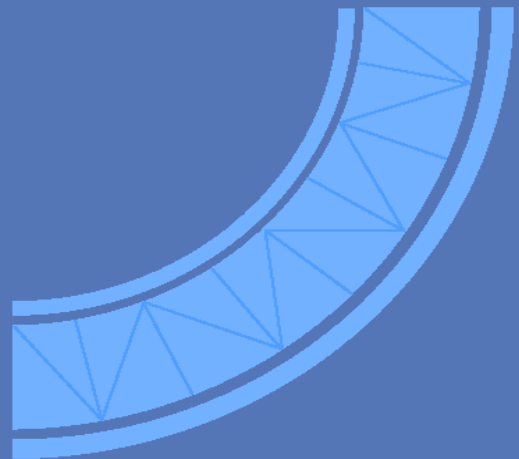
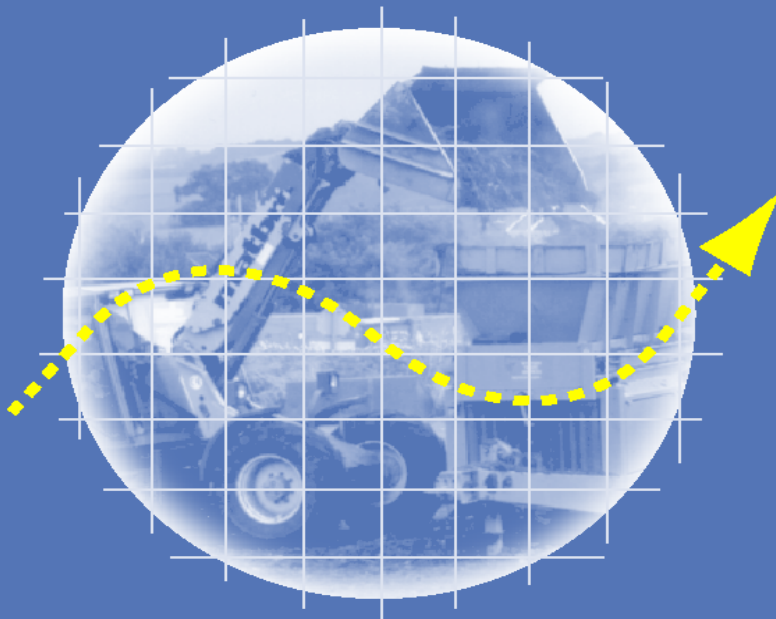




South West Public Health Observatory

Waste management and public health: the state of the evidence

A review of the epidemiological research into the impact of waste management activities on health



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This report has been prepared by the South West Public Health Observatory and the Centre for Research in Environmental Systems, Pollution and Remediation, University of the West of England, UWE, Bristol.

The South West Public Health Observatory is part of a national network of eight regional public health observatories, funded by the Department of Health. These were established in 2000 as outlined in the Government White Paper *Saving Lives: Our Healthier Nation*. Key tasks include: monitoring health and disease trends; identifying gaps in health information; advising on methods for health and health impact assessment; drawing together information from different sources and carrying out projects on particular health issues.

The South West Public Health Observatory also forms a key part of the developing South West Regional Observatory. This is a wider regional intelligence function, currently supported by the Department of Health, Government Office for the South West, the South West of England Regional Development Agency, the Regional Assembly and the Environment Agency.

Further information about the work of the South West Public Health Observatory can be found at www.swpho.org.uk.

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Summary

The aim of this project was to provide an overview of the health impacts of different methods of waste management methods so as to inform public health input into the waste management regulatory system. Public health input into the development of local, regional and national waste strategies has not been routinely sought nor offered, while public health input into the Integrated Pollution Prevention and Control (IPPC) process has only recently become a statutory responsibility. Health authorities and their consultants are ill prepared for their new role as advisors in the field of waste management. Those working in waste management lack expertise to interpret and incorporate health information into decision making. There is a need for decision makers and advisors to work together, to develop a shared understanding of the issues and to learn a common language.

This report is intended as a resource for public health advisors and decision makers in the field of waste management. It provides a summary of the epidemiological evidence about the health impacts of waste management methods. It can be used as background material to supplement the *Integrated Pollution Prevention and Control: a Practical Guide For Health Authorities* (Kibble & Saunders 2001) and as a resource pack for use in a Health Impact Assessment. It is hoped this project will build bridges between those in public health and those in waste management so that waste management decisions fully take into account the possible health impacts in light of the scientific evidence.

The questions addressed in this report are:

1. How is waste managed in England and particularly in the South West?
2. How might waste management practices impact on human health?
3. How strong is the evidence that current waste management practices have had an impact on human health?
4. How can the evidence be used in waste management strategies and practice to protect the health of the public?

A summary of the findings of each question is shown below.

Waste management practice

Waste is a complex mixture of different substances and objects, only some of which are intrinsically hazardous to health. However, any type of waste has the potential to affect health depending on the collection system used, the location where waste is generated, and the waste management strategy employed.

Waste management is broader than just the disposal of waste. It includes the generation, collection, processing and transport of waste as well as the minimisation of the production of waste and the reconceptualising of waste as a resource. The public health impacts are influenced by the overall waste management strategy adopted locally, regionally and nationally. The waste management options chosen by decision makers could have an impact on health both directly and indirectly:

1. Directly, by leading to potential adverse and/or beneficial health impacts such as increased risk of cancer or decreased quality of life,
2. Indirectly, by the broader environmental impact on the global ecology, such as the contribution to global warming, loss of bio-diversity and the depletion of non-renewable resources.

The National Waste Strategy proposes the concept of the Best Practicable Environmental Option – i.e. *"the option that provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term"*. The Best Practicable Environmental Option is likely to be a mix of different waste management methods. To guide decision makers, the Strategy proposes a "waste hierarchy" which prioritises reduction, re-use, and recovery above disposal.

This holistic approach, if adopted, would go a long way towards reducing the health risks associated with particular waste management options. An integrated waste management system requires separation of waste as well as restrictions on certain production practices that introduce toxic materials into widely distributed household products. The current system results in health risks because it does not include production and consumer use in the materials flow cycle. Many of the risks that arise in the last stage of the materials flow cycle, i.e. the disposal stage, result from actions taken at the earlier stages of production, packaging and marketing.

The main methods reviewed in this report are:

- Recycling/recovery options, i.e. composting and landspreading sewage sludge.
- Waste processing options, i.e. incineration.
- Waste disposal options, i.e. discharge of treated sewage effluent; landfill.

Potential impact of waste management practice on health

Using the World Health Organisation definition of health as a '*state of complete physical, mental and social well-being and not merely the absence of disease and infirmity*' provides a foundation for identifying factors associated with waste management that might have an impact on health. Factors may be beneficial, damaging or neutral. They may be present in the waste or formed during the waste management process.

With improvements in analytical methods, contaminants can be identified at very low concentrations, so low that their implications for human health can only be guessed at.

In most cases, a mixture of different contaminants will be present. The implications of mixtures of compounds is unknown. The risks may be additive or synergistic, i.e. there may be interaction effects that make the risks higher or lower than that predicted by analysing individual contaminants separately. There may be no interactions at all, with each compound acting independently.

It is difficult to determine what relationship any of these factors have to health impacts and even more difficult to quantify their effects. Identifying and measuring hazards gives an impression of accuracy and leads to the assumption that the measurable risks from physical hazards are more substantial and important than those from psychosocial hazards. In fact, data about physical hazards are also incomplete. Information is lacking about the toxicity, persistence and ability to bio-accumulate of many of the hundreds of thousands of chemicals that end up in waste.

Exposure

For physical hazards, the crucial link between a health hazard and a health outcome is exposure. The risk to health depends not only on how much is present but also on whether there is a route by which people may be exposed. An exposure pathway has three elements:

1. Release from the site – air, water, solids
 2. Transport through environmental media
 3. Uptake by people – inhalation, ingestion of food or drinking water, skin contact, fire and explosion
- If there is no exposure, there is no threat to health.

Exposure assessment involves the following:

1. Site characterisation
2. Characterisation of receptors
3. Characterisation of exposure pathways
4. Determination of concentrations of contaminants
5. Exposure estimation

In general, high-dose exposure and long-term, low-dose exposure are more likely to result in health impacts than short-term, low-dose exposures. However, it is extremely difficult to define exposure and thus observe a dose-response relationship in people exposed to contaminants from waste management sites.

Health impacts

Health impacts result from an interaction between the factors affecting health and the health status of exposed populations. The health outcomes are determined by the contaminant levels and the susceptibility of individuals, ranging from mortality at high levels of exposure to body burdens with no discernible effects at low levels of exposure. Commonly studied health impacts are reproductive outcomes, symptoms, diseases, and biomarkers.

Evidence of impact of waste management practice on health

In a "weight of evidence" approach to evaluating the evidence, greater weight is placed on the conclusions drawn from some types of study over others. The study designs at the top of the hierarchy (see Table 6) – i.e. studies on people – are those most likely to lead to valid conclusions from which generalisations can be made. Evidence from studies on people is more conclusive than extrapolations from studies on animals. Animal studies carry more weight than studies on parts of organisms outside the body or on related chemicals. Amongst the different kinds of studies on people, the ones higher up the hierarchy, i.e. experimental studies and prospective cohort studies are useful for testing hypotheses and establishing whether a causal relationship exists. The study designs further down the hierarchy, i.e. observational studies without controls, are useful for generating hypotheses which subsequently need confirmation from study designs further up the hierarchy.

It is difficult to establish a cause-and-effect relationship in epidemiological studies in this area because of the incompleteness of the data, inherent variability and confounding by other unrelated factors that may explain the results as well as the factor under investigation. Confounding takes place when the exposure is associated with some other factor which also increases the risk of the health outcome

studied. This includes other sources of pollutants and other factors which affect health status. Information may be incomplete because of lack of exposure data, unreliable health data, or low statistical power. Variability occurs in both the human populations studied and the waste procedures. Whilst it is technically possible to detect the presence of health hazards in waste sites and health impacts among people working or living nearby, there are many problems demonstrating the relationship between exposure and the health impacts observed. The main limitations of epidemiological investigations are the small sample size, lack of exposure information, lack of toxicological data about mixtures of chemicals and the lack of specificity of indicators of adverse health effects.

An association, even if statistically significant, is not necessarily proof of causation. To determine causation, the cause must precede the effect and the association should be "consistent, unbiased, strong, graded, coherent, repeated, predictive and plausible" (WCRF and AICR, 1997). A useful framework for describing the strength of evidence has been developed by WCRF and has been used here (see 5.1 for further details). Possible judgements are "convincing", "probable", "possible" and "insufficient" evidence of a causal association.

The results of applying this framework to the literature are shown in Table 1 below.

Protecting the health of the public

This overview of the scientific evidence exposes a high degree of uncertainty about the impact of waste management operations on health, which may or may not ever be resolved by further research. Despite the impressive amount of research and the high quality of many of the studies, the state of the evidence is such that, with a few exceptions, no certain conclusions can be drawn.

Disagreement about the management of a potentially risky activity like incineration arises not only because of different interpretations of the scientific evidence but because of the different judgements people make about how risky they believe the activity to be. Individuals as well as regulatory bodies try to avoid or control activities they judge to be too risky and ignore or tolerate others. Conflict occurs when people form different judgements about the riskiness of the activity. Disagreements about risk are inevitable because there is no way to define risk that does not include values, beliefs and assumptions – especially when information on which to base the judgement is scarce.

Where there is uncertainty, judgements about risk are based on assumptions and mental strategies that help decision making and on qualitative aspects inherent in a hazard. As well as the likelihood of

Table 1: Judgements about the evidence of the health impacts of the main waste management procedures

Evidence	Increases risk
Convincing	Gasrointestinal symptoms and bathing in sewage contaminated recreational waters.
Probable	Gastrointestinal tract problems, headache, fatigue and airways symptoms and working in sewage treatment plants.
Possible	Working at a centralised composting facility.
Insufficient	Any health outcomes and residence near landfill site Any health outcomes and working at a landfill site. Any health outcomes and working at an incinerator. Any health outcomes and residence near incinerator. Any health outcomes and residence near centralised composting facility. Cancer and working in sewage treatment facilities. Any health outcomes and landspreading sewage sludge.

harm, people consider whether incurring the risk is voluntary, has potential catastrophic consequences, is unknown and unfamiliar, and is new to society. Judgements about risk are also influenced by individuals' views of the world and the kind of society they want.

Precautionary principle

One way to manage the risks associated with waste management is to apply the precautionary principle. *"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. When in doubt about the impact of a development, it will be managed according to the worst-case scenario of its impact on the environment and human health."* (UNCED 1992.) The conditions under which the precautionary principle applies are:

- When health effects are most serious or irreversible
- When the subject is a matter of scientific uncertainty and full evidence is lacking
- When cost-effective measures are possible.

Conclusions

The data collected about waste are not detailed enough to make meaningful assessments of potential health impacts that might arise from waste management practices. The data do not include

detailed information about the composition of the waste collected nor of off-site emissions from waste management operations. Accurate exposure assessments are not possible without such data.

The nature of existing epidemiological research in this area is such that most studies are useful for generating hypotheses but are unable to test the hypotheses or to provide convincing evidence of an association between exposure and a health impact.

For most waste management methods, the evidence is insufficient to claim that adverse health outcomes will result. The exception is the convincing evidence that bathing in sewage contaminated recreational waters increases the risk of gastrointestinal symptoms, even when the water meets present guideline levels of faecal coliforms.

Implementation of the current Waste Hierarchy and the Precautionary Principle through the adoption of an integrated waste management strategy at national, regional and local level will be the most effective way to reduce the health risks from waste management procedures.

1 Introduction

1.1 Background

Waste disposal and health was identified as a priority by South West Public Health Observatory (SWPHO), in 2000. This was because changes to current waste management strategies, e.g. pyrolysis and more incinerators, may have an impact on public health. In line with their function to identify gaps in health information and to give early warning of future health issues, SWPHO wanted to find out what these impacts might be and to have an input into policy making by waste planning authorities in the South West.

1.2 Aims

These were clarified in a series of meetings with members of the South West Public Health Observatory and the University of the West of England project team. It was agreed that the following questions would be addressed:

1. How is waste managed in England and particularly in the South West?
2. How might waste management practices impact on human health?
3. How strong is the evidence that current waste management practices have had an impact on human health?
4. How can the evidence be used in waste management strategies and practice to protect the health of the public?

1.3 Methods

1.3.1 The literature search

To answer the questions above, a literature search was undertaken. The first step was a scoping exercise to find out what literature was available. Once key decisions were made to narrow down the search, a thorough search was carried out. Details of the search strategies employed are described in Appendix 1. During the literature search, a database was kept of the references found and a classification scheme developed (details available from authors). Throughout the process, there has been input from a variety of people working in the field (see Acknowledgements).

1.3.2 Evaluating the reviews

When carrying out a literature review, the second phase is to check whether adequate reviews already exist

(CRD 2001, WHO Working Group 2000). Guidelines for assessing reviews were applied (Welsh Office 1999, WHO Working Group 2000, CRD 2001) using the following questions:

- i) **Agreement on question to be dealt with**
What is the review's objective?
- ii) **Identification of all relevant studies**
What sources were searched to identify primary studies? Was there an explicit search strategy, an effort to include all available studies, searching of bibliographic databases, inclusion of non-English language reports?
- iii) **Assessment of quality of the studies**
What were the inclusion criteria and how were they applied? What criteria were used to assess the quality of primary studies and how were they applied? (study question clear, exposure assessed using valid and reliable measures, health outcome assessed using valid and reliable measures, study design appropriate, data analysis takes into consideration chance, confounding and bias, conclusions consistent with the results of the data analysis).
- iv) **Interpretation of the evidence**
How were the data extracted from the primary studies and how were the data synthesised? How was heterogeneity between studies investigated? How were data combined? Was it reasonable to combine studies and summary results of review? Do conclusions flow from the evidence reviewed? Use of meta-analysis?

Meta-analysis is an approach which involves the aggregation of results from a number of published studies in order to provide a quantitative assessment of the extent to which bias might account for observed results and of the patterns, and sources of heterogeneity. A meta-analysis can only be done if the biases and confounding factors are adequately addressed in the studies and if the studies measured the same exposures in the same way and compared risk between or among similar levels of exposure. For most epidemiological studies of the health impacts of waste management systems, exposure data are missing and there is no confounding control. With the exception of one review (Pruss 1998), none of the reviews attempted to aggregate results and none carried out meta-analyses.

1.3.3 Making judgements

As most of the reviews were unable to do more than summarise the literature and its limitations, a different model was sought to make sense of the evidence. The model used to appraise the evidence in this paper is the one used by the World Cancer Research Fund to evaluate the role of food and nutrition in the prevention of cancer (WCRF & AICR 1997). The model consists of guidelines for making judgements about the reliability and strength of the evidence and was chosen because the judgements are straightforward and easy to comprehend with relatively clear criteria for inclusion.

Assessment of the strength of the evidence depends on two factors:

1. the scale of the association demonstrated between exposures and presumed health outcomes and
2. its statistical significance (i.e. the likelihood that such an association could have arisen by chance.)

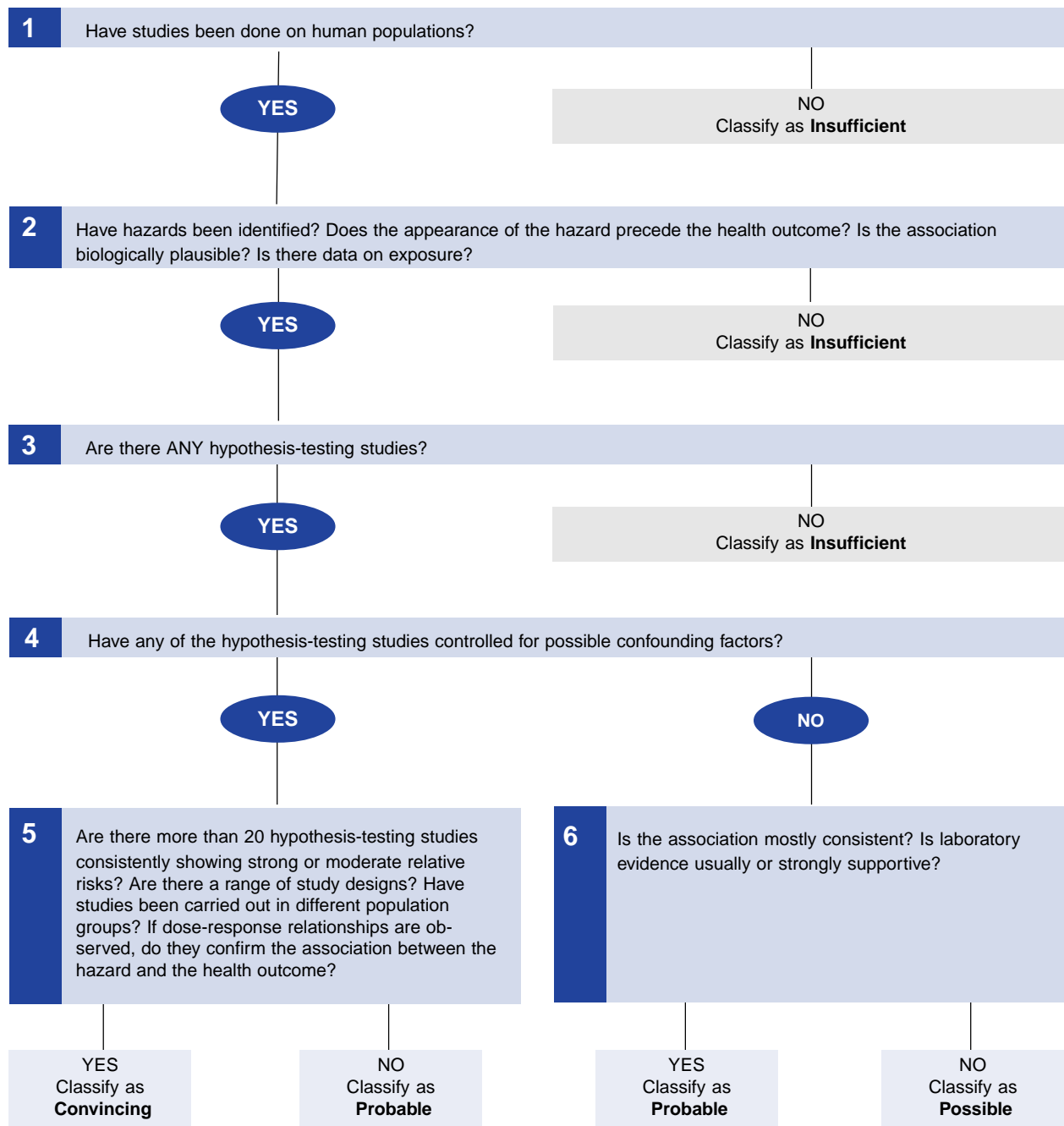
To determine the strength of an association, the concept of relative risk is generally used. (See section 4.3 for further details). However, an association, even if strong and statistically significant, is not proof of causation. To determine causation, we took the following criteria from the approach used to evaluate the diet and cancer evidence:

Judgement	Interpretation	Criteria
Convincing	There is conclusive evidence of a cause-and-effect association.	<ol style="list-style-type: none"> 1. The studies are on human populations, not just laboratory studies on animals or chemicals. 2. There are a considerable number of hypothesis-testing studies, with strong relative risks, preferably more than 20. 3. The association is consistent and observed in most of the studies, with few studies showing the opposite. 4. Possible confounding factors have been controlled for. 5. There are a range of hypothesis-testing study designs, preferably including prospective studies. 6. Studies have been carried out in different population groups. 7. The appearance of the hazard must precede the health effect. Data should refer to the time preceding the occurrence of the health outcome. 8. If dose-response relationships are observed, they should confirm the relationship. 9. The associations should be biologically plausible. 10. Coherence - the cause and effect interpretation of the data do not conflict with other knowledge of the health outcome. Laboratory evidence is usually supportive or strongly supportive. <p><i>Example: the evidence is convincing that vegetable and fruit consumption decreases the risk of several cancers. This judgement is based on 37 cohort, 196 case-control and 14 ecological studies. In 80% of the case-control studies, there was a statistically significant protective effect for cancers of the stomach, oral cavity, lung, oesophagus, pancreas and rectum for one or more vegetable and/or fruit categories (WCRF & AICR 1997, Chap 6.3).</i></p>
Probable	A causal association is likely.	<p>There is less consistency among the studies with some not supporting the association. There are fewer studies. Laboratory evidence is usually supportive or strongly supportive.</p> <p><i>Example: Alcohol probably increases the risk of colorectal cancer. Because there are inconsistent results from 11 cohort studies and more than 20 case control studies, the judgement is not convincing. However the studies support a time trend, results are confirmed by animal studies, and plausible mechanisms have been identified (WCRF & AICR 1997 Chap 5.5).</i></p>
Possible	There may be a causal relationship but the evidence is not strong enough to be sure.	<p>Studies show an association. However, there may not be very many studies; or existing studies are of poor quality or results are inconsistent. There may or may not be supportive evidence from laboratory studies but there is strongly supportive evidence from other disciplines.</p> <p><i>Example: Alcohol possibly increases the risk of lung cancer. This judgement is based on inconsistent results from 6 cohort studies and several case control studies where confounding factors are likely. (WCRF & AICR 1997 Chap 5.5)</i></p>
Insufficient	The evidence merely suggests a causal association. No judgement can be made.	<p>There are a limited number of studies which may be consistent but the poor quality of the studies limit the reliability of the conclusions drawn from them.</p> <p><i>Example: No judgement can be made about the link between cadmium contamination of food and prostate cancer. Although there are several reports about occupational exposure to cadmium and prostate cancer and a plausible mechanism for carcinogenicity, there are no studies showing an increased risk from dietary exposure.</i></p>

From these categories, an algorithm was developed to help to make the judgements about the evidence on the associations with health outcomes from the different waste practices.

Based on the review articles, abstracts and the primary papers found in the literature search, this

algorithm was used to assign judgements to the evidence about the health impacts of landfill, incineration, sewage treatment, sewage sludge landspreading and composting.



2 Waste management

This section is a summary of current waste management practice in England with particular emphasis on the South West and the public health implications.

2.1 Background

2.1.1 Sources of waste

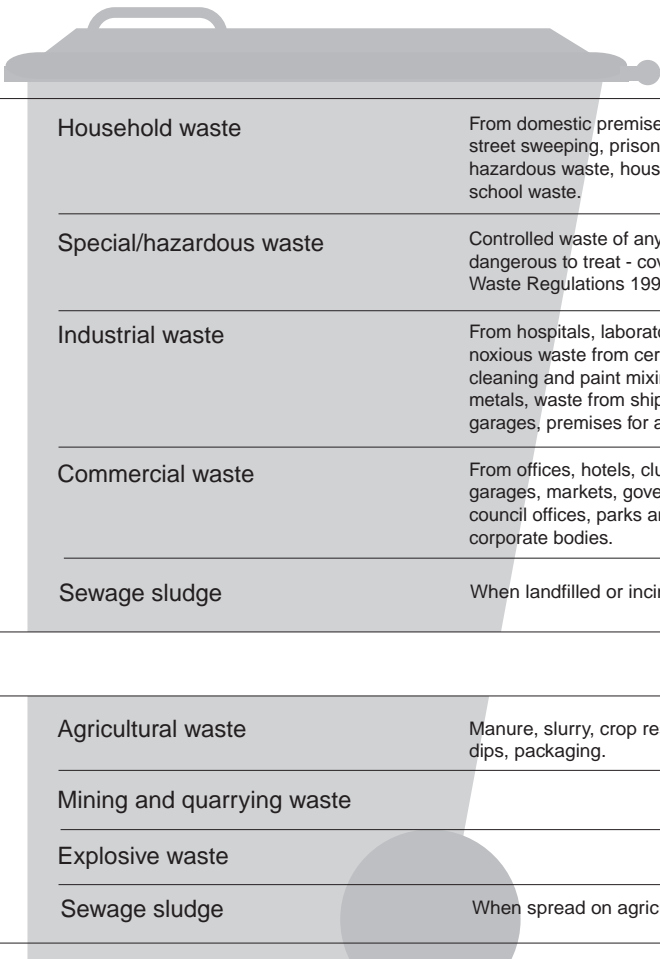
According to the Environment Act 1995, waste is defined as "any substance or object which the holder discards or intends or is required to discard." Waste is a complex mixture of different substances and objects, only some of which are intrinsically hazardous to health. However, any type of waste has the potential to affect health depending on the collection system used, the location where waste is generated, and the waste management strategy employed. For example, a plastic bottle is unlikely to be responsible for any adverse health effects when buried in landfill. However, the same plastic bottle burned in a poorly managed incinerator could generate dioxins which could potentially lead to an increased risk of cancer in people working in or living down wind of the incinerator.

Sewage is any type of waste that passes through the sewage treatment process. As well as pathogenic micro-organisms from human excrement, sewage contains many other hazards to health – heavy metals and toxic compounds from road run-off waters, toxic and endocrine-disrupting compounds from toiletries, cosmetics, and detergents, pesticides from surface water run-off, and natural hormones from human urine.

2.1.2 Quantity of waste

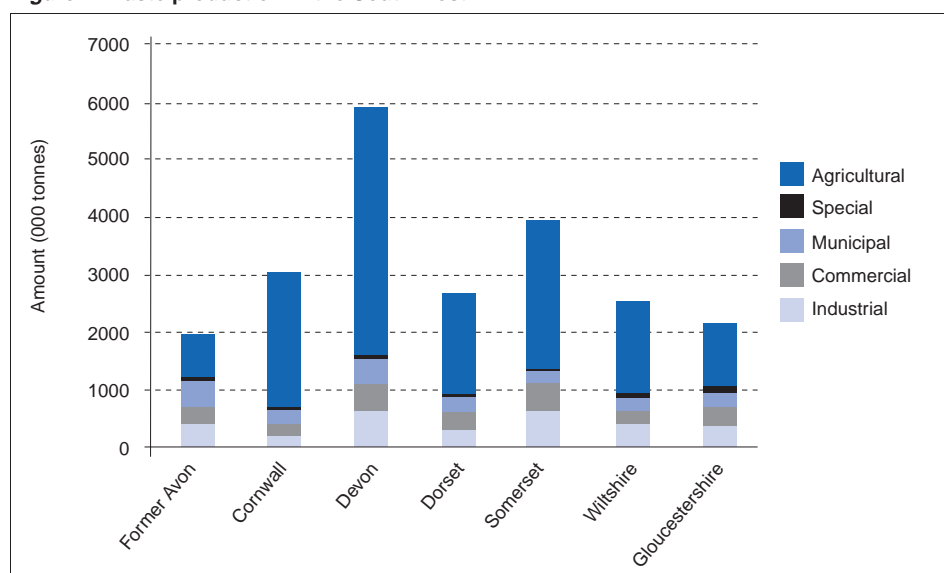
In the South West, 11 million tonnes of controlled waste were handled, treated or disposed of in the year 1998/99. This included 5.2 million tonnes of commercial and industrial waste and 2.5 million tonnes of municipal waste but does not include sewage sludge. The amount of waste produced in the South West did not exceed 12% of the total for England and Wales, which is proportional to the number of people and industries based in the South West. In addition, approximately 14.5 million tonnes of waste was produced by the agricultural sector, with Cornwall, Devon, and Somerset producing the most. (See Figure 1.)

Table 2: Types of waste



Controlled waste Covered by EPA (Environmental Protection Act 1990) and COPA (Control of Pollution Act 1974).	Household waste	From domestic premises, civic amenity sites, street sweeping, prisons, campsites, household hazardous waste, household clinical waste, school waste.
	Special/hazardous waste	Controlled waste of any kind that may be dangerous to treat - covered by the Special Waste Regulations 1996.
	Industrial waste	From hospitals, laboratories, workshops, dredging, noxious waste from certain processes, e.g. dry cleaning and paint mixing, waste oils, scrap metals, waste from ships, aircraft, commercial garages, premises for animals, nuclear waste.
	Commercial waste	From offices, hotels, clubs, showrooms, private garages, markets, government departments, council offices, parks and gardens, courts, corporate bodies.
	Sewage sludge	When landfilled or incinerated.
Uncontrolled waste Covered by separate legislation.	Agricultural waste	Manure, slurry, crop residues, animal treatment dips, packaging.
	Mining and quarrying waste	
	Explosive waste	
	Sewage sludge	When spread on agricultural land.

Figure 1: Waste production in the South West



Source: Environment Agency 2000

2.1.3 Information on waste

The data collected are not detailed enough to make meaningful assessments of potential health impacts that might arise from waste management practices and do not include detailed information about the composition of the waste collected nor of off-site emissions from waste management operations. Accurate exposure assessments are not possible without such data. (This paragraph refers to all types of waste above, not just special waste.)

Municipal waste

Municipal wastes are whatever local authorities collect and dispose of. About 90% of municipal waste comes from households (DETR 2000). The rest consists of some commercial waste, road and pavement sweepings. Extensive data are collected about municipal waste (DETR 2000). For the past four years, a questionnaire has been sent annually to all waste collection authorities, waste disposal authorities and unitary authorities asking about the amount of municipal waste collected and disposed of, the levels of recycling and recovery of household and municipal waste, methods of waste containment, levels of service provision and details of waste collection and disposal contracts.

Commercial and industrial waste

In 1989–99, a survey providing baseline information of some 20,000 businesses was carried out (Strategic Waste Management Assessment – South West, Environment Agency 2000). The information collected for each business included the type of waste (i.e. mixed, special or packaging) the quantity of waste, the waste form (i.e. solid, liquid or sludge) and the waste management method.

Agricultural waste

The South West produces nearly a quarter of all the

agricultural waste produced in England and Wales (Environment Agency 2001). There is little information available on the management of agricultural waste and by-products although compounds in quantities significant to health are produced of pesticide washings, plastics, tyres, oils and sheep dip (Environment Agency 2000 SWMA).

Special/hazardous waste

The Environment Agency has a Special Waste Tracking database, SwaT, but it is difficult to calculate how much special waste is produced. The factors that make it difficult are discussed in Chapter 2 of the *Strategic Waste Management Assessment – South West, 2000* (Environment Agency 2000).

2.2 Managing waste

Waste management is broader than just the disposal of waste. It includes the generation, collection, processing and transport of waste as well as the minimisation of the production of waste and the reconceptualising of waste as a resource. The public health impacts are influenced by the overall waste management strategy adopted locally, regionally and nationally.

2.2.1 National waste strategy

The *Waste Strategy 2000* (DETR 2001) sets out the Government's strategy for managing waste. The strategy has been influenced by the idea of sustainable development first described in the 1992 United Nations Earth Summit. The idea is that decision makers must strike a balance between continued economic development and the need to protect and enhance the environment. Sustainable development is "development which meets the needs of the present without compromising the ability of future generations to meet

their own needs" (Brundtland Report 1987).

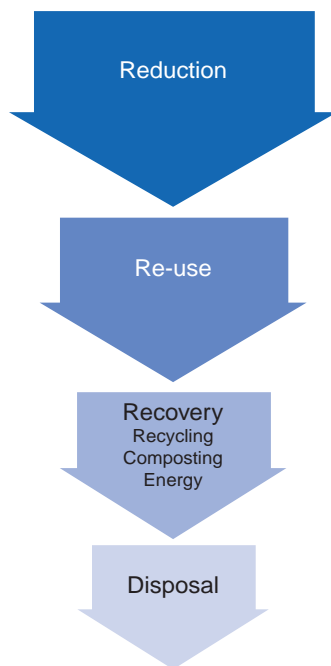
In terms of protecting human health, the Waste Strategy mentions the recently adopted Landfill Directive with its stringent controls and the high standards expected of new high temperature incinerators.

Although not explicit in the Waste Strategy, the waste management options chosen by decision makers could have an impact on health both directly and indirectly:

1. Directly, by leading to potential adverse and/or beneficial health impacts such as increased risk of cancer or decreased quality of life.
2. Indirectly, by the broader environmental impact on the global ecology, such as the contribution to global warming, loss of bio-diversity and the depletion of non-renewable resources.

The Strategy explains the concept of the Best Practicable Environmental Option – i.e. *"the option that provides the most benefits or the least damage to the*

Figure 2: The waste hierarchy



Source: DETR 2001

would go a long way towards reducing the health risks associated with particular waste management options. Because the waste stream is managed as a monolithic material using a single management technique, spurious comparisons are made between incineration and landfill as if they were alternative methods of disposal. An integrated waste management system requires separation of waste as well as restrictions on certain production practices that introduce toxic materials into widely distributed household products. An example is cadmium and other toxic metals in printing inks and plastic stabilizing agents. The current waste management system results in health risks because it does not include production and use in the materials

environment as a whole, at acceptable cost, in the long term as well as in the short term". The Best Practicable Environmental Option is likely to be a mix of different waste management methods. To guide decision makers, the Strategy proposes a "waste hierarchy". The most effective solution is to reduce the generation of waste, the option at the top of the hierarchy. Only when the options at the top are not appropriate should waste be disposed of (see Figure 2).

This holistic approach, if adopted, would go a long way towards reducing the health risks associated with particular waste management options. Because the waste stream is managed as a monolithic material using a single management technique, spurious comparisons are made between incineration and landfill as if they were alternative methods of disposal. An integrated waste management system requires separation of waste as well as restrictions on certain production practices that introduce toxic materials into widely distributed household products. An example is cadmium and other toxic metals in printing inks and plastic stabilizing agents. The current waste management system results in health risks because it does not include production and use in the materials

flow cycle. Many of the risks that arise in the last stage of the materials flow cycle, i.e. the disposal stage, result from actions taken at the earlier stages of production, packaging and marketing. For example in the case of toxic heavy metals, the most difficult and expensive method of reducing the risk of exposure is to delay action until after incineration has dispersed them throughout the environment.

2.2.2 Reduction at source

Although it is the most sustainable form of waste management, waste minimisation is not an option which waste management authorities can easily implement in isolation from the rest of society. It involves every individual and every sector of society and every stage of the life cycle of every product – from extraction of raw materials, transportation, design, manufacturing, purchasing, packaging, consumption and on to its post-consumption fate. In an ideal sustainable society, there would be no waste and no concept of waste. Products discarded in one process would become the source of raw materials for another process. Waste minimisation requires a different concept of economic growth based on reduced consumption and a re-use and recycle mentality. The benefits are the conservation of resources, a reduction in waste toxicity and a reduction in pollution, including greenhouse gases that contribute to global warming. A programme for zero waste in the UK is proposed by Murray (Murray 1999).

Waste management authorities can encourage waste minimisation by a variety of measures, including:

- Waste audits in the commercial sector.
- Education of householders.
- Financial incentives such as the Landfill Tax and payments by householders scaled to the amount of waste collected.
- Implementation of the Landfill Directive, 1999/31/EC, which will increase the cost of waste disposal to waste producers and provide an incentive for them to re-use, recycle and otherwise minimise waste arisings (DEFRA 2001).
- Reducing the size of bins provided to householders.

2.2.3 Re-use

Re-use systems are being encouraged and are coming back into popularity. A number of initiatives are described in the *Waste Strategy 2000* (DETR 2001) including bring-back schemes, refurbishment and reconditioning centres, and educational projects to encourage consumers to re-use products. The advantages of re-use are:

- Energy and raw material savings, reducing need for manufacture of new products. These benefits are realised only if products are not discarded before the end of their useful life.
- Reduced waste disposal costs.
- Cost savings for consumers and businesses.
- New market opportunities and more jobs.

Sewage treatment can be categorised as a system for the re-use of water. It is described in section 2.2.5 as a waste processing system.

2.2.4 Recovery

Recycling

Recycling is the recovery of materials from products after they have been used by consumers. The benefits of recycling are:

- Conservation of resources.
- Energy savings.
- Supply of raw materials to industry.
- Reduction in emissions to air and water in the production process.
- Job creation.
- Development of greener technologies.
- Reduction in the need for new landfills and incinerators as there is less waste to dispose.

The disadvantages are:

- Emissions from transport of material to be recycled.
- In some cases, more energy may be used for processing than for original manufacture.
- Dust, bio-aerosols, odours and vermin at processing sites.

Composting

Composting is a process for the recovery of valuable material from biodegradable organic matter in the waste stream. It is an aerobic, biological process of degradation that produces material that can be used as a soil-amendment. Centralised composting is a large scale composting process whereby organic wastes from local authority parks and civic amenity sites are brought to one centralised location. Composting is also done at home and in allotments. The advantages of composting are:

- Reduction in the volume of waste disposed of to landfill. Organic biodegradable matter makes up to 60% of municipal solid waste which can be removed by composting.
- Recovery of useful organic matter for use as fertiliser in gardening, agriculture and landscape.
- Reduction in amount of landfill gas and leachate produced and the need for new landfill sites.

The disadvantages of composting are:

- Emissions from transport.
- Dust, spores, odours and possibly vermin.

Soil amendments

Valuable material from sewage can be recovered for use as a soil amendment on agricultural land, either by landspreading sewage sludge or by irrigating the land with wastewater. Sewage sludge consists of the solids that have settled out during primary and secondary sewage treatment (see *Sewage treatment* below). The raw sludge is further treated to reduce its water content and the concentration of pathogenic micro-organisms. In

the past, raw sewage wastewater was applied to land and the sludge dumped at sea but this has now been banned in the UK. The Landfill Directive restricts the amount of sewage sludge that can be dumped in landfill and most sewage sludge is sent to agricultural land (Environment Agency 2000).

Energy recovery

Energy can be recovered from:

- Incineration of waste – old style incinerators do not recover energy but modern incinerators are designed as waste-to-energy plants. Mixed waste incinerators capture only 20% of the energy generated (Murray 1999 p26).
- Refuse derived fuel – waste is used as a fuel substitute.
- Collection of methane-rich gas from landfill sites.
- Anaerobic digestion of organic wastes with energy released as a by-product of the process.

New and emerging energy recovery technologies are listed in the *Waste Strategy 2000* (DETR 2001 Chapter 5).

2.2.5 Waste processing

Sewage treatment

Sewage is the waste which is discharged through the drains and processed at sewage treatment works. Sewage consists of foul domestic and industrial wastewater as well as storm water. Raw sewage is 99.9% water with 0.1% suspended and dissolved solids. The treatment process results in a liquid effluent and a semi-solid sludge. There are two objectives of sewage treatment:

1. To produce an effluent which is suitable for abstraction for treatment to produce a supply of drinking water.
2. To make the sludge easier and cheaper to dispose of while minimising adverse effects on the environment.

During sewage treatment, pathogenic micro-organisms may be destroyed or concentrated in the sludge. Toxic and offensive materials may be concentrated in the sludge or biodegraded. The treated effluent is discharged to rivers or the sea while the sewage sludge is disposed of in landfill, used as a soil amendment on agricultural or horticultural land, dumped at sea or incinerated. Dumping at sea is no longer permitted in the UK.

Incineration

Incineration is a waste processing option which converts waste to energy and reduces the volume of waste going to disposal. It is an interim waste processing function and not the final stage of waste management. Incineration produces combustion products which are released into the atmosphere as gases and ash which is disposed to landfill or used in construction. Modern

incinerators are designed to produce nearly complete combustion and to release negligible amounts of air pollutants from the stacks. However, pollutants are not destroyed by the process of incineration. Instead, they are released from the incinerator as solid residues rather than as gases. There is a direct link between air emissions and the nature and amounts of solid residue produced – as more effective pollution control devices are fitted to incinerator stacks, the concentration and leachability of toxic metals in the fly ash increase. Most of the studies of health effects are of old incinerators with less efficient pollution control technologies, but even incinerators operating to current emission standards may have off-normal emission incidents. The process of incineration does not eliminate health hazards from waste. It transfers the risks to another waste management method, usually landfill.

The benefits of incineration are:

- Reduces weight and volume of waste – about 30% of weight is left as ash (Farmer & Hjerp 2001).
- Reduces potential infectivity of clinical waste.
- Can use bottom ash for materials recovery.
- Produces energy which can be recovered partially for electricity generation.

The disadvantages of incineration are:

- Produces hazardous waste that must be disposed of.
- Enhances mobility and bio-availability of toxic metals present in waste (Denison & Silbergeld, 1988).
- Discharges contaminated wastewater.
- Emits toxic air pollutants.
- Produces carbon dioxide, a greenhouse gas.
- Causes emissions from transport of waste to and from incinerator.
- Does not alter the process of waste collection and transfer.

2.2.6 Waste disposal

Discharge to rivers and sea

The liquid effluent from sewage treatment works is disposed of by discharge into rivers and the sea. Water quality is inevitably affected by the level of sewage treatment. In the South West, water companies are investing in sewage treatment improvement programmes to ensure compliance with the minimum standard of sewage treatment stipulated by EU legislation. However, some of the improvement schemes are behind schedule (Environment Agency 2001). There is concern in the South West about the quality of bathing waters, river water, and shellfish waters as a result of sewage discharges. The hazards of concern are the faecal pathogens which could pose a health risk to

recreational users of surface waters, to consumers of shellfish and to drinking water supplies.

Landfill

Landfill is the dumping of waste on the land. The term landfill includes a wide spectrum of sites ranging from managed, engineered, regulated sites to illegal, uncontrolled dumps.

Currently, in a typical UK municipal landfill, waste is deposited in a pre-constructed cell in an engineered site. The base is impermeable clay or is lined with a plastic, rubber or composite layer covered by earth. At the end of each day, the waste is covered with an inert material such as soil. When the cell is full, it is covered over with a layer of inert material. During operation, a fence is built around the site to prevent the wind from blowing material off site. A drainage system is built to collect water runoff and leachate. An energy recovery system is constructed to collect gas which can either be used to generate electricity or is flared (Tubb & Iwugo 2000b).

The Landfill Directive (99/31/EEC) regulates the operation of landfill sites in the UK. To protect human health, the Directive bans the disposal of all liquids, infectious clinical wastes, and tyres to landfill. It requires treatment prior to landfilling except for inert wastes and requires aftercare of closed landfills. In sites receiving biodegradable waste, landfill gas must be used or flared. Co-disposal of hazardous waste with municipal waste is no longer allowed.

The benefits of landfill are:

- It has been a cheap way to dispose of waste by dumping it in disused quarries and abandoned industrial sites.
- Waste is used to backfill quarry before reclamation.
- Landfill gas contributes to renewable energy supply. In the South West, about two thirds of the region's renewable energy supply is from landfill gas (Environment Agency South West 2001).

The disadvantages of landfill are:

- Water pollution from leachate and runoff.
- Air pollution from the anaerobic decomposition of organic matter producing methane, carbon dioxide, nitrogen, gases, sulphur, and volatile organic compounds.
- It is not a sustainable option. The South West has less than seven years of licensed landfill capacity for biodegradable waste (Environment Agency South West 2001).

A summary of the potential advantages and disadvantages of different elements of the waste hierarchy is shown below in Table 3.

Table 3: Strategies for waste disposal: advantages and disadvantages

Waste strategy	Advantages	Disadvantages
Waste minimisation	<p>Conservation of resources.</p> <p>Reduction in waste toxicity and pollution.</p> <p>Reduction in greenhouse gases.</p>	<p>Requires major economic, social and psychological changes in society and by individuals.</p> <p>Immediate action needed to deal with waste produced now.</p>
Re-use	<p>Energy and raw material savings, reducing need for manufacture of new products. These benefits are realised only if products are not discarded before the end of their useful life.</p> <p>Reduced waste disposal costs.</p> <p>Cost savings for consumers and businesses.</p> <p>New market opportunities and more jobs.</p>	
Recycling	<p>Conservation of resources.</p> <p>Energy savings.</p> <p>Supply of raw materials to industry.</p> <p>Reduction in emissions to air and water in the production process.</p> <p>Job creation.</p> <p>Development of greener technologies.</p> <p>Reduction in the need for new landfills and incinerators as there is less waste to dispose.</p>	<p>Emissions from transport of material to be recycled.</p> <p>In some cases, there may be more energy used for processing than for original manufacture.</p> <p>Dust, bio-aerosols, odours and vermin at processing sites.</p>
Composting	<p>Reduction in the volume of waste disposed of to landfill. Up to 60% of municipal solid waste can be organic biodegradable matter which can be removed by composting.</p> <p>Recovery of useful organic matter for use as soil amendment in gardening, landscape and agriculture.</p> <p>Reduction in amount of landfill gas and leachate produced and in the need for new landfill sites.</p> <p>Employment possibilities at centralising composting facilities.</p> <p>Satisfaction and pleasure from home composting.</p> <p>Does not contribute to global warming or to resource depletion.</p>	<p>Emissions from transport.</p> <p>Odours, noise and possibly vermin nuisance.</p> <p>Bio-aerosols - organic dust containing bacteria or fungal spores.</p> <p>Emits volatile organic compounds.</p> <p>Possible long term build-up of potentially toxic substances in soils amended with compost which does not meet strict quality guidelines and requirements.</p> <p>Occupational hazards.</p>
Land spreading sewage sludge	<p>Recovery of nutrients for use as fertiliser in agriculture and horticulture.</p>	<p>Contamination of sludge with organic compounds</p> <p>Contamination with heavy metals.</p> <p>Contamination with protozoal spores, worm cysts or eggs, enteroviruses, enteric bacteria or fungi.</p> <p>Nuisance affecting quality of life.</p> <p>Occupational hazards to workers.</p>
Sewage treatment	<p>Safe disposal of human waste - avoids pestilence and nuisance, protects sources of potable supply, produces sewage effluent suitable for treatment to produce potable supply.</p>	<p>Sewage discharges may contain organic compounds and endocrine disrupting compounds.</p> <p>Sewage discharges may contain heavy metals.</p> <p>Sewage discharges may contain pathogenic micro-organisms.</p> <p>Hydrogen sulfide exposure.</p> <p>Odour and litter nuisance.</p> <p>Occupational hazards to workers.</p>

Table 3 Strategies for waste disposal: advantages and disadvantages (Continued)

Waste strategy	Advantages	Disadvantages
Incineration	<p>Reduces weight and volume of waste, about 30% of weight is left as ash.</p> <p>Reduces potential infectivity of clinical waste.</p> <p>Can use bottom ash for materials recovery.</p> <p>Produces energy which can be recovered partially for electricity generation. Job creation during building of new incinerator.</p>	<p>Produces hazardous solid waste that must be disposed of.</p> <p>Enhances mobility and bio-availability of toxic metals present in waste.</p> <p>Discharges contaminated wastewater.</p> <p>Emits toxic air pollutants.</p> <p>Causes emissions from transport of waste to and from incinerator.</p> <p>Does not alter the process of waste collection and transfer.</p> <p>Emits toxic organic compounds (e.g. dioxins) heavy metals, particulates, acidic gases and acidic aerosols.</p> <p>Fire risk.</p> <p>Road traffic hazard.</p> <p>Psychosocial hazards.</p> <p>Occupational hazards.</p> <p>Drop in property values.</p> <p>Combustion generates carbon dioxide and contributes to global warming.</p> <p>Adds to resource depletion.</p> <p>Increases use of fossil fuels (e.g. plastics burned rather than their use minimised or recycled).</p>
Landfill	<p>Has been a cheap way to dispose of waste by dumping it in disused quarries and abandoned industrial sites.</p> <p>Waste used to backfill quarry before reclaimed.</p> <p>Landfill gas contributes to renewable energy supply.</p>	<p>Water pollution from leachate and runoff.</p> <p>Air pollution from anaerobic decomposition of organic matter producing methane, carbon dioxide, nitrogen, sulphur, and volatile organic compounds.</p> <p>Not a long term sustainable option for energy generation.</p> <p>Emits toxic chemicals, heavy metals, microbial pathogens.</p> <p>Vermin near open sites.</p> <p>Road traffic hazards.</p> <p>Fire and explosion risks.</p> <p>Psychosocial hazards affecting quality of life - nuisance, stress, fear and worry.</p> <p>Occupational hazards.</p> <p>Drop in property values.</p> <p>Landfill gases add to global warming if not utilised.</p> <p>Adds to resource depletion.</p> <p>Disposal to landfill increases use of fossil fuels.</p>

2.3 Waste management regulation

2.3.1 Roles and responsibilities

The roles and responsibilities of different authorities with respect to risk management is shown in Table 4.

2.3.2 Strategies and Plans

Waste Local Plan

This is a guide to the land use planning aspects of waste management. It is prepared by the county councils as a statutory requirement of the Town and Country Planning Act 1990. Together with the Minerals Local Plan and the District Local Plans, it makes up the county's statutory Structure Plan, i.e. the overall development plan for the county. The statutory consultation procedure is laid down in the Town and Country Planning Act.

Waste Management Strategy

This is a non-statutory document, providing guidance for

improving waste management practice and priorities in the county. It is the overall framework from which the more detailed Waste Local Plan is prepared. There is no statutory consultation procedure.

Progress with Waste Strategies and Local Plans in the South West are presented in Appendix 3.

2.4 Waste management in the South West

Most waste (approximately 85%) is dumped in landfill. Of the 6 million tonnes sent to landfill, approximately 3.5 million was biodegradable and over 2 million tonnes was inert or construction and demolition waste. Recycling rates vary across the region (Environment Agency 2000, data for 1998/99) and are shown in Figure 3.

A summary of waste management facilities in the South West is shown in Figure 4.

Table 4: Roles and responsibilities of different authorities involved in waste management

Function	Responsible body	Advisory body
Policy		
National Waste Strategy	England - Department for Transport, Local Government and the Regions Wales - National Assembly for Wales, to be published in Spring 2002 when it will replace Waste Strategy 2000 England and Wales	Environment Agency Public consultation
Regional Waste Strategy	Regional Assembly	Public consultation
Strategic Waste Policy for County Structure Plan	County Council as Waste Planning Authority	Public consultation
Waste Local Plan for County	County Council as Waste Planning Authority	Public consultation
Municipal Waste Strategy	County Council as Waste Disposal Authority	Public consultation
Recycling plans	District Council as Waste Collection Authorities	Public consultation
Management		
Regulates management of waste from production to disposal through a licensing system, (IPPC regulation) of larger schedule A (1) pollution processes	Environment Agency as Waste Regulation Authority	
Has responsibility for protecting and improving rivers and groundwater	Environment Agency as Waste Regulation Authority	
Carries out Development Control - determines planning applications, monitors and enforces planning controls	County Council as Waste Planning Authority	Environment Agency and Health Authorities - statutory consultees
Handles contracts for the management of waste collected by Waste Collection Authorities	County Council as Waste Planning Authority	
Provides facilities for management of bulky household waste and recycling	County Council as Waste Planning Authority	
Undertakes 'Closed Site' management for sites previously operated by the County Council	County Council as Waste Disposal Authority	
Collect household waste and transport to waste management facilities	District Council as Waste Collection Authorities	
Run recycling facilities	District Council as Waste Collection Authorities	
Collect business and commercial waste	District Council as Waste Collection Authorities	
Information		
Provides data on waste arisings	Environment Agency as Waste Regulation Authority	

Source: Gloucestershire County Council Waste Local Plan 2001, p2

Figure 3: Recycling rates by local authority 1998. South West

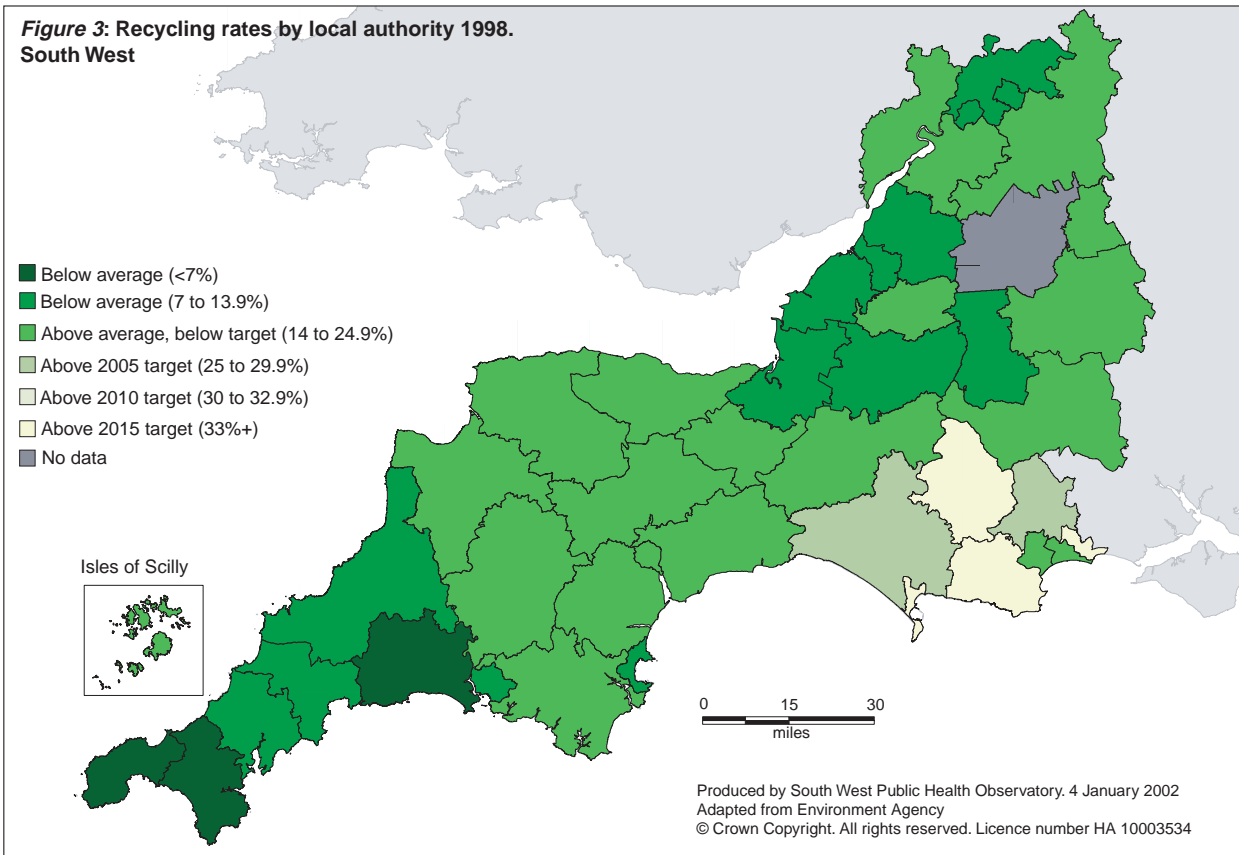
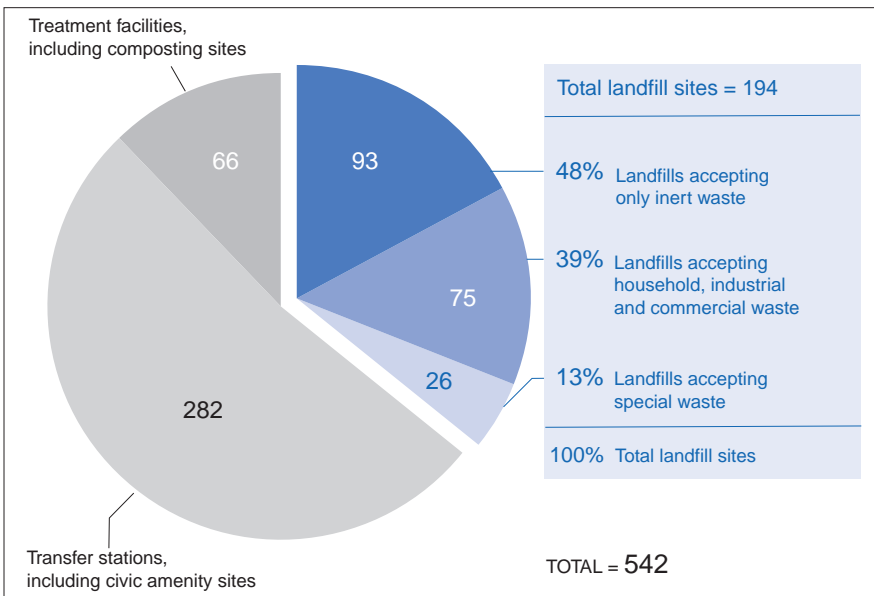


Figure 4: Waste management facilities in the South West in 1998-99



Source: Environment Agency 2000

3 Impact on human health

How might waste management practices impact on human health?

3.1 Definition of health

An often-quoted definition of health is one provided by the World Health Organisation – health is a *'state of complete physical, mental and social well-being and not merely the absence of disease and infirmity'*. *Better Health, Better Wales* (Welsh Office 1998) added to this by saying that sustainable health is achieved *'when people and communities can take control of their lives and are able to live their lives to the full.'*

3.2 Case studies

Two case studies illustrate the issues involved in finding evidence of the effects of waste management operations on health. The background to each case is presented in this section and the relevant findings in the sections which follow.

3.2.1 Nant-y-Gwyddon, Wales

In 1988, the Nant-y-Gwyddon landfill site was opened to dispose of household, commercial and industrial waste. In the same area, there were up to seven other operating and closed landfill sites (Roberts et al 2000). There had also been a municipal waste incinerator located in a steep north westerly valley running through the area. The incinerator operated between 1974 and 1987 and had been closed because of local complaints, poor performance and air pollution (Roberts et al 2000). In 1996, residents complained about the odours emanating from the Nant-y-Gwyddon landfill site. They formed an action group called RANT – Residents Against Nant-y-Gwyddon tip and asked the health authority to investigate the effects on their health. The health authority met with the residents and identified a list of health concerns (Fielder et al 2000). These were mortality, hospital admissions, and various reproductive health outcomes. No exposure data were available and there was no community monitoring during the peak of the problem. The exposed population was defined as residents living in the five electoral wards within 3 km of the site, a population of 20,000 people. The comparison group was the population living in 22 other electoral wards in the same local authority, matched for deprivation by the Townsend score.

The odour was identified as hydrogen sulfide but monitoring of the site in 1997 revealed higher than normal levels of potentially toxic chemicals such as styrene, dimethyl styrene, ethyl benzene and C4 alkyl benzenes. Hydrogen sulfide is not known to cause

congenital abnormalities but is likely to cause headaches, eye irritation and sore throats.

3.2.2 Love Canal, United States

A canal in Niagara Falls, New York state, was used as a landfill site by the Hooker Chemical Company. Between 1942 and 1953, the company disposed of 19,000 tonnes of organic chemical wastes which were produced during the manufacture of pesticides. In 1953 when the canal was full, it was covered with a clay cap and sold to the Niagara Board of Education for \$1.00. A school and playground were built on the canal and housing built adjacent to it. The integrity of the clay cap was breached in the process with the result that rain seeped in and eventually caused the chemicals to overflow the canal. The residents and city officials were aware of *"black sludges bleeding through basement walls, smells like a chemical factory, rancid liquids of yellow and orchid and blue"* oozing out of yards, etc (Brown 1980). However, there was no concern about the health effects of such exposure until the late 1970s. In 1978, the New York State Department of Health evacuated the 235 families in the ring of homes closest to the canal. Two years later, the federal government evacuated 800 more families in the next ring of homes. The public alarm over the incident was instrumental in bringing about Superfund legislation.

At Love Canal, records from Hooker Chemical Company revealed that the waste consisted of lindane and other chlorinated hydrocarbon by-products. Investigations of the canal led to the identification of 248 chemicals by 1980. These included lindane, benzene, toluene, chloroform, trichloroethylene, tetrachlorethylene, hexane, xylenes, trichlorophenol, hexachlorocyclopentadiene and dioxin isomers (Paigen et al 1987). Toxicology data were available on fewer than half of these chemicals and much of the available data were incomplete. For those contaminants where toxicological data were available, the implications for human health were not reassuring. Benzene was one of the volatile organic chemicals identified in the canal. From toxicological and occupational studies, benzene is known to cause leukaemia, aplastic anaemia, bone marrow depression, central nervous system depression and skin irritation. It is suspected of embryotoxicity, teratogenesis and of leading to female infertility and lymphoma (Buffler et al 1985).

3.3 Quantifying factors which may affect health

The definitions of health in 3.1 provide a foundation for identifying factors associated with waste management which might have an impact on health. These may be

beneficial, damaging or neutral. They may be present in waste or formed during the waste management process. Table 5 illustrates the factors which may impact on health and have been studied in relation to methods of waste management.

The references listed in Table 5 are examples of

studies found in the literature which have investigated an association between the factor mentioned and the waste management method. This table is **not** a comprehensive listing of all the studies found in the literature nor is it evidence of a causal association.

Table 5: Health hazards associated with waste management methods

Factor	Landfill	Incineration	Composting	Sewage sludge	Sewage treatment
Physical hazards					
Organic chemical	The main ones found are: Polycyclic aromatic hydrocarbons (Silkworth et al 1995). Benzene, benzo(a)anthracene, benzo(a)pyrene, chrysene, heptachlor, polychlorinated biphenyls, tetrachloroethylene, dichlorodiphenyltrichloroethane, trichloroethylene (Dayal et al 1995). Volatile organic compounds (Zmirou et al 1994). Organochlorine pesticides and volatile organic compounds (Arndt et al 1999). PCDD/F dioxins and furans (Ewers et al 1994). PCBs (Stehr-Green et al 1988). Alkanes, chlorinated saturated and unsaturated hydrocarbons (Laurent et al 1993).	Dioxins and furans, PCBs, chlorinated benzenes, halogenated phenols, polychlorinated dibenzothiophenes, PAHs, volatile organic compounds (Allsopp et al 2001, National Research Council 2000, Marty 1993).	Volatile organic compounds (Environment Agency 2001).	Polycyclic aromatic hydrocarbons, pesticides, halogenated aliphatic compounds, PCBs, chlorobenzenes, volatile organic compounds, phenols, dioxins, furans, phthalates (Health Canada 2000).Pharmaceutical chemicals (Rogers 1996).	PCB (Nethercott & Holness 1988). N-Nitroso compounds, aromatic amines, genotoxic PAHs, (White & Rasmussen 1998). Herbicide isoproturon (Nitschke, & Schussler 1998).Endocrine disrupting compounds - PCBs, dioxins, pesticides such as DDT, methoxychlor, HCH, chlordane, mirex, dieldrin, herbicides such as atrazine, simazine, fungicides such as vinclozolin, synthetic hormones such as contraceptive pill, natural hormones such as oestradiol in urine, alkylphenol polyethoxylates, phthalates such as DEHP (IEH 1995).
Heavy metals	Chromium (Wedeen et al 1996, McCarron et al 2000). Arsenic, cadmium, chromium, mercury and lead (Beccaloni et al 2000) Mercury (Reif et al 1993).	Mercury, lead, cadmium, arsenic, chromium (National Research Council 2000, Allsopp et al 2001, Marty 1993, Denison & Silbergeld 1988).	Heavy metal accumulation in soils and crops of land treated with compost (Eitzer et al 1997, Deportes et al 1995).	Manganese, copper, cadmium, mercury, lead, chromium, nickel, zinc (Health Canada 2000)	Mercury - dental amalgam (Fan et al 1997, Rowe et al 1996)
Dust	Lead dust (Sterling et al 1988). Dust from hazardous waste site (Neutra et al 1991).	Particulate matter (National Research Council 2000).	Dust (Environment Agency 2001).		
Microbial pathogens	Clostridium botulinum type C (Ortiz & Smith 1994).	Unlikely to be associated with incineration.	Bioaerosols i.e. organic dust, containing bacteria such as <i>Clostridium botulinum</i> and endotoxin-producing Gram negative bacteria and/or fungal spores such as <i>Aspergillus fumigatus</i> , (Bunger et al 2000, Environment Agency 2001, Bohnel & Lube 2000).	Protozoa - amoebae, <i>Toxoplasma gondii</i> , <i>Giardia lamblia</i> , <i>Cryptosporidium</i> Helminths - cysts or eggs of <i>Ascaris</i> spp, <i>Trichuris</i> spp, <i>Taenia</i> spp Viruses - enteroviruses such as Hepatitis A, adenoviruses, rotaviruses, coronaviruses, Bacteria - enteric bacteria such as <i>Salmonella</i> , Also <i>Streptococcus</i> , <i>Clostridium</i> , <i>Mycobacterium</i> , <i>Listeria</i> , Fungi - <i>Aspergillus fumigatus</i> , <i>Candida albicans</i> , <i>Cyrtococcus neoformans</i> (Health Canada 2000, Straub et al 1993)	Health benefits from sewage treatment - safe disposal of human waste, avoids pestilence and nuisance, protects sources of potable supply, produces sewage effluent suitable for treatment to produce potable supply (Royal Commission on Sewage Disposal 1898-1915). Health hazards from sewage treatment - Pathogenic microorganisms (Dumontet et al 2001, Collins & Kennedy 1992).Bacteria: Enteric bacteria/faecal streptococci (Alkan 1999, Pruss 1998) <i>Campylobacter</i> (Koenraad et al 1997). Antibiotic resistant bacteria in hospital sewage (Fara & Collina 1989).Viruses: Hepatitis B (Arvanitidou et al 1998). hepatitis A (Desenclos et al 1991). Norwalk virus (Grohmann et al 1980). Rotavirus (Gerba et al 1996).
Vermin	Risk of spreading disease but low probability of occurrence (Health Canada 2000). Residential complaints about rodents, flies and birds near landfill operations (Redfearn et al 2000).	Unlikely to be associated with incineration.	Possibility.	Insects, vermin (Health Canada 2000)	

Table 5: Health hazards associated with waste management methods (continued)

Factor	Landfill	Incineration	Composting	Sewage sludge	Sewage treatment
<i>Physical hazards (cont'd)</i>					
Radionuclides	Radium (Bosco et al, 2001)	Not mentioned anywhere	Unlikely to be associated with composting		Clinical waste
Inorganic compounds	Hydrogen sulfide (Fielder et al 2000)	Acidic gases -SO ₂ , HCl and HNO ₃ . Acidic aerosols with H ₂ SO ₄ (National Research Council 2000)	Unlikely to be associated with composting	Nitrates, nitrites, ammonia nitrogen, potassium, calcium, magnesium (Health Canada 2000)	Hydrogen sulphide (Schneider et al 1998)
Road traffic	Transportation risks associated with removing soil during remediation of hazardous waste site (Mar et al 1993) Residential complaints about landfill operations (Redfearn et al 2000)	Possibility	Possibility		
Fire and explosion	Explosion in Loscoe, Derbyshire (BMA 1991 p116).31 cases in USA 1967-1987 (Health Canada 2000).	Fire at Dundee incinerator (ENDS 2000)	Unlikely to be associated with composting		
Psychosocial factors					
Quality of life	Nuisances - bad smells all year round, preventing residents from opening windows or going for walks, windblown rubbish in gardens, hundreds of flies in houses, flocks of seagulls and crows defecating on washing left outside (Robinson 2001). Residential complaints about odour, litter, noise, hours, mud, dust, traffic near landfill operations (Redfearn et al 2000). Noise from traffic and machine operation - may lead to disturbed sleep if work starts early morning.	Resident perception of neighbourhood quality (Greenberg et al 1995) Disruption of cohesion, neighbourhood change, increase or decrease in population, lack of community control (National Research Council 2000).	Noise and odour nuisance (Environment Agency 2001).	Nuisance (Health Canada 2000)	Odour (Shusterman 1992).Litter on UK beaches from sewage discharges (Philipp et al 1997).
Psychological factors	Concerns, stress, worry by residents living near hazardous waste sites (Carruth et al 1997, Whiteman et al 1995, Unger et al 1992, Shusterman et al 1991, Neutra et al 1991, Horowitz & Stefanko 1989).	Public concerns, distrust of government and scientific institutions, anxiety, stress, feelings of powerlessness and alienation, increase in self esteem and social connection due to involvement in community activism against site (National Research Council 2000, NSCA 2001).	Benefit to health with home composting - satisfaction, fun.		
Occupational factors					
Health and safety precautions	New York landfill workers vs other New York sanitation workers (Gelberg 1997).	Adverse health effects in workers (Callender et al 1997, Wrbitzky et al 1995).	Possible adverse effects on health of workers (Environment Agency 2001).	Fungal and bacterial spores and viruses in air pose risk to workers who apply sludge or work on treated site (Health Canada 2000)	Health among municipal sewage and water treatment workers (Scarlett-Kranz et al 1987)

Table 5: Health hazards associated with waste management methods (continued)

Factor	Landfill	Incineration	Composting	Sewage sludge	Sewage treatment
Economic factors					
Employment	Jobs created but not many compared with other types of waste disposal operations.	Increase or decrease in overall employment or unemployment and change in occupational distribution (National Research Council 2000). Most jobs created by incineration are associated with building the incinerator (Leonardi & Hankin 2001).	Employment at centralised composting sites.		
Economic benefits to agricultural sector	None.	None.	Compost used to improve soil structure, retain soil moisture, act as fertiliser - benefit to agriculture. Compost contaminated with heavy metals - disadvantage to crop production.	Benefit - Source of fertiliser Disadvantage - Source of contaminants	
Property values	Devaluation and price downgrading (Health Canada 2000, Vol 2, p189).	Increase or decrease in land values, change in taxation resulting from change in land use and income change in types of housing and occupancy (National Research Council 2000).	Possibility.		
Environmental factors					
Global warming	Landfill gases add to global warming if not utilised. Utilisation of gas would displace 350,000 tonnes of CO ₂ each year from conventional electricity generation, saving between £2.7m and £10.7m in global warming impacts, according to DEFRA (DEFRA 2001 p60).	Adds to global warming. Combustion generates carbon dioxide, a greenhouse gas.	Does not add to global warming, compared with incineration.		
Resource conservation	Adds to resource depletion - disposal to landfill increases use of fossil fuels - plastics dumped in landfill rather than minimised or recycled.	Adds to resource depletion. Incineration increases use of fossil fuels - plastics burned rather than their use minimised or recycled.	Does not add to resource depletion.		

3.3.1 Quantifying factors which may impact on health

Health hazards can be measured or estimated with varying degrees of accuracy. The number of jobs lost or created by a waste management policy can be counted. Community involvement can be measured by assessing the extent of activity in community recycling schemes. Physical hazards can be identified by measuring concentrations in:

- Waste – i.e. in emissions, incinerator ash, sewage sludge, etc.
- The environment around the waste management site – i.e. in the soil, air, plants, animals, water, groundwater.
- People – i.e. the body burden.

With improvements in analytical methods, contaminants can be identified at very low concentrations, so small that their implications for human health is a matter for conjecture.

Identifying and measuring hazards gives an impression of accuracy and can lead to the assumption that the measurable risks from physical hazards are more substantial and important than those from psychosocial hazards. In fact, data about physical hazards are also incomplete. Information is lacking about the toxicity, persistence and ability to bioaccumulate of many of the hundreds of thousands of chemicals that end up in waste. Out of some 100,000 chemicals notified before 1981, the so-called Existing Chemicals, most have not been assessed. Of some 2,000 chemicals notified since 1981, the so-called New Chemicals, many assessments are not complete (Santillo, 1999).

3.3.2 Measuring toxicity

Most information on toxicity is derived from animal experiments. Toxicity is usually defined in terms of LD50, the dose in mg/kg body weight required to kill half of the animals tested. This value is specific to the species tested as well as to the conditions under which it was tested. It is hard to know what order of magnitude to use to extrapolate from animals to humans as there are vast differences between species. Extrapolation to humans is usually based on the most sensitive animals species tested.

Chronic toxicity is more relevant than acute toxicity to the type of exposure from hazardous waste sites but is even harder to determine for humans. Some knowledge is derived from occupational exposure but most is extrapolations from short term high doses in animals to long term low doses in humans. This can lead to under or over estimations of toxicity. Some chemicals such as cyanide may be hazardous at high doses but harmless at low doses while others, such as PCBs, do not cause acute toxicity at high doses but are carcinogenic or teratogenic at chronic low doses.

The toxicity of heavy metals is well known from clinical and epidemiological studies and is not dependent on extrapolations from animal studies (Denison and

Silbergeld 1988). Heavy metals, i.e. lead, mercury, cadmium, accumulate both in the environment and within the human body. Long term low level releases from waste management operations have the potential to lead to substantial levels in the environment and the body. Given that there are other environmental sources of metals and that every person carries measurable levels in their bodies, a small increase in exposure from incineration could theoretically raise levels in people enough to cause overt toxicity. In some populations, existing levels of exposure and body burdens are already in a range associated with detectable adverse impacts. Exposure to persistent chemicals cannot be considered in isolation from other sources.

3.3.3 Combination of chemicals

In most waste, a mixture of different contaminants will be present. Little is known about the toxicity of combinations of contaminants, or whether their interaction is to increase toxicity or to modify it. Assessment of the potential health hazard of mixtures is a challenging task for toxicology. The risks may be additive or there may be interaction effects that make the risks higher or lower than that predicted by analysing individual contaminants separately. There may be no interaction at all, with each compound acting independently. Nor is there an adequate understanding of the effects on toxicity of the changes which occur when chemicals migrate through soil or water. Unlike laboratory conditions where animals are exposed to one chemical at known doses, people's exposure to waste sites is typically complex with many agents and multiple pathways (Hansen et al 1998, Carpenter et al 1998).

3.3.4 Comparing hazards from different waste management options

Both incinerators and landfill sites result in the emission of toxic pollutants, including dioxins. While most people assume that the greatest risk to health from airborne pollutants arises from incinerators, a generic comparison using modelling techniques came to the opposite conclusion (Bridges et al 2000). The comparison was based on worst case off-site exposures and concluded that landfills without gas collection pose a potentially higher risk than municipal solid waste incinerators performing to UK standards. It must also be understood that incineration and landfill disposal are inextricably linked. Improvements in air quality controls reduce the toxicity of emissions from incinerators but increase the toxicity of fly ash and bottom ash disposed of in landfill. This practice of risk transfer must be considered when evaluating the health risks from waste management methods.

3.4 Exposure routes

For physical hazards, the crucial link between a health hazard and a health outcome is exposure. The risk to health depends not only on how much is present but

also on whether there is a route by which people may be exposed. *"Indeed, in the absence of exposure, even the most toxic compound carries less risk than an innocuous one."* (Kipen 1996 p221.) A complete exposure pathway is a pathway which starts at the source of contamination and travels through environmental media to the point of exposure and by some route of exposure to an exposed population (WHO European Centre for Environment and Health 2000). An exposure pathway has three elements:

- release from the site
- transport through environmental media
- uptake by people.

If any of these elements are missing, there is no threat to health.

3.4.1 Release

Pollutants are released from waste operations as gases, liquids and solids:

Gases

- Gases exit from incinerator stacks and migrate off landfill sites.
- Organic chemicals volatilise into the atmosphere. This is a problem where the soils are very heavily contaminated or where there are open pools of pure chemicals in a concentrated aqueous solution (Eduljee 1992).

Liquids

- Leachate is carried out of the contaminated area by percolating water into groundwater. Leachate is a combination of liquid waste arriving in the site and water added due to rainwater ingress or groundwater infiltration. Leachate is formed by:
 - dissolution of soluble matter
 - bacterial degradation of organic matter – oxidative decomposition by acetogenesis and anaerobic decomposition by methanogenesis.
 - solubilisation – chemical degradation where insoluble inorganics become soluble.
- Leachate is carried off-site by surface runoff.
- Wastewater from incinerator cleaning equipment.
- Treated sewage effluent.

Solids

- Dust emissions resulting from unloading solid waste, loading temporary landfill cover material, lift construction, vehicle traffic to the site, wind erosion from site if large areas are left exposed.
- Incinerator ash includes bottom ash (i.e. the solid residue at the bottom on the grates, the ash remaining after combustible material has been burnt) and fly ash (i.e. the solids collected by particle trapping devices beyond the combustion chamber). Ash contains highly concentrated and bioavailable toxic heavy metals and dioxins.

Amounts released

The quantities released are crucial to an assessment of exposure. In landfill operations, levels of pollutants vary greatly according to the nature of the wastes deposited and the time period since they were dumped. The types of chemicals found in landfill gas change during the chemical and microbial decomposition of the waste. Even after the landfill site is closed, there will be emissions for many years, perhaps up to 50 years. (For discussion of the different chemicals produced during the stages of landfill degradation, see Bridges et al 2000.) Some pollutants, such as metals, are present in incinerator emissions because the combustion process does not destroy them while others are formed during the cooling of the gas stream (Bridges et al 2000).

3.4.2 Transport of pollutants

Pollutants are transferred into and out of various environmental media. Rates of transfer are affected by biodegradation, partitioning, bio-concentration, dilution, and other physical, chemical and biological processes (National Research Council 2000).

The ground level concentrations of pollutants from an incinerator are affected by the height of the stack, the gas cleaning technology in operation, prevailing wind and other weather conditions and the local topography. Metals are neither created nor destroyed by incineration but are transported from their embedded, inert phase in the waste to a highly mobile particle. Some particles condense on the surface of the fly ash and are eventually sent to landfill where certain conditions enhance their leachability in water. Many of these particles are of respirable size, less than 10 micrometers, and can travel long distances through the air. Metals are also released from incinerators as fumes.

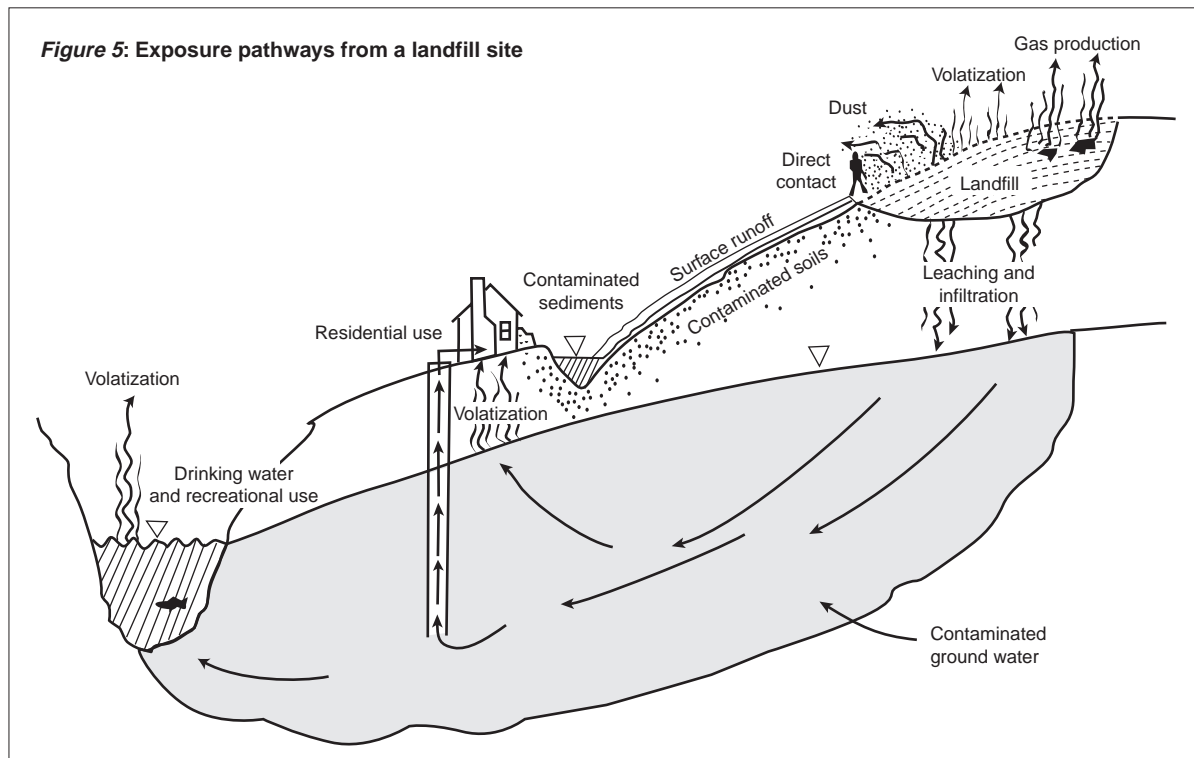
3.4.3 Uptake

Pollutants may be released from the waste site and may remain toxic after passing through various environmental media but will only pose a risk to health if they are taken up by people in sufficient quantities and over a sufficient length of time. Potentially exposed populations are waste site workers, construction workers involved in development of operational or closed site, on-site trespassers, neighbouring residents and those using the site and surrounding area for recreation. The main routes by which people may become exposed to pollutants from waste sites are shown below.

Inhalation

Pollutants released into the air from incinerators, composting facilities, and landfill sites may be inhaled by people living in the vicinity or working at the sites. Many particles from incinerator fumes and fly ash are of respirable size and can be directly inhaled. Volatile organic chemicals may evaporate into the atmosphere from landfill sites and be inhaled. Measurements made

Figure 5: Exposure pathways from a landfill site



Source: Eduljee 1992

below ground level using fixed-point samples in a landfill site do not indicate a health risk since there is no chance of a person inhaling the pollutants there. There may be a health risk from the inhalation of the combustion products of landfill gas from flaring and use of the gas in gas turbines and internal combustion engines (Bridges et al 2000).

Love Canal – inhalation was an important exposure route for some of the residents. Because of the way the groundwater moved, volatile chemicals escaping from the canal seeped into the basements of houses that were built near former stream beds and ponds. Chemicals either migrated through the porous walls or sump pumps allowed evaporation into the homes. High concentrations of benzene, toluene and other Love Canal chemicals were measured in indoor air.

Nant-y-Gwyddon – inhalation was the only exposure route considered, as the investigation arose out of complaints about odour.

Ingestion

Particulates with adsorbed chemicals or heavy metals can be carried by the wind and deposited on soil, surface water, food and dust. This is particularly a risk with toxic metals such as lead and cadmium and persistent organic chemicals which contaminate soil either by direct deposition or when contaminated sewage sludge or incinerator ash is applied to agricultural land.

Toxins may be taken up by crops or eaten by livestock, both of which may be consumed by people. An example of how this may happen was described in a

report to the Society for Clean Air and Environmental Protection (Farmer & Hjerp 2001, section 5.8). The incident concerned the use of fly ash and bottom ash from the Byker incinerator to construct footpaths in allotments in Newcastle over a six year period. The allotment soil became heavily contaminated with heavy metals and dioxin. Eggs from the allotments were found to have higher than background levels of dioxins.

Small children tend to put things in their mouths that have been in contact with the soil.

Love Canal – ingestion was considered to be one pathway by which children were exposed. "Children picked up raw chunks of lindane and phosphorous and threw them around and slobbered through liquid organic wastes." (Albert 1987)

Nant-y-Gwyddon – not relevant.

Ingestion – drinking water

Both groundwater and surface water may be contaminated by pollutants from all types of waste disposal systems. Leachate that percolates downward from a landfill site ends up in the water table from where it may be extracted for domestic water supply. Since ash residues from incinerators are dumped in landfill sites, this must be considered an important exposure route from incineration as well as from landfill. Surface waters may be contaminated by discharges from sewage treatment works. Alkylphenols, known for their endocrine disrupting effects, have been detected in UK rivers with concentrations of 180 µg/l in the River Aire downstream from a sewage works (Dixon et al 1996). Abstraction of drinking water from rivers contaminated with sewage effluent or landfill leachate

could potentially lead to exposure to chemicals in the water if they are not removed by the water treatment procedures. A Friends of the Earth report (Dixon et al 1996) found that not all water authorities carry out analyses for alkylphenol ethoxylates nor for all the alkylphenol ethoxylate-type compounds of concern in the drinking water.

Love Canal – drinking water was supplied by the city and was not contaminated but chemicals from the canal were found in sewers and neighbourhood creeks where children played. While the canal was being filled, children swam in the canal and they could have swallowed the water.

Nant-y-Gwyddon – this form of uptake was not considered by the investigators.

Skin contact

Direct contact with the waste or with contaminated soils is particularly a threat to landfill workers, construction workers and workers carrying out remedial measures on waste sites. Tars, oils and corrosive substances can cause irritation. Children are more likely than adults to come in contact with soil.

Love Canal – there were incidents where children were burned by exposed residues on the playground.

Nant-y-Gwyddon – not relevant

Fire and explosion

Combustible materials such as coal, coke particles, oil, tar, pitch, rubber, plastic and household waste may ignite in landfill. These may release toxic gases and cause a risk of explosion. Methane from landfill sites is an explosion risk.

Love Canal – there were reports of exploding rocks (Edelstein 1988, p47).

Nant-y-Gwyddon – not relevant

3.5 Assessing exposure

The WHO European Centre for Environment and Health convened an expert working group in Lodz, Poland in April 2000 to recommend methods of assessing exposure to health hazards released from landfills and to produce practical guidelines for future exposure assessment in local situations (WHO European Centre for Environment and Health 2000). The aim was to encourage the use of standardised exposure assessment methods so that it would be possible to make comparisons between sites and to combine the results from a range of epidemiological studies. The report provides guidelines for assessing exposure to hazards released from waste sites. A summary of the five essential steps follows:

Box 1: Guidelines on assessing exposure to hazards released from waste sites: five essential steps (Source: WHO European Centre for Environmental Research 2000)

1) Site characterisation

What is the current use of the site?
Is there any information on the nature of the waste in the landfill?
Is the site engineered or not?
Is the site accessible or not to the general public?
Are there any contaminants of concern and are they emanating from the site?

No – no further action
Yes/don't know – go to step 2

2) Characterisation of receptors

What is the size and composition of the population at risk?
What are the characteristics of the most highly exposed population?
Are there direct or indirect pathways leading to human exposure?

No – no further action
Yes/don't know – go to step 3

3) Characterisation of exposure pathways

Are there water resources such as surface water or groundwater used in the vicinity of the landfill?
Are the hazards dispersed through the air?

No – no further action
Yes/don't know – go to step 4

4) Determination of concentrations of contaminants

Measure or estimate the concentration of the contaminants of concern in the environmental media with which humans might be in contact.

What are the maximum concentrations?
Do the levels exceed the applicable limit or standard?

No – no further action
Yes/don't know – go to step 5

5) Exposure estimation

Carry out exposure assessment by calculating the intake of contaminants using data on concentration intakes and the population at risk.

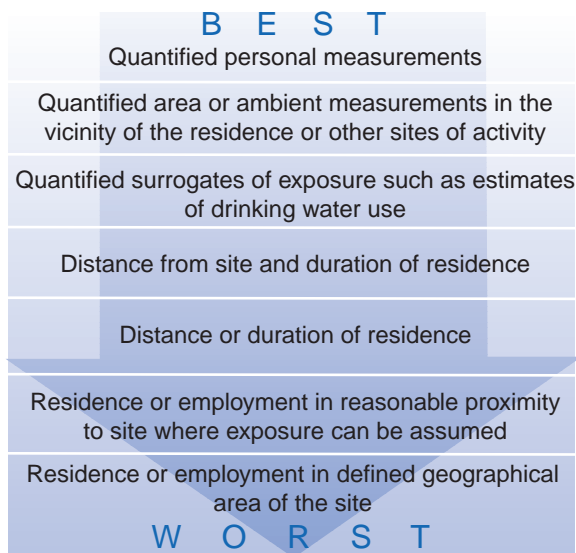
Is there potential for population exposure which might result in a health concern?

No – no further action
Yes/don't know – decide whether epidemiological studies or health surveillance should be carried out, additional data for exposure assessment should be collected or risk management measures should be installed or improved.

3.5.1 Hierarchy of exposure data

A hierarchy of exposure data has been proposed which ranks the exposure assessment from best (i.e. yields the most convincing evidence) to worst in terms of its relation to actual exposure – Figure 6 (National Research Council 1991).

Figure 6: Hierarchy of exposure data



Source: National Research Council 1991

The majority of the epidemiological studies investigating links between waste management and health outcomes rely on the worst type of evidence – that of residence or employment near the site. A tiny minority of studies are based on quantified ambient or personal measurements of pollutants taken at the time of potential exposure. In most studies, the waste management facility is like a black box, assumed to be emitting toxic compounds but with no actual measurements to use in the exposure assessment.

3.5.2 Risk assessment

A risk assessment methodology to characterise and evaluate the health effects arising from exposure to landfill sites is described by Eduljee who tested it out on three landfill sites in England (Eduljee 1992, Department of the Environment 1994). The risk assessment involves simplifications of the exposure scenarios, of off-site transport of pollutants and of uptake at the point of exposure. He claims that it is still possible to develop a credible estimate of the health risks to exposed populations even with these simplifications. However, in the UK, the data needed even for simplified risk assessments are not routinely collected. In particular, there is rarely an adequate characterisation of the waste within the landfill nor are there data about flow characteristics. Risk assessments cannot be carried out for the majority of landfills in the UK.

Love Canal – in the health impact studies carried out on Love Canal residents, no exposure measurements were possible as many of the chemicals were not persistent. Tests were done by the Environmental Protection Agency for chemicals in the blood of 36 Love Canal residents but these did not show higher than expected levels (Heath 1987). Exposure in other Love Canal studies was estimated on the basis of distance of residence from the canal (Vianna and Polan 1984). Paigen and Goldman (1987) explained

how their study proving an effect on birthweight, children's growth and indigenous wildlife was limited by the lack of "certainty whether those classified as exposed really had exposure, or whether those classified as unexposed really were unexposed."

Nant-y-Gwyddon – No exposure data were available and there was no community monitoring during the peak of the problem.

The procedures for assessing the health risks and calculating a lifetime excess risk are not discussed in this report. (For a detailed analysis of the risk to health posed by contaminated soil, see Hawley 1985). Hawley describes the assumptions and calculations used to derive annual average intake values, absorption rates, toxicity and excess lifetime cancer risk for young children, older children and adults exposed to contaminants in soil from indoor and outdoor activities.

In general, high-dose exposure and long-term, low-dose exposure are more likely to result in health impacts than short-term, low-dose exposures (Buffler et al 1985). Since it is extremely difficult to define exposure and thus observe a dose-response relationship in people exposed to contaminants from waste management sites, it is very difficult to prove that the health impacts observed are caused by the exposure.

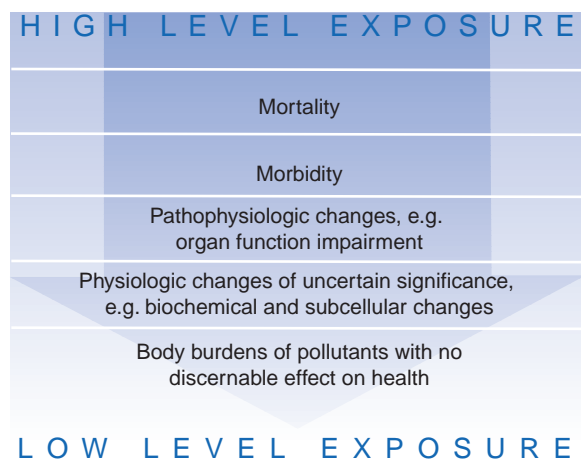
3.6 Potential impacts on health

Health impacts result from an interaction between the factors affecting health and the health status of exposed populations. In any population, there will be unexplained health problems. The types of health impacts experienced by people exposed to contaminants from waste management sites and those experienced by unexposed people are primarily the same. Health effects are non-specific – the human body has only a limited number of responses to a wide range of internal and external assaults. The responses are determined by the contaminant levels and the susceptibility of individuals along the range shown in Figure 7 (Hansen et al 1998).

The types of health impacts that have been investigated is very wide. Ideally, the selection of possible health outcomes for study should arise from the measurements of hazardous compounds at the site and the likely toxic effects of such compounds. However, as described earlier, such exposure data are often missing. In practice, the selection of health outcomes depends on the availability of data, the level of effort planned, the frequency of the outcomes and biological plausibility. The literature includes studies of a wide range of health outcomes but the most promising are believed to be adverse reproductive outcomes, chromosomal damage and neurotoxic effects (Marsh & Caplan 1987).

The following categories represent the main health outcomes found in the literature; other categories have been presented (BMA 1998, Marsh & Caplan 1987 p17). The examples given are from studies on the database.

Figure 7: Health impacts



Source: Hansen et al 1998

3.6.1 Reproductive outcomes

Reproductive outcomes include early fetal loss, perinatal death, low birth weight, prematurity, congenital abnormalities, chromosome abnormalities detected in fetuses, sperm abnormalities, altered sex ratio, multiple births, decreased fertility, sexual dysfunction, childhood morbidity, and age at menopause (list from Marsh & Caplan 1987 p20). The most commonly studied outcomes in the literature on waste management are congenital abnormalities, low birth weight, sperm abnormalities, miscarriage and infertility. The usefulness of selecting these outcomes to investigate causality is discussed in the review by Marsh and Caplan (1987).

It is reasonable to look for increased rates of adverse reproductive outcomes because in any waste stream, there will be many agents with known or suspected reproductive toxicity (see Kipen 1996 for examples). Although only five non-infectious agents have been shown in epidemiological studies to cause adverse reproductive outcomes through environmental exposure, rather than through occupational or pharmacological exposure, there are hundreds more agents which test positive in animal studies or in mutagenicity assays (Kipen 1996).

Field and laboratory studies on a range of wild animals have demonstrated adverse reproductive outcomes from xeno-oestrogens, natural and synthetic substances with oestrogenic or anti-oestrogenic properties (IEH 1995). These compounds (listed in Table 5) occur in sewage discharges and have been associated with endocrine disruption in wildlife, including "thyroid dysfunction in birds and fish, decreased fertility in birds, fish, shellfish and mammals, gross birth deformities in birds, fish and turtles, metabolic abnormalities in birds, fish and mammals, behavioural abnormalities in birds, demasculinisation and feminisation of female fish and

birds, and compromised immune systems in birds and mammals" (Colborn & Clement 1992 quoted in IEH 1995). The relevance of these studies to human health is not clear but there is concern about the fall in quantity and/or quality of sperm in recent decades (IEH 1995, Colborn et al 1997).

Love Canal – Low birth weight, prematurity and birth defects in children living near the hazardous waste site (Goldman et al 1985).

Nant-y-Gwyddon – congenital malformations, spontaneous abortions, stillbirths (Fielder et al 2000).

3.6.2 Non-communicable diseases

According to the chair of the US Committee on Environmental Epidemiology, the main health outcomes from exposure to hazardous waste sites that should be considered are a range of diseases, including asthma, adult-onset respiratory hypersensitivity, disturbance of lung function and growth, degenerative neurologic diseases, immunologic and endocrine diseases such as diabetes and cancer, including leukaemia (Miller 1996).

Love Canal – cancer incidence in the Love Canal area (Janerich et al 1981).

Nant-y-Gwyddon – rates of hospital admissions for general medical and geriatric, all respiratory disease and asthma (Fielder et al 2000).

3.6.3 Symptoms

Symptoms are either self reported or inferred from consumption of over-the-counter drugs or prescribed medications.

Love Canal – complaints by residents of chloracne, skin irritation, eye irritation, ulcers, pains, and wide range of unexplained health problems. Those who believed in the chemical risks suffered from "unpredictably recurring, debilitating and diagnostically elusive illnesses" (Edelstein 1988).

Nant-y-Gwyddon – residents complained of stress, fatigue, headaches, eye infections, coughs, stuffy nose, dry throat, nausea (Fielder et al 2000).

3.6.4 Injuries and poisoning

These are more likely to be associated with occupational health problems than with residence near a site.

Death, disabling and non-disabling injury associated with the removal of contaminated soils (Mar et al 1993).

Heat stress in hazardous waste workers (Favata et al 1990).

3.6.5 Microbial diseases

These include viral, bacterial, fungal and parasitic diseases.

Health risks associated with bathing in sewage-contaminated sea water (Balarajan et al 1991).

Risk of infection associated with a wastewater spray irrigation system used for farming (Linnemann et al 1984).

3.6.6 Mortality

Love Canal – cause specific mortality (Stark 2000).

Nant-y-Gwyddon – assessed whether there was difference in age standardised rates of death, all cause, respiratory and cancers (Fielder et al 2000).

3.6.7 Psychosocial impacts

Love Canal – stress, stigma, lack of support, community spirit, health preoccupation, dread, fear, well-being, depression, dissatisfied with life, loss of personal control, increase in stress related behaviours such as smoking, increased irritability (Edelstein 1988).

Nant-y-Gwyddon – only physical health problems were reported (Fielder et al 2000).

3.6.8 Economic impacts

Love Canal – declaration of a health emergency by state department of health led to evacuation of pregnant women, then relocation of some residents with economic costs.

Nant-y-Gwyddon – not described.

Other example:

Social and economic consequences of health effects to incineration workers – workers' compensation benefits, loss of home, loss of car, loss of employment (Callender et al 1997).

3.6.9 Subclinical abnormalities – biomarkers

Some of the biomarkers studied are:

- Tests for organ function – e.g. liver function tests.
- Immunological abnormalities – e.g. lymphocyte tests.
- Cytogenetic effects – chromosome aberrations, assays of sister chromatid exchanges.
- Neurotoxic effects – nerve conduction abnormalities, evoked-potential studies.

The significance of these, as they have little discernible clinical effect, is difficult to assess. The advantages and limitations of using biomarkers is described by Marsh and Caplan (Marsh & Caplan 1987).

Love Canal – Cytogenetic findings in persons living near the Love Canal (Heath et al 1984).

Nant-y-Gwyddon – no biomarkers investigated.

3.6.10 Broad environmental factors

Global warming can contribute to health indirectly by disturbing crop production, and affecting the spread and transmission of contagious and vector-borne diseases such as cholera and malaria.

4 Evidence of an impact on health

How strong is the evidence that current waste management practices have had an impact on human health?

4.1 Types of study

In a “weight of evidence” approach to evaluating evidence, greater weight is placed on the conclusions drawn from some types of study over others. Study designs at the top of the hierarchy (see Table 6) are the ones most likely to lead to valid conclusions from which generalisations can be made (CRD 2001, WHO Working Group 2000). Evidence from studies on people is more conclusive than extrapolations from studies on animals, while animal studies carry more weight than studies on parts of organisms outside the body or on related chemicals. Amongst the different kinds of studies on

people, the ones higher up the hierarchy, i.e. experimental studies and prospective cohort studies, are useful for testing hypotheses and establishing whether a causal relationship exists. The study designs further down the hierarchy, e.g. observational studies without controls, are useful for generating hypotheses which subsequently need confirmation from study designs further up the hierarchy.

From some study designs it is possible to infer whether the intention was that the study be a hypothesis-testing or a hypothesis-generating study. For the most part, cross sectional studies are about hypothesis generation whereas cohort and case control studies are concerned with hypothesis testing. However in many cases, the actual execution of the study is flawed in ways that make hypothesis testing problematic. Studies which purport to be hypothesis testing cannot be seriously regarded in that light unless

Table 6: Hierarchy of study designs

Type of study	Illustrative examples from the literature on waste management
STUDIES ON PEOPLE	
Experimental studies e.g. Randomised controlled trial with concealed allocation.	Likelihood of gastroenteritis from sea bathing: results from randomised exposure trial involving immersion of subjects in sea water and checking for resulting gastroenteritis (Kay et al 1994).
Quasi-experimental studies e.g. Experimental study without randomisation.	
Controlled observational studies- e.g. Prospective cohort studies. Historical retrospective cohort studies. Case control studies.	Mortality among workers at municipal waste incinerators in Rome: a retrospective cohort study (Rapiti et al 1997). Whether men who lived near a municipal solid waste landfill site in Quebec were at higher risk for developing cancer than individuals who lived at more remote locations. Subjects selected from a previously completed population-based, interview, cancer case-control study of men who lived in Montreal. Thirteen sites of cancer (n = 2 928 subjects) and a population-based control group (n = 417) were analyzed (Goldberg et al 1999).
Ecological studies - observational studies without control groups Correlation studies (also known as geographical comparison studies). Cross-sectional surveys. Cluster analysis.	Cluster analysis Cancer incidence and mortality in the area near a hazardous waste depot were calculated and compared to that in New South Wales, Australia using the indirect method of age and sex standardisation. Over an 18-year period, brain cancer in males (6 cases) was the only cancer where incidence in the study area was significantly higher than expected (Williams & Jalaludin 1998). Hypothesis-generating prospective morbidity survey Self reported health problems of workers at a landfill site were compared with municipal employees in other outdoor occupations. No exposure information. Observed increases in morbidity were graded for credibility according to biological plausibility, strength of association, time cluster, and risk gradient of intensity of exposure. Chronic bronchitis, daily cough, combined respiratory, narcotic symptoms and mood disorders were highly credible of an association with the landfill site (Hertzman et al 1987).
Case studies	Case report of a man living in the neighbourhood of a municipal leaf compost site who suffered from allergic bronchopulmonary aspergillosis (Kramer et al 1989).
Expert opinion based on pathophysiology, bench research or consensus.	
STUDIES ON ANIMALS	
Animal toxicological studies - <i>in vivo</i> assays, toxic response to agent, development of disease in exposed animals.	Toxicology studies of a chemical mixture of 25 groundwater contaminants: hepatic and renal assessment, response to carbon tetrachloride challenge, and influence of treatment-induced water restriction (Simmons et al 1994).
STUDIES ON PARTS OF ORGANISMS	
<i>In vitro</i> assays, short-term assays, cell cultures, bacterial assays.	Ames bacterial mutagenicity assay of fly ash from municipal incinerator (Shane et al 1993).
STUDIES ON CHEMICALS	
Predictions from chemical structure.	

there is evidence in the report that:

- a. there is an adequate control group
- b. there is adequate exposure data
- c. there is clear evidence of an hypothesis to be tested.

Some studies described as cross sectional studies may be better described as cohort studies because they include evidence of a temporal relationship. For example, occupational exposures are necessarily retrospective in nature.

(For a useful description of epidemiological study designs, see Marsh & Caplan 1987, WHO European Centre for Environment and Health 2000 Annex A4.1.)

4.2 Study limitations and confounding factors

It is difficult to establish a cause-and-effect relationship in epidemiological studies in the field of waste management. Particular challenges concern confounding by other unrelated factors that may explain the results as well as the factor under investigation, incompleteness of data, and variability.

4.2.1 Confounding

Confounding takes place when the exposure is associated with some other factor which also increases the risk of the health outcome studied. For example, a positive correlation between breast cancer and pesticide exposure may be confounded by factors such as higher socio-economic status and delayed child-bearing which also apply to the sample under study. It may be possible to adjust for the effects of potential confounding factors if enough detailed data are collected.

Factors which affect exposure

Other sources of pollutants could be a confounding factor, undermining the conclusion linking a particular waste management site to the health outcomes observed in a study. There are few areas where there is only one source of pollutants to which a population is exposed. As well as other environmental pollutants from industrial and traffic pollution, there is usually concurrent exposure to occupational hazards, indoor air pollutants, tobacco smoke, alcohol, prescription drugs and recreational drugs.

Where there are several sources of pollutants, there may well be interactions between the exposures. In the absence of exposure data, models and epidemiological methods cannot clarify what these interactions may be. Exposure to one source of pollutants may potentiate or may suppress the relationship between the other exposure and the health outcome (Marsh & Caplan 1987).

Nant-y-Gwyddon – the conclusion that the landfill site in Nant-y-Gwyddon may have been responsible for an increased rate of congenital abnormalities in residents near the site (Felder et al 2000) has been

challenged by researchers who pointed out that a municipal incinerator operated in the same area just before the landfill site opened (Roberts & Redfearn 2000). There was no direct evidence that the landfill, rather than the poorly performing and heavily polluting incinerator, was the cause of the adverse health outcomes.

Factors which affect health

Matching – Where there is a control group or reference population, an attempt can be made to adjust for the other factors which may have a significant effect on the health outcome being studied, i.e. age, social class, occupation, race, gender. To adjust for social class, researchers use measures of deprivation such as the Carstairs deprivation index which is based on social class, unemployment, access to a car, and overcrowding (used by Elliott et al 2001). McNamee and Dolk (McNamee & Dolk 2001) point out that the Carstairs index may not be an adequate proxy measure for all relevant risk factors and that failure to account for important risk factors could substantially distort the relative risks, especially if the relative risks are small as they were in the SAHSU study (Elliott et al 2001).

Symptoms – Many studies are of self-reported symptoms but these studies do not clarify the cause of the higher symptom rates. Miller points out that there may be several explanations for higher symptom rates in communities near waste management facilities other than toxicological or immunological reactions to pollutants (Miller 1996). The increased rate may be due to psychosomatic reactions to the stress brought on by the presence of a nearby facility, mass psychogenic illness as a reaction to publicity relating to the site, recall bias and confounding factors that have not been identified or considered in the analysis.

Biomarkers are becoming more popular as a way of indicating exposure and as predictors of outcome. However, there is uncertainty about the interpretation of positive biomarker results and lack of knowledge about how long the abnormalities persist after exposure. For some biomarkers, exposure must be current or very recent to be detectable. In the case of chromosomal damage, exposure to pollutants may cause DNA damage, leading to DNA repair problems. This can be detected in cytogenetic challenge studies. The assumption is that individuals with an abnormal cytogenetic response are defective in DNA repair and thus have an increased risk for cancer. However, there is no proof of this association. Many other ubiquitous agents such as sunlight and X-rays cause DNA damage, the rate of DNA repair is not known and laboratory conditions can affect the amount of damage. (For a useful discussion of the use of biomarkers in studies of waste sites see WHO European Centre for Environment and Health 2000 Annex 5.)

4.2.2 Incompleteness of data

Exposure data

Most studies have no exposure data whatsoever, using residence near the site based on postcodes or census tracts as a surrogate for actual exposure measurements. Residence, however, is an inadequate and crude substitute. Misclassification can occur if people move into or out of the area during the time they were meant to be exposed. Leachate from a landfill site may contaminate groundwater or surface water and affect a much wider population living further away. People living upwind may be minimally exposed to air pollutants compared to those living downwind. In some studies, residence selection is refined slightly to account for this. Where exposure data are absent, the reliability of any conclusions drawn is substantially weakened.

Love Canal – residence in a Love Canal census tract was used as a surrogate measurement of exposure in most Love Canal studies (Janerich et al 1981, Vianna & Polan 1984, Goldman et al 1985, Paigen et al 1985, Paigen et al 1987). There was one study which used actual measurements of chemicals likely to have arisen from the canal (Heath et al 1984). This study reported no differences in chromosome aberrations in 46 people who lived in houses where chemicals were detected compared with people who lived in an adjacent census tract. However, the exposure data were limited as there were no data on how long and sustained the exposure was.

Nant-y-Gwyddon – residence within five electoral wards within 3 km of the landfill site was used as a surrogate measurement of exposure (Fielder et al 2000).

Defining the exposed population is fraught with difficulties but is necessary to establish the denominator from which an incidence rate can be calculated. If groundwater is contaminated, communities far from the waste site may be drinking the water and the exposed population may in fact be greater than those living within 2 km of the site. However, the concentration of contaminants in groundwater far from the site will be very small and thus it will be even harder to pick up health effects. In many studies, there are large gaps between exposure and the start of the study. Immediate health problems can be missed and people move out of the area making it hard to trace them.

Studies without a control group can prove very little as health is strongly affected by characteristics such as race, social class, smoking, alcohol use, age, sex, diet and occupation which have little to do with exposure to contaminants from waste management sites. It is difficult to find an appropriate control group matched for all confounding risk factors. Most important, the control group should not be exposed to hazards either from the waste management site being studied or other ones in the area.

Love Canal – a study by the New York State Department of Health found no evidence for higher cancer rates in Love Canal residents than in the state of New York as a whole or in the city of Niagara Falls of which Love Canal is a part (Janerich et al 1981). The study was done by examining data from a standardised reporting system, the New York Cancer Registry, whose completeness and accuracy could not be guaranteed. The exposed population was not well defined as the study was based on census tracts which did not correspond exactly to proximity to Love Canal nor did it include people who had left the area. The US Environmental Protection Agency commissioned a cytogenetic study of Love Canal residents which showed an increase in chromosome damage (Picciano 1980). The study was subsequently discredited as having virtually no scientific validity because the control group was not matched with Love Canal residents and because they were not tested simultaneously (Kolata 1980). A later study with proper controls showed no difference in chromosome damage between exposed people and the control group (Heath et al 1984).

Nant-y-Gwyddon – the control group was the population in 22 wards in the same authority matched for Townsend deprivation score. The exposed population was slightly less deprived by this socioeconomic measure than the comparison group (Fielder et al 2000).

Health outcome data

Unreliability – Data about health outcomes may be incomplete or unreliable for a number of reasons with major implications for the conclusions reached in the epidemiological studies. Data on congenital malformations and stillbirths are highly dependent on the motivation by health authorities to notify to the register, to changes in reporting criteria and to definitions used. When discussing the issues limiting the reliability of the conclusions from the SAHSU study (Elliott et al 2001), the authors mention over-reporting of anomalies in Scotland, under-reporting of anomalies in England and Wales and changes in the rules about which malformations were notifiable.

Recall bias inevitably leads to over-reporting in communities where people are worried about the health effects of a waste site. People are already aware of and looking out for health problems. Recall bias is especially important for symptoms but less so for other conditions with more objective measurements such as low birth weight. The limitations of using health outcome data based on recall is described in a study of 22 people exposed to fumes from ruptured drums containing nitric acid during a hazardous waste site clean-up operation (Hopwood & Guidott 1988). The people were interviewed immediately after the incident by emergency room staff, the next morning by a researcher and six months later. There was a low level

of agreement between the symptoms reported six months after the incident and those reported at the time. The trend was not random. Subjects consistently recalled more symptoms in the later interview.

Love Canal – from informal surveys carried out by the residents of Love Canal, a long list of health impacts was produced. On the list were birth defects, deafness, rashes, headaches, cancer, epilepsy-like seizures, nervous disorders, miscarriage, asthma, liver damage, the death of a child from kidney failure and a case of nausea, thick perspiration and sores (Brown 1980).

Latency periods – Studies of illnesses such as cancer which have a long latency period can lead to false negatives if not followed for a sufficient period of time. Latency periods may be in the order of one year for childhood leukaemia, several years for adult leukaemia and longer for solid tumours (Elliott et al 2001). For fetal exposure to hormone-disrupting chemicals, the latency period may be even longer.

Colborn argues that fetal exposure may "derail development in a variety of ways that will become evident at different times, e.g. a boy exposed may have undescended testicles at birth, low sperm count at puberty or testicular cancer in middle age." (Colborn et al 1997)

Love Canal – A limitation of the Janerich study (1981) was that exposure from chemicals leaking from Love Canal was greatest during the 1970s. Cancers appearing 10 to 15 years later would not have appeared in that study which used data only up until 1977. In a study of chromosomal aberrations (Heath 1987), measurements of the chemicals were made in 1978 but the chromosome tests were not carried out until 1980. It is not clear how long after exposure cytogenetic damage persists and can be detected.

Sample size and statistical power

The population affected by a particular waste site is usually small. This limits the range of health effects and the number of cases that can be observed. The rarer the disease, the larger the exposed and control group need to be in order to detect a significant increase among the exposed. To design an epidemiological study looking for a doubling in reproductive effects with a probability of less than 0.05 ($p < 0.05$), the size of the exposed and control groups need to be:

Miscarriage	– 15% recognised pregnancies 160 pregnancies
Minor birth defects	– 10% live births 266 live births
Major birth defects	– 2% live births 1525 live births
Club foot	– 0.6% live births 5199 live births

(Zielhuis 1985)

In a review of published public health investigations at 16 hazardous waste sites in the United States, only two studies included more than 1000 people while the rest had fewer than 500 people (Levine and Chitwood 1985).

Love Canal – a statistically significant excess of low birth weight was found in babies living along the swales by Love Canal from 1940 to 1953 when the landfill was active. From 1954 to 1978, there was no difference in birth weight between babies born in the Love Canal area and the rest of upstate New York. Included in the study were 383 women who had a total of 617 children and who lived in the study area from January 1940 through June 1978 (Vianna and Polan 1984).

Single site studies are limited in their statistical power to detect excess risks for rare health outcomes. Multi-site studies increase statistical power but have other problems. They may dilute out adverse health outcomes, obscuring a few highly polluting sites amongst the statistical average. Even in a study with an impressively large sample size, the observed increase in risks could be due to study bias. The recent British study of reproductive outcomes among women living within 2 km of landfill sites included about 8 million pregnancies and 9,565 landfill sites (Elliott et al 2001). Statistically significant excess risks of congenital abnormalities were found. However, the excess risks were so small, i.e. less than 10%, that they could be explained by other biases in the data (McNamee & Dolk 2001).

4.2.3 Variability

Variability is defined as the "individual-to-individual differences in quantities associated with the predicted risk" (National Research Council 2000).

Variability in human populations

Unlike laboratory animals which are bred for homogeneity, the exposed human population is heterogeneous. Children, fetuses, women of child-bearing age and the elderly are particularly sensitive. Children are not just small adults but differ in body composition and maturity of biochemical and physiological functions (Hansen et al 1998). The fetus is particularly vulnerable. Many chemicals cross the placenta and can affect development without obvious effects on the mother. Young children exposed to lead in soil are more at risk than adults because of their behaviour which leads to ingestion of lead from dirty hands and toys. Adults over 40 years are more susceptible to carbon monoxide exposure because a small proportion have decreased cardiovascular capacity.

As well as differences across age-groups, inter-individual variation affects an individual's predisposition to health outcomes. The interaction between genes and the environment affects people's resistance or sensitivity

to a range of chemical and physical insults and may explain why some families living near a waste site are affected while others are not and why within these families, some individuals are affected while others are not.

Variability of waste procedures

Unlike a health care intervention, waste management methods are not controlled processes but broad categories with large variations between individual facilities and large gaps in the information available. Waste management sites vary from facility to facility and from country to country with regard to:

- *What goes in*
The composition and feed rate of wastes treated.
- *How the waste is treated*
Operating practices, age of facility, waste disposal technology used, frequency of off-normal emission events, gas and leachate control systems.
- *What comes out*
The type and amount of pollutants emitted, climate affecting atmospheric dispersion, landscape data affecting migration through soil and water, facility data, pollution-control technologies in use.
- *How the emissions reach people – the exposure route*
Transfers by deposition and partitioning to exposure media – extent to which groundwater is extracted for drinking water, human activities which bring people into contact with pollutants – consumption of locally grown food, consumption of drinking water, contact with soil, construction of homes close to the site, occupational exposure, etc., proximity to other sources of pollutants.

4.2.4 Conclusion

Whilst it is technically possible to detect the presence of health hazards in waste sites and health impacts among people working or living nearby, there are many problems demonstrating the relationship between exposure and the health impacts observed. The main limitations of epidemiological investigations are the small sample size, lack of exposure information, lack of toxicological data about mixtures of chemicals and the lack of specificity of indicators of adverse health effects.

Even in the case of Love Canal, where contamination was undisputed and great efforts were made to study possible health effects, the studies did not show an alarming increase in ill health.

Given these limitations, there will always be a high level of uncertainty about the health risks to people exposed to hazards from waste management sites.

4.3 The strength of the association

An association, even if statistically significant, is not

proof of causation. To determine causation, the cause must precede the effect and the association should be "consistent, unbiased, strong, graded, coherent, repeated, predictive and plausible" (WCRF & AICR, 1997). The strength of the association is an important part of assessing causality, but other factors must be taken into account: consistency of the observed association, speciality of association, temporal sequence of events, dose-response relationship, biological plausibility of the observed association and experimental evidence (Lilienfield 1994).

4.3.1 Relative risk

Relative risk, RR, is a measure of the strength of the relationship between two variables, usually the proposed cause and effect. For example, it is the ratio of the risk or incidence of a disease among people with a particular characteristic (say, residents living near an incinerator) to that among people without that characteristic (say, residents living far from the incinerator).

- A relative risk of less than 1 implies a protective effect.
- A relative risk of more than 1 implies an increased risk. For example, a RR of 2 indicates a doubling of the risk. A RR of 1.1 indicates a 10% increase.
- A relative risk of 1 implies no effect.

Small relative risk values, those less than two, may be important when the number of affected people is large or the disease is very common and when confirmed in several large, well-designed studies. Because observational studies are plagued by biases, uncertainties and confounding factors, many epidemiologists believe that epidemiological studies may be inherently incapable of accurately discerning weak associations. As Michael Thun, the director of analytic epidemiology for the American Cancer Society, puts it, "With epidemiology you can tell a little thing from a big thing. What's very hard to do is to tell a little thing from nothing at all." (Quoted in Taubes 1995.)

The odds ratio, OR, is another way of expressing the size of the effect. It is the ratio of the odds of an effect in the exposed group compared to the odds in the control group. When the rates are very low or very high, the odds ratio is very similar to the relative risk (CRD 2001).

Table 7: Relative risk and judgements

Judgement	How strong is the association?
Strong	RR or OR is >2 or <0.5 and is statistically significant
Moderate	RR or OR >2 or <0.5 but not statistically significant or RR or OR is between 1.5-2.0 or 0.5-0.75 and statistically significant
Weak	RR or OR is between 1.5-2.0 or 0.5-0.75 but not statistically significant
No association	RR is between 0.87 and 1.5 and not statistically significant

Source: WCRF and AICR 1997

Table 8: Examples of environmental factors where there is strong and conclusive evidence of an adverse impact on health

Cause	Effect	Relative risk
Cigarette smoking - more than 25 cigs/day	Bladder cancer	5.0
Heavy alcohol consumption - more than 100g ethanol/day	Oesophageal cancer	17.5
Cigarette smoking - more than 25 cigs/day	Lung cancer	30.0
Hepatitis B virus chronic infection	Liver cancer	>100.0
Heavy alcohol consumption - and heavy smoking	Oesophageal cancer	101.5
Occupational exposure to asbestos	Methothelioma	>200.00
Occupational exposure to benzididine and/or beta naphthylamine	Bladder cancer	500.00

Source: Tomatis 1990, p288

Table 9: Examples from studies on waste management and health

Cause	Effect	Relative risk or odds ratio*
Exposure to landfill site - Nant-y-Gwyddon (Fielder et al 2000)	Congenital anomalies - all	
	Before site opened - 1983-1987	1.9 (1.3-2.9)
	When site first used - 1988-1989	3.6 (2.3-5.7)
	After site opened - 1990-1996	1.9 (1.2-3.0)
Exposure to landfill site - Love Canal (Paigen et al 1987)	Children's height	1.14 (1.06-1.23)
	Children's weight	1.06 (not significant)
Exposure to landfill site - Love Canal (Janerich et al 1981)	Cancer - female	SIR***
	Digestive organs	1.1
	Respiratory system	2.0
	Liver, lymphoma, leukaemia	1.3
	Bladder, kidney, ureter	0.4
Exposure to landfill site in Canada (Hertzman et al 1987)	Respiratory problems - bronchitis, shortness of breath, cough and phlegm	1.56 p<0.001
Exposure to landfill site Canada (Hertzman et al 1987)	Skin problems - recurrent or severe problems with scaly, dry, itchy skin, rashes, unusual acne, boils, warts, patches	1.76 p<0.001
Exposure to landfill site Canada (Hertzman et al 1987)	Narcotic symptoms - frequent or severe headaches, dizziness, blurred vision, fatigue, problems with balance, clumsiness	2.29 p<0.001
Exposure to landfill site in Canada (Hertzman et al 1987)	Mood symptoms - insomnia, anxiety, depression, irritability, hyperactivity, memory disorders	1.70 p<0.001
Maternal exposure to landfill site in Canada (Geschwind et al 1992)	Congenital malformations	1.63 (1.34-1.99)
Maternal exposure to landfill sites that emitted solvents in United States (Marshall et al 1997)	Congenital malformations - central nervous system birth defects	1.3 (1.0 - 1.7)
Maternal residence in a census tract containing a landfill site in California (Croen et al 1997)	Neural tube defects	0.9 (0.7-1.3)
	Heart defects	1.3 (0.8-2.1)
Maternal residence within 1/4 mile of a hazardous waste site (Croen et al 1997)	Congenital malformations - heart defects	4.2 (0.7-26.5)
Maternal residence within 3 km of a hazardous waste landfill (Dolk et al 1998, EUROHAZCON)	Cardiac septa malformations (248 cases)	1.49 (1.09-2.04)
	Neural tube defects (130 cases)	1.86 (1.24-2.79)
	Hydrocephaly (32 cases)	1.06 (0.44-2.59)
	Gastroschisis (13 cases)	3.19 (0.95-10.77)
Maternal residence within 2 km of all landfill site types, operating and closed sites, adjusted for confounders (Table 27, Elliott et al 2001)	All congenital anomalies	1.01 (1.01-1.02)
	Neural tube defects	1.05 (1.01-1.09)
	Abdominal wall defects	1.08 (1.01-1.15)**
Residence within 2 km of operating and closed landfills of all site types, adjusted for deprivation (Table 113, Elliott et al 2001)	Bladder cancer	1.01 (1 - 1.021)
	Hepatobiliary cancer	1.04 (0.983- 1.025)**

* 95% confidence intervals in parentheses

** 99% confidence interval

*** Standardised Incidence Ratio - ratio of observed to expected number, age standardised

Relatively few environmental factors have been conclusively shown to cause health impacts and examples are shown in Table 8.

By contrast, many studies about waste and health have relative risks of less than 1.5. (see Table 9).

5 Summarising the evidence

5.1 Introduction to judgements

The model for making judgements which was described in Section 1.3.3 was applied to the evidence on waste management in sections 5.2 to 5.5. A summary of the process is shown in Appendix 2.

5.2 Landfill

5.2.1 Reviews and primary studies

The literature search revealed more than 220 papers published about the hazards to health from landfill sites. Of these, 101 were primary studies about the health impacts of landfill sites and 23 about the health impacts of contaminated drinking water (Table 10). Six review papers were found which covered the epidemiological evidence linking health effects with landfill sites (see Appendix 4).

Table 10: Health outcomes investigated in primary studies of landfill sites

Health outcome	Number of drinking water studies	Number of landfill studies
Reproductive outcomes/ developmental effects on children	9	22
Cancer	7	22
Symptoms	1	27
Psychosocial impacts	1	18
Biomarkers	1	12
Health problems - not specified in abstract	5	9
Mortality	1	4
Injuries/poisoning	0	2
Total	23	101 *

* Some studies are about more than one health impact.

The drinking water studies were included in this section because an important source of exposure from landfill sites is leachate into groundwater. However, in many studies, the source of the contamination was not known. In some studies the source was leaking chemical storage tanks, in others, chemical accidents. Studies were not included if the water was contaminated by sewage.

Only seven of the total were occupational health studies, the rest being studies about the health impacts on nearby communities.

The types of studies carried out included case control studies, cross sectional studies, cohort studies, cluster analyses, correlation studies and descriptive surveys. Results were inconsistent, with some showing associations between landfill and various health impacts while other studies found no associations. In the largest review, of 41 single site studies and 10 multisite studies, correlations were found for some health outcomes in some of the studies but not in all (Vrijheid 2000). Authors who make definite statements that their study reveals real excess risks are frequently challenged (Staff 1998, von Mühlendahl 1999, Greenacre et al 2000). All of the primary studies are hypothesis-generating studies rather than hypothesis-testing studies.

5.2.2 Judgement

In reviews, discussion papers, conferences and consensus meetings, many attempts have been made to determine whether the findings indicate real risks associated with exposure to landfill sites. There is general agreement with the cautious position taken at a meeting convened by the WHO Regional Office for Europe in 1998 which concluded:

"Many of the studies detected an increased risk of the studied diseases and symptoms in populations living close to the landfills. However, the evidence supporting the causality of the association is inconsistent and inconclusive. Probably the strongest suggestion for causality was generated by studies on reproductive outcomes, such as reduced birth weight or some birth defects. However, all studies lacked direct exposure assessment, and the limited sample size of most studies makes a more specific analysis impossible. ... Considering all the uncertainties, the meeting concluded that the present data do add to a suspicion that population exposure to emissions from hazardous wastes may pose a risk to population health. The present studies are not powerful enough to indicate which of the characteristics of the very inhomogeneous group of landfills that are included in the studies might be responsible for the observed small increase in the risk." (WHO meeting 1998)

Substantially similar conclusions were reached by other authors of discussion papers or consensus documents (Rushbrook 1990, National Research Council 1991, Morris 1995, Kipen 1996, Miller 1996, Johnson 1997 for the US Agency for Toxic Substances and Disease Registry, IEH 1999, Vrijheid 2000).

Overall judgement

Exposure to landfill and any health outcomes – insufficient.

5.3 Incineration

5.3.1 Reviews and primary studies

The literature search yielded 5 reviews, 24 discussion papers and at least 51 primary studies of the health impacts of incineration (Appendix 4 and Table 11).

Table 11: Health outcomes investigated in primary studies of incineration

Health outcome	Number of primary studies
Occupational health studies	17
Cancer	15
Health problems/diseases/unspecified health effects	12
Biomarkers	10
Reproductive outcomes/developmental effects on children	9
Symptoms	8
Mortality	5
Injuries/poisoning	3
Psychosocial impacts	2
Economic	1
Total	51

Incineration is a method of processing waste during which major portions of the waste stream are physically and chemically transformed. Incineration produces energy, gases which are emitted into the atmosphere and solid residues which must be disposed of. The main hazards arising from incineration are toxic metals (such as lead, cadmium, arsenic and mercury), dioxins and particulates. Metals are not destroyed by incineration but are liberated from their immobilised state in waste materials and are released by combustion as highly bioavailable forms. They leave the incinerator in particles of respirable size, in particulates which are deposited on soils, water, food and dust, and in readily confounding factors inherent in these types of epidemiological study (described in section 4.2) rule out any definitive statement of causality. The lack of consistency in finding associations could mean that incineration does not cause the adverse health effects or it could mean that the health effects are not detectable using existing epidemiological methods and the available data.

5.3.2 Judgement

Incineration and any health outcomes – insufficient.

5.4 Composting

5.4.1 Reviews and primary studies

Two review papers were found of the health impacts of

composting (Maritato et al 1992, Environment Agency 2001). The main health impacts from composting (Bunger et al 2000) are:

- Inflammatory responses of the upper airways – congested nose, sore throat and dry cough
- Toxicoses – toxic pneumonitis due to endotoxins
- Infections – respiratory tract and skin
- Allergies – bronchial asthma, allergic rhinitis, extrinsic allergic alveolitis (hypersensitivity pneumonitis)

The people most likely to be affected are workers in centralised composting facilities. Of the primary studies of health impacts, one is a case control study and the rest are case reports. The case control study (Bunger et al 2000) found that compost workers had significantly more symptoms and diseases of the airways ($p=0.003$) and the skin ($p=0.02$) than the control subjects and they had significantly increased antibody concentrations against fungi and actinomycetes. No studies were found about the health impacts to residents living by composting facilities.

From its assessment of the hazards and the potential health consequences, the Environment Agency has produced a position paper outlining regulatory and health and safety guidance to prevent exposure. (Environment Agency 2001).

5.4.2 Judgement

Composting and occupational health effects – probable.
Composting and health effects to residents – insufficient

5.5 Sewage discharges

5.5.1 Reviews and primary studies

Seven review papers (Appendix 4), 3 discussion papers and 70 primary studies (Table 12) were found about the health effects of sewage treatment. These were either about the effects of sewage discharges in recreational waters or occupational exposure.

Sewage discharges to recreational water

Most of the studies found a significant relative risk ($1.0 < RR < 3.0$) of contracting a disease, especially gastrointestinal symptoms, related to the number of indicator organisms present in relatively polluted recreational water (Pruss 1998, IEH 2000). The best dose-illness correlation was found with *enterococci/faecal streptococci*. Given the number of potential confounding factors, the pathogen threshold level for increased risk is still controversial. For example, it is possible that increased immunity in adult populations and in populations of countries with higher endemicity may result in higher threshold levels. Different countries detect different ranges of pathogens in water and use different detection methods.

The reliance on indicator organisms to define water quality has been frequently criticised as these organisms are now considered to be a poor indicator of the risks

Table 12: Health outcomes investigated in primary studies of sewage discharges

Health outcome	Number of primary studies
Health problems/diseases/unspecified health effects	44
Occupational health studies	36
Symptoms	24
Unknown	4
Mortality	4
Cancer	3
Injuries/poisoning	2
Psychosocial impacts	2
Reproductive outcomes/developmental effects on children	1
Biomarkers	0
Economic	0
Total	67

associated with viruses, protozoa and even bacteria. It has been shown (e.g. Deuter et al 1991) that there is a poor correlation between waterborne human viruses and faecal coliforms in marine water. Many pathogens survive longer than faecal indicator bacteria. Infective doses of viruses and protozoa are still present after 99.9% removal from raw sewage by secondary treatment methods (Ashbolt 1996). Pathogens undetectable by conventional methods can remain viable in marine water. Also, pathogens may accumulate in sediments and plankton and can be released and become infective in suitable conditions (e.g. Henrickson et al 2001). New molecular cell culture techniques are now available for a more accurate detection of water quality (e.g. Josephson et al 1991).

Occupational diseases of sewage treatment workers

Compared with workers in other occupations, workers at sewage treatment plants suffered from more gastrointestinal tract symptoms, airways symptoms, fatigue and headache. No dose response relationship was found between cancer and exposure to agents commonly found in sewage treatment plants.

5.5.2 Judgement

- Convincing** Gastrointestinal symptoms and bathing in sewage contaminated recreational waters.
- Probable** Gastrointestinal tract problems, headache, fatigue and airways symptoms and working in sewage treatment plants.
- Insufficient** Cancer and working in sewage treatment facilities

5.6 Soil amendments

5.6.1 Reviews and policy studies

As wastewater irrigation is banned in the UK, the only soil amendment discussed here is landspreading of sewage sludge.

A total of 43 documents were found about the health impacts of landspreading sewage sludge. Nine documents published since 1990 were reviews or discussion papers about the health hazards from sewage sludge. There were 21 primary studies about health hazards and one primary study of the health impacts. The latter was about the effects of Gram-negative bacteria on the health of workers at wastewater sludge facilities between 1979 and 1981 (Clark et al 1984).

A discussion paper (Health Canada 2000, Vol 2) described the risks to human health as minimal because:

- pathogens have a short lifespan and their persistent forms remain in the soil,
- metals are not usually metabolised by soil microorganisms and will persist in the soil,
- most pollutants bind to soil components,
- most organic compounds, i.e. dioxins, are broken down by soil microorganisms,
- most organic compounds do not migrate into surface or ground waters because they adhere to soil components,
- volatile organic compounds evaporate within 48 hours of landspreading.

However, there is a lack of understanding of the potential for transfer of toxic compounds to food and about the degradability and persistence of some toxic contaminants (Rogers 1996).

5.6.2 Judgement

Sewage sludge landspreading and health impacts – insufficient.

5.7 Summary of judgements

An overall assessment of the evidence linking waste disposal to an impact on health is shown in Table 13.

Table 13: Summary of judgements

Evidence	Increased risk
Convincing	Gastrointestinal symptoms and bathing in sewage contaminated recreational waters.
Probable	Gastrointestinal tract problems, headache, fatigue and airways symptoms and working in sewage treatment plants.
Possible	Airways symptoms and working at a centralised composting facility.
Insufficient	<p>Any health outcomes and residence near landfill site.</p> <p>Any health outcomes and working at a landfill site.</p> <p>Any health outcomes and working at an incinerator.</p> <p>Any health outcomes and residence near incinerator.</p> <p>Any health outcomes and residence near centralised composting facility.</p> <p>Cancer and working in sewage treatment facilities</p> <p>Any health outcomes and landscpreading sewage sludge.</p>

6 Protecting the health of the public

How can the epidemiological evidence be used in waste management strategies and practice to protect public health?

6.1 National policy

In its Waste Strategy, the government has stated that the protection of human health is one of the important objectives of its waste management strategy (DETR 2001): *"We have long sought to protect the local environment and human health from the adverse effects of waste management through a comprehensive system of planning and pollution control legislation"* (Section 3.5 DETR 2001). A key feature of the Framework Directive on Waste, 91/156/EEC, and the licensing system is "the objective of ensuring that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment" (Waste Strategy 2000 Section 3.36 DETR 2001).

The government issues guidance on how local authorities and the Environment Agency are to implement its policies. The Planning Policy Guidance Note 10 (DETR 1999) sets out the national planning framework for waste and states that the Government wishes to see decisions based on four key principles – the Best Practicable Environmental Option, regional self sufficiency, proximity principle, and the waste hierarchy.

6.2 Decision making in the face of uncertainty

6.2.1 Uncertainty

"The major problem in marrying policy and the science which informs it is that the timescales of the two never match. This is true almost by definition, since if there were sufficient science in place, then the problem of characterizing the scientific essentials of an issue is solved and policy formulation is then determined by consideration of other issues such as the social, economic and political aspects of the problem. Unfortunately, life is generally not this simple, and one often finds that there is insufficient scientific information compared with what ideally would be required." (Maynard & Howard 2000)

This overview of the scientific evidence exposes a high degree of uncertainty about the impact of waste management operations on health, which may or may not ever be resolved by further research. Despite the impressive amount of research and the high quality of many of the studies, the state of the evidence is such that, with a few exceptions (see section 5.7), no certain

conclusions can be drawn.

6.2.2 Interpretations of the evidence

In the meantime, waste management decisions have to be made and the health of the public has to be protected. In theory, decision making should be based on a rigorous assessment of the scientific evidence. In reality, waste management decision making takes place in a highly charged political environment, with different interest groups driven by conflicting values and belief systems as well as by contrary interpretations of the same scientific evidence.

Decision makers have to proceed despite the uncertainty. The following case illustrates the dilemmas they face:

Wrexham County Borough Council initially granted Shanks Waste Services permission to install an electricity generating plant on its landfill site in 1994 but refused planning permission in 1999 when the company applied to change details of its plan. In the intervening years, local residents had raised concerns about possible health risks. The Council's planning committee was persuaded that there was not enough independent scientific evidence to show that fears about health risks were unfounded. Shanks appealed and at the subsequent inquiry, the Inspector overruled the planning committee's decision and granted the company permission to install the plant. The Inspector said that the Council should base their decisions on objective assessments, not on unfounded fears. As the emissions from the electricity generating plant would not exceed National Air Quality Standards and World Health Organisation levels, he could find no evidence to justify concerns about health impacts (Described in NSCA 2001). In other inquiries, fear of adverse health effects has been allowed as a material consideration but the weight given to it has varied. (Brian Cook, personal communication, September 2001.)

Both of the decisions in this case were based on reasonable interpretations of the same scientific evidence. Neither decision was more objective nor more correct than the other. Valid arguments could be made in defence of both the Council's decision and the Inspector's. Depending on the interpretation, different courses of action will result.

Informed debate has polarised into two plausible positions:

Position one

There is no evidence of significant harm to human health from waste management operations. No human activity is completely safe but compared to other

environmental health hazards (e.g. vehicle traffic) or compared to other causes of ill health (e.g. poor diet, diseases), waste management operations are not a major public health concern.

An example of this position is taken by The National Society for Clean Air and Environmental Protection in its recent report on incineration. It concludes, *"While we cannot discount effects resulting from the small quantities of some pollutants emitted by MSW (Municipal Solid Waste) incinerators where impacts may occur at background levels (e.g. dioxins) or where current standards (limit values) may be exceeded (e.g. nitrogen dioxide) the large number of other important sources of such pollutants suggest that these deserve a greater emphasis on regulatory control."* (Farmer & Hjerp 2001)

Position two

Lack of evidence is not the same as evidence of lack of health impacts. Waste management methods may have a major impact on health but the limitations of the research make it impossible to determine whether this is the case.

An example of this position comes from the Greenpeace incineration report. It concludes, *"With the limited data available, it is, therefore, impossible to predict health effects of incinerators, either new or updated installations... There is an urgent need for the complete phase out of incineration and the implementation of sound waste management policies based on waste prevention, re-use and recycling."* (Allsopp et al 2001)

6.2.3 Judgements about risk

Disagreement about the management of a potentially risky activity like incineration arises not only because of different interpretations of scientific evidence but because of the different judgements people make about how risky they believe the activity to be. Individuals as well as regulatory bodies try to avoid or control activities they judge to be too risky and ignore or tolerate others. Conflict occurs when people form different judgements about the riskiness of the activity. Disagreements about risk are inevitable because there is no way to define risk that does not include values, beliefs and assumptions – especially when information on which to base the judgement is scarce.

Where there is uncertainty, judgements about risk are based on assumptions and mental strategies that help decision making and on qualitative aspects inherent in a hazard. As well as the likelihood of harm, people consider whether incurring the risk is voluntary, has catastrophic consequences, is unknown and unfamiliar, and is new to society. Judgements about risk are also influenced by individuals' views of the world and the kind of society they want. A summary of current thinking about risk perception can be found in Saffron (1993).

When scientists make judgements about risk, the process is described as risk assessment. Risk assessment is perceived as an objective exercise and is

expressed in terms of probabilities – the likelihood that something bad will happen. If the probability is low, then they perceive the risk to be low; a high probability describes a high risk. This one-dimensional view of risk enables scientists to consider the risks of eating 40 tablespoons of peanut butter in a year, drinking 30 cans of diet soda in a year and cycling ten miles in a year as equivalent because each increases an individual's chance of death by one in a million. The assumptions, values and lack of actual data in risk assessment are rarely made explicit, contributing to an impression of scientific validity. An example of a fact-free, assumption-implicit risk assessment is given by Hens (Hens 2000) for an organic chemical that accumulates in the body. The risk assessment takes account of the maximal concentration of the chemical in the plume using a terrain dispersion model to estimate ground level concentrations. A theoretical amount of the chemical which an adult might expect to assimilate is then calculated. The assumptions hidden in this kind of risk assessment are that the hypothetical adult is free from any pollutant in their body and will not be exposed to chemicals or other hazards from other sources. This type of risk assessment is unlikely to lead to emission standards or acceptable daily intakes that would protect human health. Hens likens risk assessment to a *"captured spy – if you torture it enough, it will tell you anything you want to know."*

When members of the public make judgements about risk, the process is described as risk perception. Opposition to an incinerator, for example, may be condemned as irrational and ignorant but in fact, scientists make use of the same mental strategies, known as heuristics, as the non-scientifically trained public. The commonly used heuristics are:

- Availability – overestimate frequency of rare, unusual, memorable causes of death (e.g. accidents) and underestimate more common ones (e.g. diseases).
- Overconfidence – unwarranted certainty in the correctness of their estimates.
- Trustworthiness of public institutions and officials – recognition that human errors, organisational failings and patterns of management can affect real life operation of technological systems.
- Framing effect – attitudes to risk influenced by the way choices are presented, e.g. a half empty glass seems worse than one that is half full.
- Optimistic bias – impression that the individual is less vulnerable and more knowledgeable about a hazard than other people.
- Dose response – belief that chemicals are either safe or dangerous.

When there is little knowledge and much uncertainty, experts are as prone to the use of these heuristics as the public. Scientists may underestimate risks of technologies they are familiar with, may suffer from overconfidence in their judgements and may be insensitive to wrong assumptions in their work. They are

often under political or economic pressures which can bias their judgements.

There are other aspects of risk that affect how risky individuals judge the activity to be and how much dread or distress is associated with it. These so-called outrage factors can be measured, assessed and controlled in the same way that hazard can be. Outrage covers qualitative aspects such as:

Outrage factors	Higher scoring activities	Lower scoring activities
Lack of personal choice/involuntariness	Residence near a landfill site	Hang gliding
Lack of personal control	Residence near an incinerator	Burning rubbish in the garden
Global catastrophic potential	Train crash	Car crash
Fatal consequences	Cancer from fluoride	Pain from tooth decay
High risk to future generations	Birth defects from landfill sites	Sporting accident
Artificial vs natural/caused by human failure rather than natural causes	Pesticide residues on food	Aflatoxins in peanut butter
General unfamiliarity, new risk	New incineration technique	Landfill
Affects you personally	Residence near landfill site	Residence away from landfill site
Uncertainty, lack of scientific knowledge	Health impacts of incineration	Health consequences of smoking

Given the diversity of groups and views in society, there will never be consensus on risks or how to manage them. Better management of risks is possible if the different approaches to risk are recognised as valid. The main lessons for education and communication are making value judgements explicit, acknowledging and validating the outrage factors and communicating truthfully. For public decision making, the lessons are about sharing power and responsibility and about fostering public trust.

6.2.4 Precautionary principle

One way to manage the risks associated with waste management is to apply the precautionary principle, which is defined in The Rio Declaration on Environment and Development (UNCED 1992) as follows:

"Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. When in doubt about the impact of a development, it will be managed according to the worst-case scenario of its impact on the environment and human health."

The conditions under which the precautionary principle applies are:

- When health effects are most serious or irreversible.
- When the subject is a matter of scientific uncertainty and full evidence is lacking.
- When cost-effective measures are possible.

All three conditions apply to waste management (Hens et al 2000). Hens argues that to protect health, adherence to the waste hierarchy is necessary (see Figure 2). Although this is universally accepted as a good idea in Britain and throughout the EU, the majority of waste is sent to landfill, the option of last resort in the waste hierarchy. To move away from landfill and towards waste minimisation and re-use, the precautionary principle should be applied in all waste management decisions. Cost-effective measures to make waste prevention effective are environmental taxes, health impact assessment, and environmental education.

6.3 The role of public health agencies

What role could or should public health agencies and professionals play in waste management policy making and planning?

6.3.1 Questions the public want answered

Standard health risk assessment methods tend not to address the public's ways of judging risk. An analysis of 20 environmental reviews of waste management decisions in the United States (Konheim 1991) revealed the most common questions the public want answered (see Box 2 below).

The ideal approach is to carry out a health impact assessment that includes an evaluation of alternative

Box 2: Questions the public want answered

1. What are the specific risks compared to the benefits of this project? Is the risk to each group worth the benefit gained? What are the benefits and risk of alternative solutions? What are the benefits and risks of taking no action?
2. How did you calculate the risk? Is there one standard way of doing it or are there several? Is there a prevailing consensus in the scientific community on the basic premises of the analysis or are there dissidents?
3. Did you base your calculation on data from facilities already in operation or is the database theoretical?
4. If you based the data on already-operating facilities, were they similar to the proposed facility? If not, how would their differences alter the analyses?
5. Does the design of the facility make the risk as low as possible? Can the facility be updated later if new ways are found to lower the risk?
6. Who in the community bears the burden of risk? Are older, younger and sick people more at risk?
7. What is the chance of a serious accident? If one occurred, what would be the worst possible impact? How often do accidents happen in currently operating facilities? Will their likelihood increase over time? What is their magnitude? Would the effects of an accident be irreversible? What provisions have been made to handle accidents?
8. Will risks be identifiable? Who will monitor the performance of the plant? Can the risk be reduced?
9. Can the public influence how the facility is designed and operated?
10. Does approving the project mean foreclosing future, potentially less risky, options?

Source: Konheim, 1991

risks and courses of action, the potential for catastrophic incidents and ways for people affected to control the risks in a meaningful way.

6.3.2 IPPC applications

Since new regulations came out in 2000, health authorities (now devolved to primary care trusts) are statutory consultees in the IPPC (Integrated Pollution Prevention Control) application process and have been asked to comment on the health impacts of plans to permit new waste disposal processes. It is not yet clear where this responsibility will rest with the abolition of health authorities; CCDCs (consultants in communicable disease control) may be asked to lead, but are not usually trained in environmental epidemiology and may not feel prepared to comment.

CIRS, the Chemical Incident Response Service, is preparing a toolkit for use by CCDCs when they are consulted about an IPPC application. The toolkit is in the form of a database plus navigation document. It provides a series of questions CCDCs can use to check whether the applicant has taken health impacts into account in their application. The questions cover site characterisation, monitoring systems, the method used by the applicant to determine the impact on the local population, modelling data, chemicals on site, emissions to the atmosphere, presence of action plans, and the possibilities of noise and odour pollution as well as completeness of the application and information about the type of permit. The toolkit is in the pilot stage and should be available by the end of 2002. For more information, contact Graham Robertson, CIRS, email Graham.Robertson@gstt.sthames.nhs.uk

The official Department of Health IPPC contact is Professor Rod Griffiths, Regional Director of Public Health for the West Midlands Region. A checklist guidance document for CCDCs has been produced on how to respond to IPPC applications that come their way (Kibble 2001).

6.3.3 Local authority waste strategies and waste local plans

Local authorities carry out extensive consultation exercises in the formation of their plans. The consultation process is laid down by statute and the views of interested parties are sought. Comments from health authorities are welcomed but there is no statutory obligation to seek out the views of public health professionals. Nor is there a statutory requirement to carry out a formal health impact assessment when preparing waste local plans and structure plans. The plans set out general policies and principles which guide policy making. To assess best practicable environmental option, key criteria are listed including an environmental statement and life cycle analysis. Under *Environmental constraints and issues*, policies are laid out for nature conservation, landscape, archaeology and the historic environment, agriculture, and water. Health is not specifically mentioned. It is assumed that health impacts are adequately covered in

the existing environmental impact assessment. Given the uncertainties in the epidemiological data, it may be the case that the current risk assessment methods based on emission standards are as accurate as can be achieved.

6.3.4 Regional waste strategy

The Regional Assembly for the South West has begun the process of producing a regional waste strategy and welcomes public health input (Joe Field and Brian Cook, personal communication).

6.3.5 Health impact assessment

The White Paper *Saving Lives, Our Healthier Nation* states that there is a need for health impact assessment of policies, plans and projects at national, local and regional level. The Government has made a commitment to consider health in all aspects of policy making, not just in relation to the health services but to any policy which affects people's well being and quality of life. The Department of Health has explained HIA as:

A prospective assessment of a proposed new policy to identify its likely impacts on health. This aims to provide assessment of policy options and their differing potential health benefits and disbenefits in order to maximise health outcomes;

or

A retrospective assessment or evaluation of a policy following implementation. This aims to monitor how a policy is affecting or has affected health. The results of such a process can then be used to fine tune the future direction of policy implementation. (Department of Health 1999)

The Welsh Assembly has produced guidelines on choosing formats for HIA (The National Assembly for Wales 1999, p28). They stress that the HIA methods which are appropriate for assessing projects are likely to be different from methods for assessing a policy. When choosing a method, decision makers should be guided by the need to make it add value to the decision making process. A HIA must do more than point out that a new development may create noise and air pollution. Methods should be chosen which provide information on the size and nature of the health impact while, at the same time, not ignoring those impacts which are impossible to quantify.

Although there is no standard methodology for carrying out an HIA, there is considerable experience with the process in other countries and within the UK. The following procedures are from the Merseyside Guidelines:

1. *Screening* – procedure whereby policies are selected for assessment. The idea is to see if the project or policy is likely to have significant impacts on health and if it is worth subjecting it to a HIA. A checklist from the British Columbia Health Impact Assessment Toolkit can be found in *Developing Health Impact Assessment in Wales*

(The National Assembly for Wales 1999 p19).

2. *Scoping* – a multidisciplinary steering group is established to agree the Terms of Reference. Steering group should include commissioners of HIA, assessors, policy proponents, affected communities and other stakeholders.

3. *Conducting the risk assessment* – characterising the nature and magnitude of the harmful and beneficial factors, how many and which people will be affected by them and how they will be affected.

- A. Policy analysis
- B. Profiling of affected communities
- C. Interview stakeholders and key informants
- D. Identify health determinants
- E. Collect evidence from other reports and assess evidence
- F. Establish priority impacts
- G. Recommend and justify options for action

4. *Appraise the assessment*

5. *Decision making*

6. *Monitoring and evaluation*

The use of an integrated environmental and health impact assessment is described by Fehr (Fehr 1999) for the planned extension of a non-toxic waste disposal site in Lower Saxony. A ten-step environmental health impact assessment model was applied and its use assessed. Fehr argues that such an assessment should be used more often as a tool for health protection and promotion but that a consensus is needed on the concept and further development of the tool.

A HIA is an iterative and an interactive process, based on principles of participation, equity, democracy, and a broad definition of health. The aim is to incorporate a public health perspective into the waste planning process. This requires intersectoral collaboration. If policy makers from local authorities were involved from the beginning of the HIA process, they would have a sense of ownership and interest in the process which would make them more likely to consider health impacts when they prepare their Waste Local Plans and Waste Strategies. If public health officials were involved in the waste planning process from its beginning, they would have more impact than if they were commenting on an already prepared and accepted plan.

7 Recommendations

In his review of epidemiological studies on the health effects of hazardous wastes, Miller (Miller 1996) points out that we "...face a stark choice. We can largely depend on analogy, as many have done in the past. This involves acknowledging that evidence exists of adverse effects ... using the large body of data available on the toxicity and carcinogenicity of substances identified in hazardous waste sites, relating this knowledge to that known on human exposure, inferring a problem, and finally acting. This basis for risk assessment may be refined a little by epidemiology, but we must recognise that the majority of studies from the past – published or remaining unpublished – are inconclusive. Alternatively, we can refine our methodology and make valiant efforts to increase the knowledge base."

Recommendations and research programmes to increase the epidemiological knowledge base are made by many agencies, including the Department of Health (Environmental Chemical Unit 1999), the Department of the Environment (DOE 1994), the Environment Agency's Waste Regulation and Management Research

Programme and the World Health Organisation (WHO European Centre for Environment and Health 2000, WHO Meeting 1998). Recommendations focus on:

- refining exposure assessment and modelling;
- improving health outcome datasets, including GIS, geographical information systems;
- determining the teratogenicity of substances emanating from waste disposal sites.

This report acknowledges the importance of increasing and strengthening the evidence base but recognises the inevitable uncertainty of epidemiological evidence in this field. It recognises also the pressing need to make public policy decisions when the evidence remains inconclusive. This report recommends the development of democratic, health-protective decision making techniques which incorporate the epidemiological evidence base as well as public values and concerns.

8 Conclusions

The data collected about waste are not detailed enough to make meaningful assessments of potential health impacts that might arise from waste management practices. The data do not include detailed information about the composition of the waste collected nor of off-site emissions from waste management operations. Accurate exposure assessments are not possible without such data.

The nature of existing epidemiological research in this area is such that most studies are useful for generating hypotheses but are unable to test the hypotheses or to provide convincing evidence of an association between exposure and a health impact.

For most waste management methods, the evidence is insufficient to claim that adverse health outcomes will result. The exception is the convincing evidence that bathing in sewage contaminated recreational waters increases the risk of gastrointestinal symptoms, even when the water meets present guideline levels of faecal coliforms.

Implementation of the current Waste Hierarchy and the Precautionary Principle through the adoption of an integrated waste management strategy at national, regional and local level will be the most effective way to reduce the health risks from waste management procedures.

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Appendix 1: The literature search

A1.1 Scoping exercise

An initial scoping exercise was carried out to discover what has been written on the subject of waste and health. Searches were conducted of online databases and references in published papers (Appendix 2). The search revealed thousands of documents about the many health hazards and health impacts associated with waste and about a number of different types of waste management. It raised questions about the focus of the topic under consideration. At this stage, any reference about waste and health was kept. As a result of the scoping exercise, decisions were needed about how to focus the search to what was considered relevant for this project.

A1.2 Decisions

Decision 1: to focus on review papers

Since the project brief was to carry out a systematic literature review, the first decision was to find out what reviews had been published. To avoid unnecessary duplication of effort, the CRD protocol recommends a thorough search for review papers before searching for primary studies. The project management team made the decision to narrow the search to reviews and not to systematically search for all the primary studies carried out.

Decision 2: to define health broadly

The decision was taken not to define health too narrowly but to use the WHO definition of health as a 'state of complete physical, mental and social well-being and not merely the absence of disease and infirmity'.

Decision 3: to focus on health impacts instead of health hazards

A health hazard is anything that can potentially cause harm. (For examples see Table 5, Factors Affecting Health.)

A health impact is any change in health risk that is reasonably attributable to a project, programme or policy. (Definitions from BMA 1998, p53.)

The decision was made to search for documents about the health impacts associated with waste disposal and not to systematically search for documents about the health hazards. This decision was made in order to focus the project on those research studies that provide the strongest evidence of a link between the waste disposal method and human health.

Decision 4: to focus on particular waste disposal methods

The initial brief was to focus primarily on the health

impacts of landfill, incineration, sewage treatment, and soil amendments such as sewage sludge. The advisory group suggested that composting and recycling be included. Disposal of radioactive waste was not included although a few papers discovered during searching were retrieved and added to the database.

Decision 5: to focus on studies of direct relevance to waste disposal

The decision was made to prioritise papers directly relevant to waste disposal methods, rather than to papers that are only indirectly related. The hazards identified are not unique to waste disposal methods. They also originate from other sources such as industrial processes, power generation and natural sources.

Examples:

- Tetrachloroethylene may contaminate drinking water when it leaches from a landfill site or when it leaches from the vinyl lining of drinking-water distribution pipes.
- The source of dioxins is any combustion process in which chlorinated organic chemicals are burned.
- Metals processing is the major source of lead emissions to the atmosphere.
- Volcanic activity and soil degassing during natural fires are important contributors to global emissions of mercury (National Research Council 2000).

A study demonstrating an association between a health impact and a hazard arising from a non-waste source is an important indication of the harmful nature of that hazard. However, the focus of this report is on waste disposal.

Decision 6: to focus on recent papers

The decision was made not to search thoroughly for papers written before 1982 partly because of the difficulties in obtaining papers from before this time but mainly because of changes in waste management practices over the years. Only reviews written since 1992 were included.

Decision 7: to focus on developed countries

No consistent decision was made about including references from other countries. Priority was given to papers about the South West of England and the UK. However, studies from other developed countries in temperate zones were included as there are likely to be many similarities with the UK in waste production and management. There was a bias towards continental Europe, the United States, Australia and New Zealand. Papers about the health impacts of waste disposal in tropical, developing countries were generally not included.

A1.3 Search strategies

The literature search involved the following methods.

1. Search of online databases – Biosis, CAB Abstracts, Cochrane Controlled Trials Register, Compendex*Plus, Index to Theses, Ingenta, Medline, Mental Health Collection, PsycINFO, ScienceDirect, The Science Citation Index Expanded.
2. Search for published and unpublished documents that would not be found on online databases – Composting Association, County Councils and Unitary Authorities in the South West of England, Department for Environment, Food and Rural Affairs, Dyfed Powys Health Authority, Entrust, Environment Agency, Friends of the Earth, Greenpeace Research Laboratories, University of Exeter, London Hazards Centre, WARMER Bulletin Library, Wastewatch.

No search strategy that relies only on online databases will retrieve all of the relevant papers. Some discussion papers and primary studies are published in journals which are not covered by any of the online databases.

The search consisted of myriad permutations of relevant keywords – air pollutants, bathing beaches, birth defects, cancer, community health, composting, congenital, dental waste, disposal, gastroenteritis, hazardous waste, health, human, incineration, Incinerator, infection, land fill, landfill, medical waste, occupational, occupational health, public health, recreation, recycling, refuse disposal, sanitary engineering, sea, sea bathing, seawater, sewage, waste, waste disposal, fluid, waste management, waste treatment, water pollution.

In any search of an online database, it is easy to miss relevant papers because of the way the papers are indexed. There are many ways to index each type of waste disposal method and there are many health impacts associated with waste. For example, many of the US papers about hazardous waste sites did not include the subject heading 'landfill' while some papers about waste incinerators did not have the subject heading 'incineration'. 'Health' and 'health impact' are not useful search terms on Medline. No search strategy

could be found that could easily differentiate between studies about health hazards and health impacts. Although laborious, the most reliable way to find most of the papers on any of the online databases was by checking the titles of the thousands of papers retrieved on a general search for waste or hazardous waste.

The most comprehensive way of finding relevant documents is by hand searching particular journals, by checking the reference sections of review papers, and by contacting agencies and researchers who collect this material.

A1.4 The database

References were added to a Procite database and categorised according to a rough classification scheme developed for this project. All were coded by type of waste disposal method and by type of document, i.e. primary study, discussion paper or review. Reviews summarise a number of primary studies and draw conclusions. Discussion papers summarise or discuss the topic and put it into perspective but do not analyse primary studies. Primary studies were coded according to whether it was a study of a health hazard or of a health impact. Details of the classification scheme and keywords used to construct the database are available from L Saffron, or the SWPHO.

A1.5 A summary of the number and types of records

The number and types of records are shown in Table A below. This table does not include the following:

- Types of document – reviews, discussion papers and primary studies on health hazards
- Types of waste – radioactive waste, hazardous waste, clinical waste, agricultural waste, mining waste, etc
- Specific hazards – dioxins, arsenic, PCBs, etc
- Issues in waste management – waste disposal, waste collection, risk perception, risk communication, planning, waste local plans, etc.

Table A: Number and types of studies identified (correct as of May 2002)

	Total	Reviews on health impacts	Discussion papers on health impacts	Primary studies on health impacts
Total	1035	54	206	327
Landfill	239	12	55	106
Incineration	166	5	24	50
Soil amendments (i.e. sewage sludge, waste water irrigation)	48	0	5	7
Sewage treatment	89	7	3	67
Composting	36	3	11	11
Recycling	11	1	2	4
Psychosocial factors	57	2	15	35
Evaluation methods (i.e. health impact assessment, epidemiological methods, risk assessment, modelling, guidance)	196			

Appendix 2: How judgements were derived or justification for judgements

The results of applying the algorithm to deliver a judgement (1.3.3) to the literature is shown below.

A2.1 Landfill

1. Have studies been done on human populations?

Yes.

The literature search revealed more than 220 papers published about the hazards to health from landfill sites. Of these, 101 are primary studies about the health impacts of landfill sites and 23 about the health impacts of contaminated drinking water. Six review papers were found which covered the epidemiological evidence linking health effects with landfill sites (Cantor, 1997, Johnson, 1997, Johnson, 1999, Miller, 1996, Sever, 1997, Vrijheid, 2000). The drinking water studies were included in this section because an important source of exposure from landfill sites is leachate into groundwater. However, in many studies, the source of the contamination was not known. In some studies the source was leaking chemical storage tanks, in others, chemical accidents. Studies were not included if the water was contaminated by sewage (see section on sewage below). Only seven of the total are occupational health studies, the rest being studies about the health impacts on nearby communities.

The studies looked for links between the landfill sites and the following health outcomes: Reproductive outcomes/ developmental effects on children (31 studies), Cancer (29), Symptoms (28), Psychosocial impacts (19), Biomarkers (13), Health problems - not specified in abstract (14), Mortality (5), Injuries/poisoning (2)

2. Have hazards been identified? Does the appearance of the hazard precede the health outcome? Is the association biologically plausible? Is there data on exposure?

No.

The main weakness of the studies about landfill health effects is the complete lack of exposure data. All use residence near the site as a proxy measure of exposure – i.e. data based on census tract, post code, or residence within 2 or 3 km of the site. A few studies provided more detailed exposure data. For example, in a French study (Zmirou et al, 1994) individual exposure was estimated for one point in time, using a dispersion model of volatile air pollutants and the daily activity patterns of each

individual within the area under investigation. The landfill site had been in operation for the previous 9 years. In this study, there were no statistically significant differences in consumption of prescription drugs.

Where the hazards from landfill sites have been identified, as is the case in the National Priorities List sites in the United States, it is possible to estimate exposure using the EPA Human Exposure Model (Wolfinger, 1989). The model is based on assumptions about the rate and toxicity of site emissions and can be used to estimate cancer risks from inhalation for each site in terms of risk to the maximally exposed individual (MEI risk), to the average individual (AEI risk), and to the population. The results of this type of analysis are uncertain and are based on risky assumptions. These remain estimates, not data. However, there is some biological plausibility in the association of congenital abnormalities and landfill sites due to the sensitivity of the fetus.

3. Are there ANY hypothesis-testing studies?

No.

Because of the lack of exposure data, the studies are hypothesis-generating studies rather than hypothesis-testing studies.

4. Have any of the hypothesis-testing studies controlled for possible confounding factors?

No.

With ecological studies of this type, it is impossible to control for other sources of pollutants. For example, the conclusion that the landfill site in Nant-y-Gwyddon may have been responsible for an increased rate of congenital abnormalities in residents near the site (Fielder et al, 2000) has been challenged by researchers who pointed out that a municipal incinerator operated in the same area just before the landfill site opened (Roberts et al, 2000). There was no direct evidence that the landfill, rather than the poorly performing and heavily polluting incinerator, was the cause of the adverse health outcomes. As well as other environmental pollutants from industrial and traffic pollution, there is usually concurrent exposure to occupational hazards, indoor air pollutants, tobacco smoke, alcohol, prescription drugs and recreational drugs.

5. Are there more than 20 hypothesis-testing studies consistently showing strong or moderate relative risks?

No.

There are more than 20 hypothesis-generating studies but the results were inconsistent, with some showing associations between landfill and various health impacts while other studies found no associations. Relative risks ranged from no association to strong.

In reviews, discussion papers, conferences and consensus meetings, many attempts have been made to determine whether the findings indicate real risks associated with exposure to landfill sites. There is general agreement with the cautious position taken at a meeting convened by the WHO Regional Office for Europe in 1998 which concluded:

"Many of the studies detected an increased risk of the studied diseases and symptoms in populations living close to the landfills. However, the evidence supporting the causality of the association is inconsistent and inconclusive. Probably the strongest suggestion for causality was generated by studies on reproductive outcomes, such as reduced birth weight or some birth defects. However, all studies lacked direct exposure assessment, and the limited sample size of most studies makes a more specific analysis impossible. ... Considering all the uncertainties, the meeting concluded that the present data do add to a suspicion that population exposure to emissions from hazardous wastes may pose a risk to population health. The present studies are not powerful enough to indicate which of the characteristics of the very inhomogeneous group of landfills that are included in the studies might be responsible for the observed small increase in the risk." (WHO meeting, 1998)

Judgement - insufficient

A2.2 Incineration

1. Have studies been done on human populations?

Yes.

The literature search yielded 50 primary studies and three reviews (Allsopp et al, 2001, Hu and Shy, 2001, National Research Council, 2000). The majority were studies on communities but there were 14 occupational health studies.

All types of health outcomes were investigated, including: Cancer (15 studies), Health problems/diseases/unspecified health effects (12 studies), Biomarkers (10 studies), Reproductive outcomes/developmental effects on children (9 studies), Symptoms (8 studies), Mortality (5 studies), Injuries/poisoning (3 studies), Psychosocial impacts (2 studies), Economic (1 study).

2. Have hazards been identified? Does the appearance of the hazard precede the health outcome? Is the association biologically plausible? Is there data on exposure?

Yes.

Among the occupational health studies, there were 3 studies where exposure was presumed from occupation in the incinerator; two studies with quantified ambient measurements of PM10 (particulates) or metals; and 7 studies providing quantified personal measurements (of blood levels of lead or of urinary mutagens). There was not enough information about the remaining two studies to categorise the exposure data.

Among the studies of communities living near to incinerators, 4 used quantified ambient measurements, 2 used quantified estimates and 27 studies used residence as a proxy measure of exposure.

3. Are there ANY hypothesis-testing studies?

Yes.

The following were hypothesis-testing studies:

1. An occupational health study of a cohort of incinerator workers with high, medium and low exposure to toxic compounds such as metals (Bresnitz et al, 1992),
2. A study simultaneously measuring air quality and respiratory function and symptoms in populations living in the neighborhood of waste incinerators compared with three matched-comparison communities. (Shy et al, 1995)
3. A study of six communities in southwestern North Carolina investigating the respiratory health status of residents whose households are located near an incinerator. This diary study estimated the daily variation of pulmonary function measured as peak expiratory flow rate (PEFR) related to 24-h mean PM10 levels, which were observed at each monitoring station placed in the six study communities, as a surrogate exposure measure of outdoor air pollution. This study did not show any difference in respiratory health between subjects of an incinerator community and those of its comparison community. (Lee and Shy, 1999)
4. Study of 713 children in 2 regions near 2 sludge burning incinerators in Sydney. Controls were 626 children in a region with no incinerator. Exposure assessment by air monitoring and region of residence. Outcomes - prevalence of respiratory illness, airway hyperresponsiveness, atopy, FEV1. Results - no significant differences in baseline FEV1 and prevalence of current asthma, atopy, symptom frequency or severity of asthma illness between study and control regions. (Gray et al, 1994)

4. Have any of the hypothesis-testing studies controlled for possible confounding factors?

Yes.

For example, the study by Lee & Shy (1999) analyzed how health outcomes varied according to the degree of exposure to ambient pollutants as well as to other cofactors including, sex, age, respiratory hypersensitivity, hours spent outdoors within the area of the selected community, and surrogate measures for indoor air pollution exposure (vacuum use and experience of air irritants at work).

5. Are there more than 20 hypothesis-testing studies consistently showing strong or moderate relative risks?

No.

The 4 hypothesis-testing studies consistently showed no association between the hazards from incineration and any health outcomes. Even among the hypothesis-generating studies, the results were inconsistent. Roughly half the primary studies found an increase in the incidence of a health problem and half did not.

Using the algorithm above, we judged the evidence linking incineration with any health outcomes as insufficient.

The association between bioaerosols and these health outcomes is biologically plausible. The route of exposure is inhalation. The data on exposure is measurements of specific IgG antibodies to fungi and bacteria as immunological markers of exposure to bioaerosols.

3. Are there ANY hypothesis-testing studies?

Yes.

There is a case control study (Bunger et al, 2000) which found that the compost workers had significantly more symptoms and diseases of the airways ($p=0.003$) and the skin ($p=0.02$) than the control subjects. They had significantly increased antibody concentrations against fungi and actinomycetes. No studies were found about the health impacts to residents living by composting facilities.

4. Have any of the hypothesis-testing studies controlled for possible confounding factors?

Yes

The participants were interviewed for work related symptoms, conditions of exposure to bioaerosols at their workplaces, exposure to bioaerosols from other sources, atopic diseases, and smoking habits.

A2.3 Composting

1. Have studies been done on human populations?

Yes.

Two review papers were found (Maritato et al, 1992, Environment Agency, 2001) and 11 primary studies.

2. Have hazards been identified? Does the appearance of the hazard precede the health outcome? Is the association biologically plausible? Is there data on exposure?

Yes.

The main hazards identified from composting are bioaerosols containing bacteria such as *Clostridium botulinum* and endotoxin-producing Gram negative bacteria and/or fungal spores such as *Aspergillus fumigatus*. The main health impacts from composting (Bunger et al, 2000) are:

- Inflammatory responses of the upper airways – congested nose, sore throat and dry cough
- Toxicoses – toxic pneumonitis due to endotoxins
- Infections – respiratory tract and skin
- Allergies - bronchial asthma, allergic rhinitis, extrinsic allergic alveolitis (hypersensitivity pneumonitis)

5. Are there more than 20 hypothesis-testing studies consistently showing strong or moderate relative risks?

No.

Only one case-control study was found. The rest were case reports or hypothesis-generating studies. Regarding occupational exposure, it is possible that composting causes health problems. But the evidence is insufficient regarding residence near composting facilities.

A2.4 Sewage

Bathing in sewage contaminated recreational waters and gastrointestinal symptoms

Because only a few studies investigated skin, eye, ear and respiratory illnesses associated with recreational use of contaminated water, this judgement is limited to the association with gastrointestinal symptoms. The judgement is based on a review paper by Pruss evaluating the health risks caused by poor microbiological quality of recreational natural water (Pruss, 1998). Water quality was measured by indicator-bacteria of faecal origin assumed to be resulting from sewage discharge. It is possible but unlikely that the contamination could be due to other bathers.

1. Have studies been done on human populations?

Yes.

Six review papers (Ashbolt, 1996, Barrell et al, 2000, IEH, 2000, Kindzierski and Gabos, 1996, Pruss, 1998) and 37 primary studies were found about the health effects of recreational bathing in sewage contaminated waters.

2. Have hazards been identified? Does the appearance of the hazard precede the health outcome? Is the association biologically plausible? Is there data on exposure?

Yes.

The hazards are microbial pathogens known to cause gastrointestinal symptoms. The exposure data consists of measurements of viral, bacterial and fungal pathogens and faecal indicator organisms typically found in sewage discharges.

3. Are there ANY hypothesis-testing studies?

Yes.

In the review by Pruss, there were 22 hypothesis-testing studies meeting strict criteria for inclusion (Pruss, 1998 p2)

4. Have any of the hypothesis-testing studies controlled for possible confounding factors?

Yes.

The confounding factors controlled for included food and drink intake, age, sex, history of certain diseases, drug use, personal contact, additional bathing, sun, and socioeconomic factors. 12/22 studies controlled for less than 3 of the previous factors. 4/22 studies took into account 3-4 factors. 6/22 studies accounted for 7 or more studies. Given the number of potential confounding factors, the pathogen threshold level for increased risk is still controversial. For example, it is possible that increased immunity in adult populations and in populations of countries with higher endemicity may result in higher threshold levels. Different countries detect different ranges of pathogens in water and use different detection methods.

5. Are there more than 20 hypothesis-testing studies consistently showing strong or moderate relative risks?

Yes.

Of the 22 studies in the Pruss review, 19 showed

significant relationship of gastrointestinal symptoms to faecal indicator bacteria or bacterial pathogens. In 3 studies, there were no significant relationships. The relative risks included strong and moderately strong associations:
17 correlations where RR >2 (strong),
13 correlations where RR 1.5-2 (moderate)
18 correlations where RR <1.5 (weak)

6. Are there a range of study designs?

Yes.

There were 2 randomised controlled trials, 18 prospective cohort, 2 retrospective cohort studies.

7. Have studies been carried out in different population groups?

Yes.

Studies were carried out in the UK, USA, New Zealand, Hong Kong, Australia, Egypt, South Africa, Israel, Spain, France, Canada.

8. If dose-response relationships are observed, do they confirm the association between the hazard and the health outcome?

Yes.

Most of the studies showed significant dose-response relationship. The best dose-illness correlation was found with enterococci or faecal streptococci.

Occupational diseases of sewage treatment workers

1. Have studies been done on human populations?

Yes.

There was one review (Thorn and Kerekes, 2001)) and 38 primary studies. The health effects investigated were symptoms (17 studies), infections, i.e. hepatitis A, hepatitis C, legionella, leptospirosis, gastroenteritis (16 studies), mortality (3 studies), reproductive outcomes (1 study), biomarkers (3 studies) and cancer (5 studies).

2. Have hazards been identified?

Yes.

From the mortality and cancer studies, no hazards were identified. From studies on symptoms and infections, the following hazards were identified - bacteria, bacterial endotoxins, hydrogen sulphide, and organic solvents.

3. Does the appearance of the hazard precede the health outcome? Is the association biologically plausible?

Yes.

For symptoms, it is plausible that pathogenic micro-organisms, bacterial endotoxins, organic solvents and hydrogen sulfide could be related to the symptoms observed.

No.

For cancer, none of the agents commonly found in sewage treatment plants have been related to an increased risk of stomach cancer. The spread of the other cancers over a multitude of organs does not support a hypothesis of causality with agents commonly found in sewage treatment plants.

4. Is there data on exposure?

Yes.

Detailed exposure measurements were included in some of the studies on symptoms and infections but in most of the studies, the exposure was inferred by the subjects' occupation as a sewage treatment worker. The exposure route was inhalation. Measurements were given of airborne viable bacteria (Lundholm and Rylander, 1983), (Melbostad et al, 1994), airborne endotoxin levels (Rylander, 1999), (Melbostad et al, 1994), hydrogen sulphide (Richardson, 1995), airborne organic solvents (Kuo et al, 1996), and amount of specific antibodies in the blood. For the mortality and cancer studies, no exposure data was provided.

5. Are there ANY hypothesis-testing studies?

Yes.

There were 29 hypothesis-testing studies. An example is a retrospective cohort study from the United States in which 28 sewage treatment workers were compared with data from a pooled non-exposed population (Kuo et al, 1996). The health outcome was central nervous system effects, determined by postural stability assessment. Exposure assessment was by measurement of organic solvents in the sewage treatment plant. In this, there was a statistically significant correlation between postural sway and organic solvent exposure and sewage workers had an increased postural sway compared with controls.

6. Have any of the hypothesis-testing studies controlled for possible confounding factors?

Yes.

Of the 29 studies, there were 16 which adjusted for personal factors such as smoking, alcohol use, age, educational level and gender.

7. Are there more than 20 hypothesis-testing studies consistently showing strong or moderate relative risks?

No.

There were 10 studies showing strong or moderately strong odds ratios (although there were no ORs in 4 of the studies).

8. Are there a range of study designs?

Yes.

Uncontrolled cohort, cross-sectional, case-control, case reports, and retrospective cohort studies.

9. Have studies been carried out in different population groups?

Yes.

Studies on sewage treatment workers in Germany, USA, Sweden, Denmark, Norway, UK, Canada, Greece, France, Israel, and Italy.

10. If dose-response relationships are observed, do they confirm the association between the hazard and the health outcome?

Not observed.

Judgement – probable.

Sewage discharges and reproductive outcomes

1. Have studies been done on human populations?

No.

Field and laboratory studies on a range of wild animals have demonstrated adverse reproductive outcomes from xeno-oestrogens, natural and synthetic substances with oestrogenic or anti-oestrogenic properties ((IEH, 1995)). These compounds occur in sewage discharges and have been associated with endocrine disruption in wildlife, including "thyroid dysfunction in birds and fish, decreased fertility in birds, fish, shellfish and mammals, gross birth deformities in birds, fish and turtles, metabolic abnormalities in birds, fish and mammals, behavioural abnormalities in birds, demasculinisation and feminisation of female fish and birds, and compromised immune systems in birds and mammals" (quoted in (IEH, 1995)). The relevance of these studies to human health is not clear but there is concern about the fall in quantity

and/or quality of sperm in recent decades ((IEH, 1995; Colborn et al, 1997)).

Judgement – insufficient.

A2.5 Landspreading of sewage sludge

1. Have studies been done on human populations?

No.

There were no studies about the health impacts of landspreading sewage sludge although there were two studies about the health impacts of working in facilities which prepare sewage sludge for landspreading ((Clark et al, 1984),(Baker et al, 1980). These were included in the section on occupational hazards of sewage treatment workers.

2. Have hazards been identified? Does the appearance of the hazard precede the health outcome? Is the association biologically plausible? Are there data on exposure?

No.

Hazardous substances have been identified in sewage sludge (e.g. (Dumontet et al 2001), (Rogers, 1996), (Ross et al, 1992; Straub et al, 1993) but there are no studies linking those hazards to human health effects. The Canadian Handbook on Health Impact Assessment ((Anon, 2000.)Vol 2) evaluated the risks to human health as minimal because:

- Pathogens have a short lifespan and their persistent forms remain in the soil
- Metals are not usually metabolised by soil micro-organisms and will persist in the soil
- Most pollutants bind to soil components
- Most organic compounds, i.e. dioxins, are broken down by soil micro-organisms
- Most organic compounds don't migrate into surface or ground waters because they adhere to soil components
- Volatile organic compounds evaporate within 48 hours of landspreading.

However, there is a lack of understanding of the potential for transfer of toxic compounds to food and about the degradability and persistence of some toxic contaminants ((Rogers, 1996)).

3. Are there ANY hypothesis-testing studies?

No.

Judgement – insufficient.

Appendix 3: Strategies and local plans in the South West

The Government produced guidance on the format of the Waste Strategies in December 2001. The new guidance is being used to ensure that all waste management authorities present their strategies in the same format. (Source: Letter from MJ Wood, Contract and Waste Manager, Wiltshire County Council, 19 December 2001.)

Table B: Strategies and local plans in the South West (correct as of December 2001)

Waste disposal authority	Waste management strategy	Waste Local Plan
BANES - Bath and North East Somerset Unitary Authority	Public consultation held Targets and resolutions adopted by Council - November 1997 Council resolved to review Waste Strategy annually - March 1998 Report by Price Waterhouse Coopers - received	Draft went to council October 2001 Draft deposit - expected January 2002
Bristol Unitary Authority	Public consultation exercise - September 1997 to January 1998 Waste management policy - revised March 1998 Studies carried out on refuse analysis, composting, environmental impact of different methods of waste disposal using Life Cycle Assessment Public consultation before contract specification by April 2000 Council adopted waste management policy statements - May 2000 Commissioned project investigating health concerns of Energy From Waste plants - report due 2002?	Draft deposit - expected summer 2002
Cornwall County Council	Expected date of adoption end of 2002	3rd version - adopted 1998 Public consultation, consulted local public health consultant, took legal advice from government on LA's responsibility towards health - concluded June 2001 Revised deposit draft - June 2001 Public inquiry - February 2002
Devon County Council	Draft - never finalised - 1996 Draft being rewritten now Final version expected to be adopted - April 2003	Consultation draft - October 1998 Draft plan on deposit - Autumn 2001 Adoption - 2004
Dorset County Council	Currently preparing their policy. Going out for consultation	Pre-deposit consultation - March 2001 First deposit draft - Feb/March 2002 Second deposit draft - Jan/Feb 2003 Local public inquiry - Oct/Nov 2003 Modifications - Aug/Sept 2004 Adoption - April/May 2005
Gloucestershire County Council	Last strategy published 1997 Consultation - Jan 2002 Expect to be completed May 2002	Pre-deposit consultation - Autumn 1999 Deposit of revised proposals - April 2001 Public local inquiry - autumn 2001 Inspectors report - winter 2001/2001 Modification of proposals - spring 2002 Adoption - spring 2002
North Somerset Unitary Authority	Currently consulting, no consultation document. Expect to be completed 2003.	Consultation ongoing now, but no consultation document, will be done 2003.
Somerset County Council	Revised strategy - currently working on Best Value process out of which strategy will be written, sometime summer 2002	"Making a Start" report - first stage in production of Waste Local Plan - 2000. First deposit draft plan (first formal consultation document) - winter 2001 Second deposit draft plan - 2002; Public inquiry - late 2002/early 2003 Plan adoption - 2004
South Gloucestershire Unitary Authority	Doesn't exist as a separate document but follows the national strategy and is embodied in the contract with UWS	First deposit plan - autumn 1999 Second deposit plan - late summer 2000 Public local inquiry - March 2001 Inspector's report - summer 2001 Modifications - autumn 2001 Adoption - spring 2002
Wiltshire County Council	Going to committee July 2001. Will be completed and published in March 2002	Consultation document - Nov 1999 Now preparing first deposit draft - November 2000

Unitary authorities in the South West region

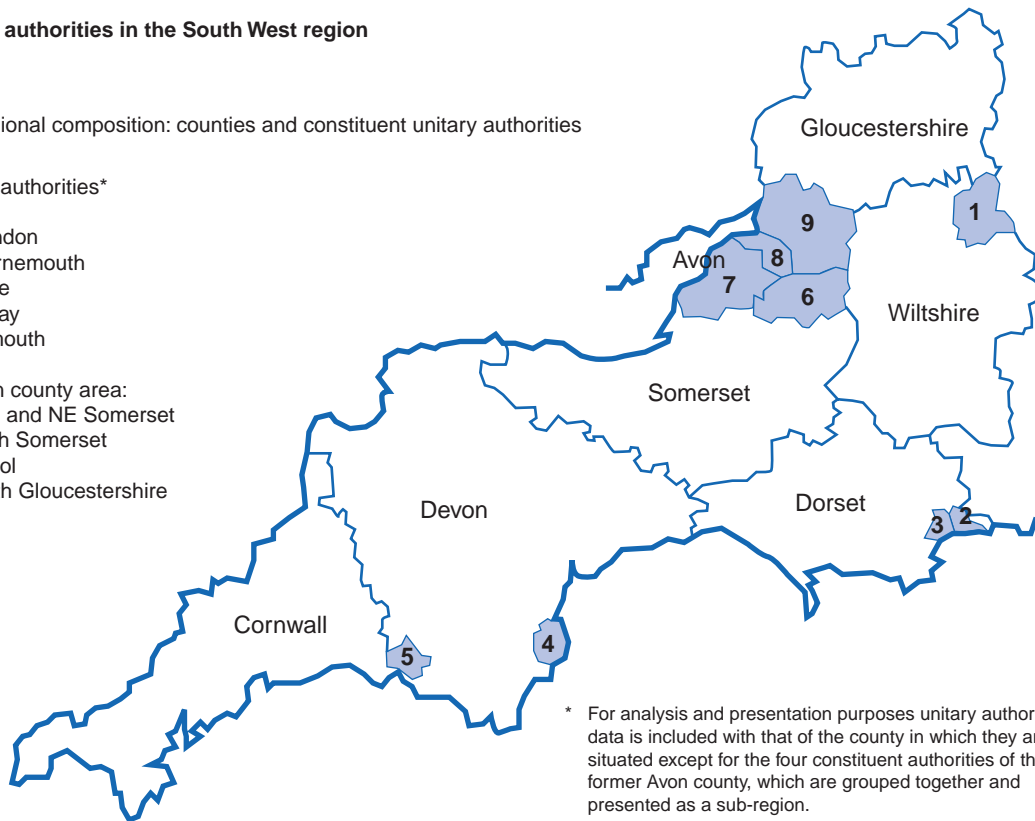
Sub-regional composition: counties and constituent unitary authorities

Unitary authorities*

1. Swindon
2. Bournemouth
3. Poole
4. Torbay
5. Plymouth

Ex Avon county area:

6. Bath and NE Somerset
7. North Somerset
8. Bristol
9. South Gloucestershire



* For analysis and presentation purposes unitary authorities data is included with that of the county in which they are situated except for the four constituent authorities of the former Avon county, which are grouped together and presented as a sub-region.

Appendix 4: Summary and appraisal of reviews

Summary and appraisal of reviews published since 1992.

A4.1 Reviews on the health impacts of landfill

Table C: Reviews on the health impacts of landfill

Review's objective	Sources searched	No. of studies included	Conclusion reached by review	Appraisal of review: conclusion consistent with evaluation?
Cantor 1997 Cantor KP. Drinking water and cancer. <i>Cancer Causes & Control</i> 1997 May;8(3):292-308.				
Exposure to contaminants in drinking water and cancer	Explicit search strategy - not stated Effort to include all available studies - not stated Searched bibliographic databases - not stated Non-English reports - not stated	14 relevant to waste disposal sites out of 225 references	"The studies reviewed here, of a diversity of health endpoints after exposure to a variety of chemicals and mixtures and using various methodologic approaches, defy easy summary...RRs are generally small, in a range where uncontrolled confounding or other sources of bias may be important."	Good description of studies with appropriate conclusion
Johnson 1997 Johnson BL. Hazardous waste: human health effects. <i>Toxicology & Industrial Health</i> 1997 Mar-Jun 30;13(2-3):121-43				
Hazardous waste sites in United States	Explicit search strategy-yes Effort to include all available studies - yes Searched bibliographic databases - not stated Non-English reports - not relevant	12	"Although epidemiologic findings are still unfolding, when evaluated in aggregate (i.e. by combining health data from many Superfund sites), proximity to hazardous waste sites seems to be associated with a small to moderate increased risk of some kinds of birth defects and less well documented, some specific cancers."	Conclusion not based on studies reviewed. Politically motivated review written to justify the Agency for Toxic Substances and Disease Registry's view that hazardous waste represents a significant hazard to health and that a huge expense is required from US government for hazardous site identification, prioritisation and remediation.
Johnson 1999 Johnson BL. A review of the effects of hazardous waste on reproductive health. <i>American Journal of Obstetrics & Gynecology</i> 1999 Jul;181(1):S12-6.				
Effects of hazardous waste on reproductive health.	Explicit search strategy - not stated Effort to include all available studies - not stated Searched bibliographic databases - not stated Non-English reports - not stated	14	"The weight of evidence points to an association between residential proximity to hazardous waste sites and adverse reproductive outcome, although some studies have not found any association."	Conclusion does not take into account confounding and bias. Conclusion not based on evaluation of studies.
Miller 1996 Miller AB. Review of extant community-based epidemiologic studies on health effects of hazardous wastes. <i>Toxicology & Industrial Health</i> 1996 Mar-Apr 30;12(2):225-33.				
Health effects of hazardous wastes.	Explicit search strategy - not stated Effort to include all available studies - no Searched bibliographic databases - not stated Non-English reports - not stated	15	"The majority of studies from the past - published or remaining unpublished - are inconclusive."	This is not a complete review, but an update of the National Research Council's 1991 review. Gives examples of some of the studies published, leading to realistic conclusion.
Sever 1997 Sever LE. Environmental contamination and health effects: what is the evidence. <i>Toxicology & Industrial Health</i> 1997 Mar-Jun 30; 13(2-3):145-61.				
Hazardous waste and environmental spills of hazardous substances	Explicit search strategy- not stated Effort to include all available studies - no Searched bibliographic databases - not stated Non-English reports - not stated	14	"Our review shows suggestive evidence, rather than convincing, for associations between either proximity or exposure to hazardous waste sites and congenital malformations and effects on birth weight."	Useful discussion of limitations of environmental epidemiology focusing on methodological aspects of selected studies.

Table C: Reviews on the health impacts of landfill (continued)

Review's objective	Sources searched	No. of studies included	Conclusion reached by review	Appraisal of review
Vrijheid 2000				
Vrijheid M. Health effects of residence near hazardous waste landfill sites: a review of epidemiologic literature. <i>Environmental Health Perspectives</i> 2000 Mar;108(Supplement 1):101-12.				
Risk associated with residence near hazardous waste landfill sites	Explicit search strategy- yes Effort to include all available studies - yes Searched bibliographic databases - yes Non-English reports - don't know	51	"Although biases and confounding factors cannot be excluded as explanations for these findings, they may indicate real risks associated with residence near certain landfill sites. A general weakness in the reviewed studies is the lack of direct exposure measurement. Although a substantial number of studies have been conducted, risks to health from landfill sites are hard to quantify. There is insufficient exposure information and effects of low-level environmental exposure in the general population are by their nature difficult to establish."	High quality review, conclusions consistent with analysis of studies.

A4.2 Reviews on the health impacts of incineration

Table D: Reviews on the health impacts of incineration

Review's objective	Sources searched	No. of studies included	Conclusion reached by review	Appraisal of review
Allsopp et al 2001				
Allsopp M, Costner P, Johnston P. <i>Incineration and human health - state of knowledge of the impacts of waste incinerators on human health</i> . UK: Greenpeace; 2001				
Impacts of incinerator releases on human health	Explicit search strategy- yes Effort to include all available studies - yes Searched bibliographic databases - yes Non-English reports - not stated	39 studies: 28 community 11 occupational	"A limited amount of epidemiological research has been directed at investigating the health impacts of incinerators. Despite this, scientific studies reveal that municipal solid waste and other incinerators have been associated with detrimental impacts on health. These studies should be seen as strongly indicative that incinerators are potentially very damaging to human health."	Comprehensive and detailed summary which acknowledges limitations of epidemiological studies but comes to stronger conclusion than other reviewers.
Hu and Shy 2001				
Hu SW, Shy CM. Health effects of waste incineration: a review of epidemiologic studies. <i>Journal Of The Air & Waste Management Association</i> . 2001;51:1100-1109.				
Health impacts of waste incineration	Explicit search strategy- yes Effort to include all available studies - no Searched bibliographic databases - yes Non-English reports - don't know	22 studies: 11 community 11 occupational	"These epidemiologic studies consistently observed higher body levels of some organic chemicals and heavy metals and no effects on respiratory symptoms or pulmonary function. The findings for cancer and reproductive outcomes were inconsistent. More hypothesis-testing epidemiologic studies are needed to investigate the potential health effects of waste incineration on incinerator workers and community residents."	Solid, good quality review which misses out some of the published studies.
National Research Council 2000				
National Research Council. <i>Waste incineration and public health</i> . Washington DC USA: National Academy Press; 2000.				
Health effects of incineration	Explicit search strategy - not stated Effort to include all available studies - not stated Searched bibliographic databases - not stated Non-English reports - not stated	22 studies: 8 community 11 occupational	"Epidemiologic studies assessing whether adverse effects actually occurred at individual incinerators have been few and were mostly unable to detect any effects. That result is not surprising, given the small populations available to study; the presence of effect modifiers and potentially confounding factors (such as other exposures and risks in the same communities); the long periods that might be necessary for health effects to be manifested; and the low concentrations (and small increments in background concentrations) of the pollutants of concern. Although such results could mean that adverse health effects are not present, they could also mean that the effects may not be detectable using feasible methods and available data sources."	

A4.3 Reviews on the health impacts of sewage discharges

Table E: Reviews on the health impacts of sewage discharges

Review's objective	Sources searched	No. of studies included	Conclusion reached by review	Appraisal of review
Barrell et al 2000				
Barrell RA, Hunter PR, Nichols. Microbiological standards for water and their relationship to health risk. <i>Communicable Disease & Public Health</i> 2000 Mar;3(1):8-13.				
Sewage discharges to recreational water	Explicit search strategy - no Effort to include all available studies - no Searched bibliographic databases - not stated Non-English reports - no	5 relevant studies	"Epidemiological research on the effects on health of swimming at bathing beaches has shown that swimming in bathing beaches carries some risk of illness, even when the beach complies with existing legislative standards." Demonstrates the superiority of enterococci as indicators of health risk.	This is not a complete review given the number of studies published. It is more concerned with law requirements and guidelines for drinking water. Conclusions are consistent with the studies reviewed.
IEH 2000				
IEH; written by Muggleston MA; Stutt ED, et al. <i>A review of the health effects of sea bathing water</i> . Leicester, UK: Institute for Environment and Health; 2000.				
Health effects of sea bathing water and relevance of WHO guidelines	Explicit search strategy- yes Effort to include all available studies - yes Searched bibliographic databases - not applicable Non-English reports - not applicable	15 studies: 11 prospective cohort studies & 4 UK randomised controlled trials.	"Across all studies, there is a general increase in reporting of gastrointestinal symptoms among bathers compared to non-bathers." Concludes that validity and reliability of WHO proposed guidelines values are in doubt and require re-analysis.	Comprehensive and critical review, highlighting the limitations of published studies and of the WHO 1998 risk assessment.
Kindzierski & Gabos 1996				
Kindzierski WB, Gabos S. Health effects associated with wastewater treatment, disposal and reuse. <i>Water Environment Research</i> 1996;68(4):818-26.				
Health impacts of: 1. Wastewater collection systems & treatment plants, 2. Contaminated water supplies 3. Contaminated fish and shellfish 4. Contaminated recreational waters 5. Exposure to hazardous substances and waste	Explicit search strategy - not stated Effort to include all available studies - partially, most effort made for studies on contaminated water supplies Searched bibliographic databases - not stated Non-English reports - no	1. Wastewater collection systems/ treatment plants-4 studies 2. Contaminated water supplies-50 studies 3. Contaminated fish & shellfish -15 studies 4. Contaminated recreational waters-9 studies 5. Exposure to hazardous substances and waste-4 studies	No overall conclusions were made by the authors but these summaries can be made from reading the studies included in this review: 1. Few studies exist on occupational risks of workers at recycling plants and composting of domestic waste. 2. Significantly higher levels of some antibodies (e.g. Hepatitis A, leptospirosis) were found in municipal sewer workers. 3. There is significant relationship between wide range of diseases and microbial and chemical contamination of water supplies. 4. There is evidence of a link between food poisoning and consumption of seafood and fish. 5. The evidence of infections contracted from contaminated recreational waters is not clear-cut, though skin infections are commonly reported.	Since the authors did not draw any conclusions, it is not possible to appraise the review's conclusions. This paper is a wide-ranging overview of five different topics with less emphasis on themes relevant to sewage treatment discharges.
Pruss 1998				
Pruss A. Review of epidemiological studies on health effects from exposure to recreational water. <i>Int J Epidemiol</i> 1998 Feb;27(1):1-9.				
Health risks caused by poor microbiological quality of recreational natural water.	Explicit search strategy - yes Effort to include all available studies - yes Searched bibliographic databases - not stated Non-English reports - no	37 studies identified; 22 met inclusion criteria. 2 randomised control trials, 18 prospective cohort studies, & 2 retrospective cohort studies.	"The review strongly suggests a causal dose-related relationship between gastrointestinal symptoms and recreational water quality measured by bacterial indicator counts."	Comprehensive and critical review.

Table E: Reviews on the health impacts of sewage discharge (continued)

Review's objective	Sources searched	No. of studies included	Conclusion reached by review	Appraisal of review
Thorn & Kerekes 2001				
Thorn J, Kerekes E. Health effects among employees in sewage treatment plants: a literature survey. <i>Am J Ind Med</i> 2001 Aug;40(2):170-9.				
Occupational health effects in sewage treatment workers	Explicit search strategy- not stated Effort to include all available studies - not stated Searched bibliographic databases - not stated Non-English reports -yes	35 studies: 34 cross-sectional studies 1 case-report	"Gastrointestinal tract symptoms, airways symptoms, fatigue and headache are more common among employees at sewage treatment plants than among controls." No dose response relationship was found between cancer and exposure to agents commonly found in sewage treatment plants.	Comprehensive review with conclusions based on the findings of the studies evaluated.
Ashbolt 2000				
Ashbolt NJ. Human health risk from micro-organisms in the Australian marine environment, in Zann LP; Sutton DC, editor. <i>The state of the marine environment report for Australia</i> . Technical Annex: 2 ed. Townsville, Queensland, Australia: Department of the Environment, Sport and Territories; 2000.				
Health risks from micro-organisms in Australian marine environment	Explicit search strategy - no Effort to include all available studies - no Searched bibliographic databases - not stated Non-English reports - no	14 relevant studies	"Traditional bacterial indicators do not reliably reflect the presence or absence of enteric pathogens in sea water or sediments." "Discharge of non-disinfected primary and secondary effluent to bathing waters is expected to represented a local health risk..."	Realistic conclusions based on analysis of available studies.