination might be. Samples should be taken from neighbouring properties.

As there is fuel underneath the property, it is important to ascertain whether there are plastic water supply pipes as organic chemicals (e.g. fuel) can permeate through the pipe material and contaminate drinking water. Therefore it is important to find out whether there are plastic water pipes and if so, take some drinking water samples for analysis.
Incident update (1)

The Local Authority has forwarded results from air samples taken inside the property to you.

You attend a joint incident control meeting at the affected property and notice the fuel odour inside the house. The odour is particularly strong in the hallway and kitchen. Representatives attend the meeting from the following agencies:

- Health and Safety Executive (HSE)
- Local Authority
- Health Authority
- CIRS
- The fuel supplier

The elderly lady is still living in the house.

- Which agency do you think should chair the meeting?
- What questions do you want answered?
- Do any other agencies that need to be notified? Why?
- What action would you take?
- What further information would be useful?

Facilitator notes (allow 10 – 15 minutes for discussion):

Further information at this stage:

- the meeting was arranged and chaired by the Health Authority
- the water company was involved (drinking water contamination – see notes above)
- the Environment Agency was informed
- the neighbour converted from the kerosene central heating system to a gas supply about five years ago
- none of the neighbours have noticed any unusual odours
- the elderly lady has had a blood test
Incident update (2)
The Local Authority has forwarded you the results from the analysis of drinking water samples taken from the affected property and neighbouring properties.

- What do the results suggest?
- What action should be taken?
- Should residents be evacuated?
- If yes, at what point would you consider it safe for them to return home?

Facilitator notes (allow 5 – 10 minutes for discussion):
Drinking water pipes were replaced with plastic coated copper and the water retested

Further information at this stage:
- the elderly lady and neighbour were both evacuated whilst investigative work to identify source of contamination was undertaken
Results of incident investigation

A trial pit was excavated between the two properties and a large pool of kerosene was revealed (Figure 1). Soil samples contained kerosene at very high concentrations (over 9000mg/kg) and groundwater sample contained 95% kerosene. However, the kerosene pipe at the site was intact so further investigative work was undertaken (Figure 2).

The site of leak discovered just over a month after incident reported. The protective plastic sheath around part of the kerosene pipe had been damaged and the pipe underneath had corroded (Figure 3).

A pump was used to draw excess groundwater from site, which was then filtered to extract kerosene and contaminated soil and groundwater taken off site to licensed facility.

Facilitator notes:

1. This is just a summary of the incident investigation. No real Public Health involvement but it is interesting to know what happened!

2. If it seems appropriate to mention, a remediation notice was served under Part IIA of Environmental Protection Act 1990 (Section 57) as the area was considered to be 'contaminated land' according to the legal definition.
The suitability of an area of grassland adjacent to a large housing estate for use as allotments is being considered. The land is currently used for recreational activities including dog walking and children playing. Residents who attend a meeting of the local council to oppose the proposed relocation of the allotments comment on the fact that attempts to grow vegetables in gardens on the estate in the past had usually failed.

The soil on the proposed allotment site is very ashy and small pieces of coal have been identified. Soil samples taken have been found to contain heavy metals (lead, zinc, copper, nickel and mercury), arsenic and Polycyclic Aromatic Hydrocarbons (PAHs). At the bottom of one of the boreholes a black sludgy mixture containing pieces of glass and similar material has been found but not identified.

Further investigation has identified the former land use of the area and part of the adjacent housing estate as a tip for ash and colliery spoil. The extent of the former tip is unknown. There is also a history of mining and quarrying in the area.

In your response summarise:

• The key areas of concern
• Any further action that needs to be taken
• Any further information that you require
• Which other agencies/organisations you would contact for information/advice
Landfill

It is now October. Since April local residents have been complaining to the local authority and the PCT that that odours from a nearby landfill site have given rise to adverse health effects and in June/July levels of complaints were really high.

Between April and October, sewage sludge from a local treatment works was accepted at the site. Lorries transporting the sewage were driven through the town. Also earlier in the year, the site was identified as suitable for receiving animal carcasses culled has a precaution during the foot and mouth crisis. These animals were not infected. Animals were received at the site between April and the end of November 2001 and were tipped into areas that had recently had other waste tipped. Emission measurements for putricine and cadavarine were carried out and were either below the odour threshold/very low/undetectable. However, re-excavating recently tipped waste that had started to decompose did result in an odour problem.

You are going to attend a multi-agency site meeting to discuss the problem and decide what action should be taken.

In your response summarise:

- The key areas of concern
- Any further action that needs to be taken
- Any further information that you require
- Which other agencies/organisations you would contact for information/advice
Site re-development

The planning department of the local authority has received an application to build executive homes on the site. The planning department has requested the assistance of the environmental health department, as the site is potentially contaminated.

An initial site investigation has revealed the presence of some elevated levels of heavy metals in samples taken from a number of trial pits across the site.

In light of this the local authority has called a meeting and invited the health authority to attend to assist in determining whether the levels of contamination present in the soil are potentially hazardous to human health and any further action that needs to be taken.

In your response summarise:

- The key areas of concern
- Any further action that needs to be taken
- Any further information that you require
- Which other agencies/organisations you would contact for information/advice
Secondary contamination of an inland watercourse

The local inland drainage board has contacted the Environment Agency, the local authority and public health to raise concerns about the possibility of drainage from a tip and formed coking plant polluting an inland watercourse. There are two primary concerns.

Occasionally, drainage board employees work in the watercourse usually using machinery to clear weed and sediment but sometimes by hand particularly in culverts. They wear standard protective clothing;

In dry summers farmers with land adjacent to the drain may, under an abstraction license use the water for irrigation.

A meeting is to be held in order to establish whether there is a significant pollution problem in the drain. You are given the following information in advance:

The watercourse is approximately 100m downstream of the tip. It is believed that the discharge to the watercourse is from 4 old lagoons that are on the site. These were used to dispose of slurry. The Environment Agency has analysed the water downstream of the tip on a monthly basis for a number of years and recently raised levels of iron and ammonia have been detected in the water.

In your response summarise:

- The key areas of concern
- Any further action that needs to be taken
- Any further information that you require
- Which other agencies/organisations you would contact for information/advice
M. FUEL INCIDENTS LITERATURE REVIEW

A search was carried out using Web of Science, Edina Ei Compendex, MHIDAS (Major Hazard Incident Data Service), Cambridge Scientific Abstracts and more specialist databases at the Institute of Petroleum to identify incidents involving fuel that had been published. A number of newspaper articles from more recent events were also collected. A search on the MHIDAS CD-ROM highlighted 313 reported incidents involving a leak or spill of fuel between 1990 and 1997. Of these incidents, 81 occurred in the UK. A number of incidents were entered into the database twice as there was more than one type of fuel involved thus reducing the total number of individual incidents. Ten incidents reported on MHIDAS are listed in Table 1.

Of the papers identified in the literature search, several focussed on marine or coastal spills. A few of these discussed emergency response and spill management and were therefore considered further because they might contain ideas and information that could be applied in the management of an inland spill. The others were considered to be inappropriate for this study and therefore not analysed further. Two of the papers identified discussed the management of actual inland events in detail - one in Canada and one in the UK – and these are summarised below.

The incident in Alberta, Canada in 1995 involved a spill of between 70m³ and 160m³ of light crude oil along section of a pipeline located near the bank of a major river less than 1 km upstream of the water supply intake. Initial emergency response activities involved the development of a site safety plan, the containment and recovery of free oil pooled on ground surface, exposing and capping the pipeline and the removal and disposal of oil stained vegetation and snow. Some of the oil had migrated further downslope and accumulated at the water table within the flood plain sediments adjacent to the river, so remediation systems were installed to recover the oil, recover and treat the impacted groundwater and prevent further migration of the impacted groundwater and oil toward the river. A remedial action plan was developed based on the results of samples taken from test holes, boreholes and groundwater monitoring and recovery wells. In addition approximately 3000m³ of
contaminated soil was excavated from the area and placed in two lined treatment cells for bioremediation (Doupe & Livingstone, 1998).

Table 1: Ten incidents reported on MHIDAS (date of last entry – July 97)

<table>
<thead>
<tr>
<th>Date of incident</th>
<th>Location</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/07/97</td>
<td>Edinburgh Lothian</td>
<td>1000 litres oil spilled from a tanker, which had overturned in a road accident. Sand was used to absorb the oil and prevent it from reaching a colony of newts.</td>
</tr>
<tr>
<td>26/05/97</td>
<td>Stoke on Trent Staffordshire</td>
<td>A tanker suffered a tyre blow out and collided with a bridge support. The tanker split and kerosene spilt onto the carriageway.</td>
</tr>
<tr>
<td>08/01/97</td>
<td>Westhill Grampian</td>
<td>Tanker hit patch of ice causing it to skid and crash on its side. 4000 litres of fuel oil and/or kerosene cargo spilled. Fire engine skidded and subsequently hit the overturned tanker.</td>
</tr>
<tr>
<td>10/4/97</td>
<td>Brockworth Gloucestershire</td>
<td>Tanker containing 5500 gallons of spent engine oil overturned spilling some of the oil. Barriers were put in place to contain the flow and the oil was siphoned into a second tanker.</td>
</tr>
<tr>
<td>18/02/97</td>
<td>Cowbridge South Glamorgan</td>
<td>3000 litres of diesel spilled from a tanker, which was making a delivery to an old peoples home. Fire fighters tried to stop the spillage from spreading by building a barrier of earth and sand. Some oil entered the drains.</td>
</tr>
<tr>
<td>16/01/97</td>
<td>Nr Solihull West Midlands</td>
<td>Petrol tanker and lorry carrying paint collided on motorway. Petrol tanker suffered split towards rear of vehicle and thousands of gallons of petrol and some paint spilled onto the carriageway.</td>
</tr>
<tr>
<td>20/11/96</td>
<td>Fairfield Worcestershire</td>
<td>Tanker carrying 7500 gallons of petrol overturned and spilled more than half the load. 25-50 gallons seeped into a brook affecting 200-300 yards of brook.</td>
</tr>
<tr>
<td>15/11/96</td>
<td>Fareham Hampshire</td>
<td>Tanker spilled gallons of crude oil cargo on junction of motorway roundabout</td>
</tr>
<tr>
<td>07/11/96</td>
<td>Strichen Grampian</td>
<td>Up to 100 gallons of diesel spilled onto farmland when agricultural consultant left diesel tank open during 20-minute telephone call. Minimal pollution to river and no resulting fish kill.</td>
</tr>
<tr>
<td>20/09/96</td>
<td>Llan Ffestiniog</td>
<td>Tanker carrying 16,300 litres of diesel overturned and crashed into rock face close to houses. Thousands of gallons of diesel spilled onto trunk road.</td>
</tr>
</tbody>
</table>

The second incident occurred in May of 1998 in the Southwest of England when contractors damaged an underground fuel pipeline during planned maintenance work. Approximately 27,000 litres of aviation fuel (similar to kerosene) leaked from the pipeline. The Fire Service, Police and contractors responsible for the pipeline were involved in the emergency response, which involved recovery of fuel and removal of the most heavily contaminated soil. On the day following the incident a strong smell of fuel was reported in a property 16 houses from the leak and a pool of fuel was identified under the floorboards. It was discovered that a number of old land...
drains ran through the gardens and under the properties. One of these had provided an easy conduit for the fuel to the house, where it had backed up due to a blockage in the drain (Madden, 2000).

Both of these incidents demonstrate that fuel is able to migrate through the subsurface, emphasising the potential for widespread and long-term environmental damage. They also highlight the importance of response time in minimising the impact of the event.

**Leaks from underground storage tanks**

Leaks of fuel from underground storage tanks (USTs) and underground pipelines represent a specific category of fuel incidents that have the potential to cause widespread environmental damage, especially as the problem may go undetected for some time. Incidents involving leaks from USTs are widely reported in the ENDS Report since they frequently result in a prosecution. A number of examples are summarised below. In addition Harris (1994) presented a number of examples of leaks from USTs that resulted in groundwater contamination. Six of the chemical leaks, including four involving fuels, are listed in Table 2.

| Incident 1 | Leak at a large site used to store fuel oil and chlorinated solvents in underground storage tanks
|           | Leak proven to have extended over an area of 18 km²
|           | Contaminated nine potable groundwater abstractions |

| Incident 2 | Tanks and pipes replaced at petrol filling station
|           | Refilled with unleaded petrol
|           | Chemical used as an unleaded petrol additive was detected in two potable abstractions 500m away from the source |

| Incident 3 | Leak of aviation fuel from a cracked pipe
|           | 30000 litres of hydrocarbons recovered over four year period
|           | Kerosene still trapped in aquifer matrix - potential source of pollution for many years |

| Incident 4 | Failure of underground storage tank at oil storage depot
|           | 27000 litres of fuel lost of which 13000 recovered
|           | No oil reached public supply river
|           | All underground tanks on site replaced with above ground facilities |

---

1 Groundwater is a very important resource and in the UK almost 30% of our drinking water is abstracted from groundwater sources.
In 1993 a senior Shell manager highlighted the groundwater pollution threat posed by petrol filling stations. He revealed that up to one-third of the company's sites had problems with underground fuel leaks and believed that this may also be true for other retailers (ENDS, 2000; ENDS, 1993). It was considered that leaks from suction lines and single skin tanks and the absence of spillage detection and overspill prevention systems had all contributed to the problem. In 1995, Shell UK became the first petrol retailer to be prosecuted by the National Rivers Authority (NRA) for causing groundwater pollution. The station's records revealed that about 50 gallons of petrol had been lost from an underground storage tank in one week. The company was fined £2,500 (ENDS, 1995).

Esso was fined £13,500 in February 1999 after about 7,000 litres of unleaded petrol had leaked from a petrol station from one of its service stations causing a major groundwater pollution incident. Vibrations in the underground pipework had apparently worn a hole in one of the pipes, allowing the fuel to escape (ENDS, 1999).

An incident at a petrol station in North Wales in 1996 also drew attention to the problem of leaks from USTs and their potential to contaminate water resources. The incident involved a leak of around 60,000 litres of petrol that led to the pollution of a high-quality river. In addition an explosion in a house near to the petrol station six months after the incident had been reported forced the evacuation of a school and homes (ENDS, 1997). This resulted in a penalty of £38,000 charged to the contractor working on behalf of the Environment Agency to investigate groundwater pollution as a result of the leak (ENDS, 1998). The petrol station proprietor was fined £4,000 (ENDS, 1999).

Two incidents in Hertfordshire and Essex resulted in a multinational oil company being fined £66,000. The first of these incidents involved a leak of 55,000 litres of unleaded petrol between January 1998 and February 1999 from an underground storage tank. This incident prompted an investigation at a second site where it was established that a leaking fuel line had led to the release of 7000 litres of super-
unleaded fuel since July 1997. Although the scale of the leak was smaller, the consequences were significantly higher; the site was 250 metres from a water supply borehole. In light of this an alternative water supply had to be provided and some of the water mains made of plastic were replaced to prevent permeation (ENDS, 2000).

A further incident in Hertfordshire involving a leak of 28,000 litres of heating oil from a manufacturing plant based was reported in Industrial Emergency Journal in October 1996. The fuel had been lost from a fractured oil supply line that was buried underground and had become damaged as a result of minor ground movement as well as pressure due to flooding. The incident was on a major aquifer and two extraction wells used for public water supply were located nearby. Two options for recovery of the oil were considered. The first was the complete removal of all the oil soaked terrain. However, the investigation showed that as the oil plume covered an area of 25000 square meters so this would not be practical. Therefore the remedial option selected was to recover as much of the free flowing oil as possible and then deal with the remaining contaminated soil separately (Read, 1996).

Conclusions
The incidents reported demonstrate some of the distinguishing features that make acute incidents involving fuel unique in terms of the management response required. This includes the likelihood of explosion if vapours accumulate within a confined area and the subsequent need to evacuate residents and other property owners, the potential to affect water either through the direct contamination of groundwater aquifers used for drinking water abstraction or the permeation of low molecular weight hydrocarbons from the soil through plastic drinking water supply pipes and also the difficulty in remediating soil and groundwater once contaminated.

The literature review has also highlighted the increasing percentage of acute incidents that involve fuel and the huge potential for further incidents, which emphasises the importance of developing a structured approach to the management of such events to minimise long-term harm human and environmental health.
APPENDIX O
Case Study 1: A leaking kerosene pipe

Background
A resident who could smell fuel inside their property reported this incident to the local authority. The smell had apparently been a problem for about 5 years but had recently become a lot worse.

Elevated levels of kerosene were found in air and drinking water samples taken from the affected property (Table 1) and one neighbouring property (although when asked the neighbour reported never having smelled or tasted anything unusual). The residents of both houses were evacuated whilst further investigative work was carried out.

Table 1: Results of environmental samples

<table>
<thead>
<tr>
<th>House number</th>
<th>Highest kerosene level detected inside property (mg/m³)</th>
<th>Hydrocarbon levels detected in drinking water (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;0.2</td>
<td>Nil detected</td>
</tr>
<tr>
<td>2</td>
<td>5.4</td>
<td>Nil detected</td>
</tr>
<tr>
<td>3*</td>
<td>137</td>
<td>1.87</td>
</tr>
<tr>
<td>4**</td>
<td>29.8</td>
<td>0.0284</td>
</tr>
<tr>
<td>5</td>
<td>&lt;0.1</td>
<td>Nil detected</td>
</tr>
<tr>
<td>UK PCV</td>
<td></td>
<td>10 µg/l</td>
</tr>
</tbody>
</table>

* UK Prescribed Concentrations or Values for drinking water quality (Croner, 1996)
* the house initially affected
** the closest neighbour

Incident Investigation
The houses were on an estate of around 600 properties built in the 1960s. When the houses were built they had oil based central heating systems with fuel provided from a central storage tank through a network of underground pipes. Over the years most of the houses on the estate had converted to electricity or gas including the house reporting the smell and all of the neighbouring properties.
A trench was dug between the two affected properties and the site of the leak located at the end of the gardens, about 10 metres away from the houses. The protective plastic sheath around part of kerosene supply pipe from the original central heating system had been damaged and the pipe underneath had corroded (Figure 1).

Figure 1: The corroded pipe

The drinking water supplies to the two properties had become contaminated because the pipes ran underneath the ‘spill area’ and were made of plastic so the fuel was able to permeate through the material (Box 1).

Box 1: Organic Chemicals and Plastic Pipes

Organic chemicals in contact with plastic pipes can cause drinking water contamination via two principle mechanisms, penetration or permeation. Penetration occurs when the pipe material has been physically damaged, leading to cracks or fissures, or weak areas that can easily be damaged if put under stress. In permeation, the plastic pipe acts like a sieve to low molecular weight hydrocarbons that can pass through undamaged pipe material (Goodfellow et al., 2001).
Over 9000mg/kg kerosene was detected in one of the soil samples taken at the site of the leak and a groundwater sample contained 95% kerosene. Groundwater was pumped from site then filtered to extract kerosene and the contaminated soil removed. Subsequently a remediation notice was served on the two residents under Part IIA of the Environmental Protection Act 1990 as the land was identified as ‘contaminated land’ in accordance with the legal definition outlined in the Environment Act 1995 (refer to Chapter 2.3).

Case Study 2: An accidental leak of fuel from an underground storage tank

Background
In August 1999, a local resident notified the local authority of a smell of gas. It was known that in the past the area had contained a number of pits that were used for the disposal of waste and consequently investigations centred on the detection of landfill gas. The local authority dug trial holes and a thin film of petrol was found on the surface of the perched water table about one metre underground. Local information suggested that there were a number of potential sources of contamination. These included old coal depots, old garage sites, pits and existing industrial units as well as a petrol filling station and garage adjacent to the residential area. A leak of petrol at the petrol filling station 30 years previously had accumulated in the cellar of the public house opposite. However, there was no evidence to suggest that a similar incident had occurred.

In December 1999, the Fire Authority received a call from the local Environmental Health Department following reports from local residents of a strong smell of petrol in the surface water drains along the road adjacent to the petrol filling station. The water from the drains ran to a ditch that also became contaminated with petrol. Absorbent pads were used by the Environment Agency to soak up the fuel.

A multi-agency incident committee with representatives from the Local Authority, Health Authority, Water Company, Environment Agency, Highways Department and the Fire Brigade was established in February 2000 to investigate the incident. Regular meetings were held to share findings and agree steps for further investigation.
**Incident Investigation**

It was considered that the most likely source of contamination was the garage and petrol filling station, which had perhaps suffered a leak from an underground storage tank or a spill during the filling of a tank. Initial investigations undertaken by the Fire Brigade proved inconclusive and there had been no reports of a spill. The garage owner did admit to having experienced a few problems with one of the tanks that had been converted from diesel to lead replacement petrol in August of 1999. The suction line was tested and failed and on further inspection it was noticed that parts of the pipe had corroded. It had been installed some 30 years before and current standards had not been applied at the time. However, there was very little evidence of soil contamination.

The Environment Agency undertook some investigative work using a CCTV camera in the surface drain leading from the contaminated ditch towards the garage. Some of the pipework was very old and the camera was unable to pass all the way along the pipe. Therefore, contamination could only be traced a short distance and the source was still unclear. A plan of the area is illustrated in Figure 2, with stars indicating where elevated levels of fuel had been detected.

**Figure 2: A plan of the area**
No soil samples were taken although soil vapour levels were measured between November 1999 and April 2000 around House A where the petrol smell had been strongest. Peaks were observed at the start of the sampling period and towards the end of March.

Due to the presence of petrol one metre below the ground surface, it was considered that drinking water supplies in the local area could be at risk of contamination. At the request of the health authority, the water company took a series of samples for analysis. Levels of BTEX (Benzene, Toluene, Ethylbenzene, Xylene) were measured. Elevated levels of these petroleum compounds were identified in the drinking water of two neighbouring properties opposite the petrol station (Table 5.7).

Table 5.7: Hydrocarbon levels detected in drinking water

<table>
<thead>
<tr>
<th>House</th>
<th>Sample date</th>
<th>Benzene μg/l</th>
<th>Toluene μg/l</th>
<th>Xylene μg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>22/02/00</td>
<td>7</td>
<td>47</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>28/02/00</td>
<td>1</td>
<td>10</td>
<td>&lt;1</td>
</tr>
<tr>
<td></td>
<td>1/3/000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>22/02/00</td>
<td>318</td>
<td>1579</td>
<td>790</td>
</tr>
<tr>
<td></td>
<td>28/02/00</td>
<td>18</td>
<td>55</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>1/3/000</td>
<td>34</td>
<td>63</td>
<td>22</td>
</tr>
<tr>
<td>WHO</td>
<td></td>
<td>10</td>
<td>700</td>
<td>500</td>
</tr>
</tbody>
</table>

Sample was not taken from first flush of system

Further investigation by the water company revealed that the water pipes supplying these properties were made mostly of lead except at the point where the service entered the property where black alkathene had been used. This was considered to be the most likely point of entry for the petrol into the properties and that it had permeated through the pipe material.

It was agreed that the water pipes should be replaced with plastic coated copper. The water company undertook pipe replacement on 3\textsuperscript{rd} March 2000 and during excavation a strong smell of petrol was detected in the soil. In addition the health authority was able to offer blood tests to those residents in properties where raised levels of petroleum compounds had been identified in their drinking water.
Remedial Action

The Environment Agency contracted environmental consultants to trace the source of petroleum contaminating the ditch and in addition stock records were requested from the garage owner. These revealed that approximately 5000 litres of fuel were unaccounted for between August and December of 1999. By early April 2000 soil vapour analysis undertaken by the confirmed the petrol station as the source of contamination.

It was established that the petrol had leaked as a result of the suction line failure on the recently converted pump. The made ground beneath the petrol station had provided an easy pathway to the perched water table one metre below the ground surface. This explains why the ground around the tank was not heavily contaminated with petrol. In addition it was noted that there had been some migration along service routes, which aided the overall movement of the plume.

There were considered to be two feasible remediation options available. The first involved air venting at an estimated cost of £60K - £70K. In the most commonly applied system, a series of pipes are sunk into the contaminated soil and connected to vacuum pumps. Negative pressure induces a subsurface airflow that volatilises the compounds. These are then carried with the air via the pipes to the surface where contaminants can be collected and treated prior to release into the atmosphere. The second option was to allow the fuel to continue to run through to the ditch where it would be soaked up with absorbent pads and booms placed further downstream. It was considered that although this might take 1–2 years, the cost would be significantly lower than air venting and consequently was selected as the most appropriate remedial option (Figure 3).
Case Study 3: A petrol leak incident

Background
On 13th September 2000 at the height of the UK petrol ‘crisis’, an incident involving a leak of approximately 130 litres of unleaded petrol occurred. A taxi driver had stored the fuel in plastic containers, including a dustbin and a beer barrel, on a concrete floor at the back of a private house in a busy residential area. One of the containers had a crack in the bottom and petrol leaked onto the floor. A fracture in the concrete floor close to the base of the property provided an easy pathway for the petrol into the subsoil underneath. The petrol plume migrated through the subsoil beneath the neighbouring properties. Further migration of fuel into the subsoil was facilitated by heavy rain.

The event came to light after a resident in one of the adjacent properties called the Fire Brigade to investigate the petrol smell that had been present for 12-18 hours previously.
Incident Investigation

On initial assessment the Fire Brigade concluded there to be a potential fire and explosion hazard. Consequently immediate evacuation of the residents in surrounding properties was arranged. Residents of three houses were evacuated but three others including the property where petrol had been stored were not occupied at the time of the event.

The Fire Brigade undertook air quality monitoring and varying levels of petroleum hydrocarbons were detected inside the properties with the maximum values reaching 2000 ppm. Consistently high levels were recorded in the house adjacent to the property where the leak had occurred.

A joint incident meeting was held on day following incident but this was not attended by public health although they were invited to attended a second meeting held 5 days after the incident. Following the meeting the health authority was given responsibility for answering health concerns and questions from the residents and undertaking the assessment and monitoring of the health of those evacuated following the event.

Various actions were taken to assess the health impact of the incident. Whilst residents did not display any direct health effects due to acute exposure and no hospital or GP consultation took place as a result of the event, a base-line assessment of their health was carried out with a view to provide comparison for any possible future health concerns. Blood samples for establishing a base line were taken for white blood cell count and liver function test for any future monitoring of health effects.

Remedial Action

A specialist firm was contracted to remove the petrol from the soil. Petrol was extracted gradually through the floorboards over 10 days and the soil was treated with micro-organisms that are able to break down benzene. Vapour levels were measured inside the properties at ground level and at 3 feet above ground level. After two weeks, 3 litres of petrol a day was continuing to be extracted from the house.
where the fuel had been stored. The petrol levels in surrounding houses reached zero and the residents were allowed to return. This was estimated to have cost over £100K.

The taxi driver was prosecuted and given a suspended sentence (Figure 4).

Figure 4: Headlines from the local newspaper
MATERIAL REDACTED AT REQUEST OF UNIVERSITY
Q. PORTFOLIO CONTENTS

VOLUME 1 – THESIS & APPENDICES

Chapter 1: Chemical Incidents, the Environment and Human Health
Chapter 2: Managing Land Contamination
Chapter 3: Chemical Incident Categorisation
Chapter 4: Tools for Planning and Response
Chapter 5: Tools for Land Contamination Incidents
Chapter 6: Review of Acute Incidents Involving Fuel
Chapter 7: Thesis Overview and Conclusions
Chapter 8: References

Appendix A: Case Studies
Appendix B: Definitions
Appendix C: Book Chapters
Appendix D: London Sector CBRN Project Group Meeting
Appendix E: Land Contamination and Human Health
Appendix F: The Role of the Fire Brigade in Chemical Incident Response
Appendix G: Questionnaires
Appendix H: Standards for Contaminated Soil
Appendix I: WHO Press Statement
Appendix J: Incident Timelines
Appendix K: Checklists
Appendix L: Incident Exercises
Appendix M: Fuel Incidents Literature Review
Appendix N: Review of Selected Fuel Case Studies
Appendix O: Articles Published in the Chemical Incident Report
Appendix P: Abstracts and Papers
Appendix Q: Portfolio Contents
VOLUME 2 – PROGRESS REPORTS

Report I – April 1999
Report II – October 1999
Report III – April 2000
2nd Year Dissertation – October 2000
Report V – April 2001
Report VI – October 2001
Report VII – April 2002

OTHER DOCUMENTS

EngD Coursework

- Induction: Communication & Leadership I
- Project Management
- Sustainable Development/Clean Technology
- Life-cycle Approaches
- Research Methods
- Environmental Audit
- Social Research Methods
- Risk Perception & Communication
- Risk Assessment & Management
- Scientific Paper Writing
- Understanding Environmentalism
- Advanced Leadership
- Environmental Law
- Economic Approaches
- Energy Management
- Financial Management
- Marketing
- Materials and the Environment
- Talking to the Media