# RECYCLING AND PUBLIC HEALTH

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## EXECUTIVE SUMMARY – KEY POINTS

1) Most people in the UK are living in a manner that is not sustainable. If every country consumed natural resources at the rate the UK does, we would need three planets to live on. Current patterns of consumption are depleting natural resources and generating carbon emissions which promote more rapid climate change with all its negative health effects as well as creating huge quantities of waste.
2) Recycling involves the production of a new object from physically altered waste material to maximise economic, social, environmental and health benefits. It diverts waste away from landfill; eases the demand for natural resources and it is a growing industry that is creating new jobs.
3) There is considerable popular support for recycling and government policy is driven by the EU Landfill Directive 99/31/EC, which led to the waste strategy for England 2007, the Climate Change Act (2008), the 2009 budget - Building Britain's Future, and the modernisation of landfill tax legislation (consultation paper released in April 2009).
4) The main health risks to those living near to, or working with the recycling of waste or compost come from the bioaerosols and volatile organic compounds released whenever waste is processed. Bioaerosols are particles of microbial, plant or animal origin and are often referred to as organic dust. They contain live or dead bacteria, fungi, viruses, allergens, bacterial endotoxins, antigens, toxins, mycotoxins, glucans (components of the cell wall of many moulds), pollen, plant fibres etc.
5) Bioaerosols exist naturally in the ambient air and their concentrations are difficult to measure, since they are affected by the wind in the external environment and are constantly changing. Although the presence of bioaerosols in the air does not necessarily correlate with risk of disease, they do have the potential to produce health effects such as aspergillosis and other lung or skin diseases.
6) Compared to the average worker, those who work in the waste collection or sorting industry experience an increased risk of musculo-skeletal problems and accidents that are linked to employment, but it is anticipated that the almost universal introduction of wheelie bins and mechanised lifting will significantly reduce these risks. Waste collection and sorting workers also appear to experience greater than average respiratory problems such as cough, itching nose, wheeze and chronic bronchitis. There is weak evidence, mainly derived

from small observational studies that these outcomes are linked to the workers' exposure to dust, bioaerosols, volatile organic compounds and vehicle exhausts.

7) Both workers and those who live or work in close proximity (i.e. within 250metres) of plants that recycle organic waste through composting or the production of methane by anaerobic digestion in mechanical biological treatment (MBT) plants do not appear to suffer any significantly increased risk of serious health problems. Strong evidence is lacking and there is a suggestion that surveillance systems should be developed to monitor the health of those working with or living near a compost facility.
8) Open windrow composting can create strong odours and complaints of nausea. In-vessel composting facilities are enclosed and many use sophisticated technology to minimise odour and reduce bioaerosol emissions. Proper management of facilities and compliance with health and safety recommendations appears to reduce health risks for those sorting waste or working in the compost industry.
9) The main health benefits of composting at the individual or community level are indirect and come from its links with gardening, physical activity and healthy eating.
10) Many of the occupational or population health impacts from other types of recycling relate to the specific industrial processes used.

    a) *Rubber tyres*. It is anticipated that there may be long term health risks for those involved in the shredding of tyres, but it is a relatively new industry and health risks have not yet been properly researched. Improved surveillance is needed to properly evaluate risk. The evidence suggests that children who use playgrounds lined with recycled shredded tyre crumb do not suffer any increased health risks in the short term. Long term risks are postulated, but unknown and an Environmental Protection Agency Evaluation is currently underway in the USA. Health benefits come from the reduced risk of injury.

    b) *Textiles*. There are no significant health risks specifically associated with the recycling of textiles. Health benefits derive from the diversion away from the use of potentially carcinogenic dyes and other noxious chemicals commonly used in the textile industry.

    c) *Glass*. Injury from broken glass is not a safety issue if the correct equipment is worn. The main health and safety concerns are repetitive strain injury due to heavy lifting and high levels of noise experienced during glass collection. The impact of noise can be significantly reduced by simple measures such as pouring the glass more slowly into polythene lined vessels.

d) *Paper*. Those who sort dry paper and card do not appear to suffer any increased health risks. Working in the paper recycling industry appears to be associated with slightly increased risks of certain cancers and respiratory impairment, especially if dust is not controlled. Workers who are sensitive to the materials used in paper recycling may be at risk of developing chronic respiratory abnormalities.
Paper recycling (and primary manufacture) is linked to the release of chemicals such as Bisphenol A (BPA) in the effluent. These chemicals are ubiquitous in the environment and come from a wide variety of products and processes, not only paper processing. They are bioaccumulative chemicals that can affect the endocrine system. There is a belief that their oestrogenic properties are reducing human male fertility. It has been suggested that the effluent should be monitored and more work is needed to understand how relatively small quantities of chemicals can impact on human health.
The recycling of paper saves huge quantities of carbon dioxide and trees. Forests act as carbon sinks, so the recycling of paper has significant indirect positive effects on health by mediating climate change.

e) *Aluminium and other metals*. The recycling of aluminium and other metals can lead to the creation of dioxins which are known to be carcinogenic. The Health and Safety Executive has released guidelines on how to minimise dioxin exposure among workers recycling aluminium, zinc, and copper and its alloys such as brass and bronze. The main health benefits relate to the reductions in carbon dioxide, raw materials and energy used in recycling compared to primary production.

11) Most research evidence comes from countries that adopted a recycling culture several years ago and revolves around occupational health risks. There are risks in assuming that results from this research are valid in the UK. Many recycling industries are relatively new and there is a lack of research from UK facilities. There appears to be a need to monitor the health of recycling workers in the UK more closely. Health benefits are indirect and not well researched. They mainly derive from reductions in carbon emissions, energy and raw materials used, and the diversion of materials away from landfill.

12) .One of the greatest barriers to achieving the government's vision for recycling is the difficulty in gaining local planning permission and licensing for new recycling initiatives. Ideally, recycling facilities should be located as near as possible to the source of the waste to reduce transportation costs and associated air pollution. People living in more deprived neighbourhoods often have less political power and are less able to prevent the development of new facilities. As a result new recycling plants are located more frequently in areas of relatively high deprivation. If this continues unabated it will serve to increase health inequalities.

13) There are possibly lessons to be learned from programmes in India and Pakistan where the recycling of biodegradable material to create compost has been successfully decentralised. One of the main advantages of this approach is that planning permission is less likely to be resisted if the facility is controlled by the local community. It may be worth testing a similar approach in the UK.

14) There is a need for applied research into the use of social marketing and other strategies to help win hearts and minds and achieve sustained behaviour change among local populations in relation to recycling, since adequate source separation of materials, the first step in any recycling process, requires continued community co-operation to succeed.

## INTRODUCTION

Food, water, warmth, clothing, and shelter are basic human needs that we strive to provide for ourselves and our families using whatever resources are available to us. However, most people have aspirations that go beyond this and many now have the wherewithal to live in a manner that provides a lot more than the basics. But the materials and processes used to create and deliver the modern lifestyles many of us enjoy, use considerable quantities of energy, non-renewable raw materials; and they inevitably create huge quantities of waste. 'If every country consumed natural resources at the rate the UK does, we would need three planets to live on.'[1] Living in this way is clearly unsustainable and must change. To optimise use of resources, the waste hierarchy advocates that primarily there is a need to generate less waste (i.e. waste prevention). In addition, products should be reused or their materials recycled wherever possible.

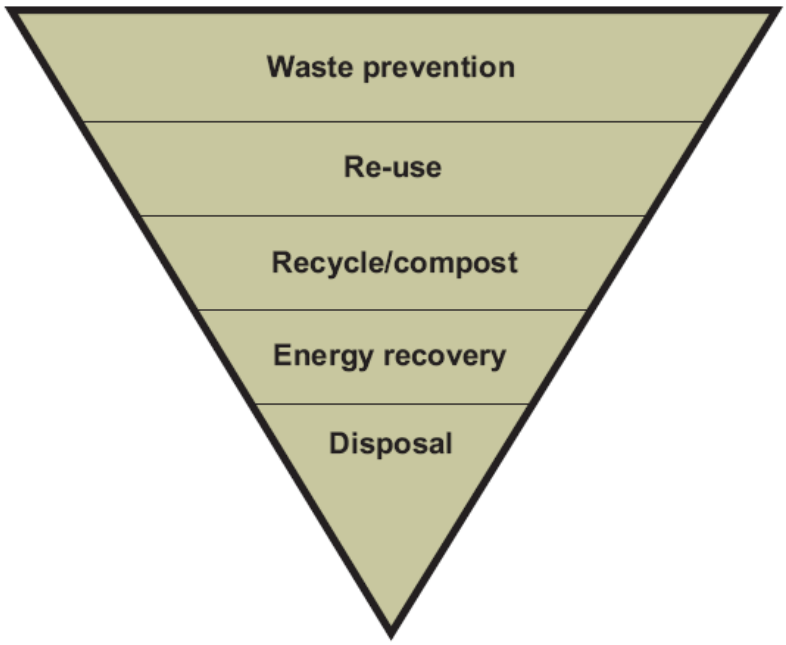
This report examines the evidence for the health impacts of recycling, which is defined as the production of a new object from physically altered waste material to maximise economic, social, environmental and health benefits. Reuse needs to be distinguished from recycling because it does not alter the physical form of the object, and will not be considered here. For example, taking items to, or buying from a charity shop constitutes reuse rather than recycling. The process of recycling waste involves sorting, collecting, transforming and then marketing and using the new product. The recycled end product may be the same thing it was before (e.g. a glass wine bottle) or waste material can be converted into a new product (e.g. glass can be ground with other materials to make road surfacing).

One of the most serious threats to human health, which is exacerbated by modern lifestyles, is climate change caused by rising levels of carbon based greenhouse gas emissions. Recycling preserves natural resources by reducing the need for new raw materials and uses less energy, so it can contribute significantly to a reduction in carbon emissions and the health consequences associated with climate change.[2]

But is recycling healthy? Are there any risks, especially to those using or working with recycled materials?

Recycling, including composting is one of the important elements in the waste hierarchy.

Figure 1 The waste hierarchy




Source: Waste Strategy for England 2007[1]

As well as cutting carbon emissions, recycling helps to preserve natural resources. Fewer trees need to be cut down, and fewer minerals and metals need to be extracted from mines. Recycling has clear environmental, economic and social benefits. It diverts waste away from landfill, and eases the demand for natural resources. Well run recycling centres also create jobs and can cost less than disposal.

There are, broadly speaking, three main types of recycling[3]:

- 'closed loop application' is where a product is recycled back into the same product; e.g. glass bottle back into glass bottle
- 'closed loop material' is where a product gets recycled into a different product, but still replaces the same virgin material or is itself recyclable e.g. waste paper is recycled to make cardboard

- ‘open loop’ is where a product is recycled into a different product but does not replace the same virgin material or cannot be recycled after this first phase, e.g. compost production.

In most cases, the biggest carbon dioxide ($CO_2$) and raw materials saving and maximum environmental and health benefits are obtained through recycling by using the closed loop routes.

## DRIVERS FOR RECYCLING

The main driver for recycling is undoubtedly the financial implications of the EU Landfill Directive (1999).

### EU LANDFILL DIRECTIVE 99/31/EC

The Landfill Directive, adopted in 1999, established a set of detailed rules for waste landfills. The objective was to prevent or minimise the negative effects that landfill sites can have, such as pollution of water, soil and air, and reduce emissions of methane, a powerful greenhouse gas. The directive also helped to promote the recovery and recycling of waste.

The EU Landfill Directive (1999) has been influential in steering waste management policy and practice within the UK. It set targets which encourage the diversion of waste from landfill, to a process that will entail recovery or recycling. Member states are required to reduce the amount of biodegradable waste they landfill to 35% of 1995 levels by 2016. However, countries with high reliance on land-filling such as many of the new member states, but also the UK and Greece have been allowed to postpone the targets by a maximum of four years to 2020. So compared to levels in 1995, the amount of biodegradable municipal waste (BMW), including household waste going to landfill should be incrementally reduced to 75% by 2010; to 50% by 2013, and to 35% by 2020. The Waste Strategy for England 2007 made commitments to the key targets of the Landfill Directive and placed great emphasis on waste prevention, recycling and re-use.[1, 4] The strategy set a new target to reduce the amount of household waste not re-used, recycled or composted from over 22.3 million tonnes in 2000 to 15.9 million tonnes in 2010 (29% reduction) and to 12.2 million tonnes in 2020 (45% reduction); with higher targets for recycling and composting of household waste – at least 40% by 2010, 45% by 2015 and 50% by 2020.

As a disincentive to landfill, the UK government had been increasing the landfill tax by £3 per tonne each year; but in the 2007 budget, the Chancellor announced that the landfill tax would increase more quickly and to a higher level than previously planned. Increases of £8 per tonne per year were announced to run from 2008/09 to at least 2010/11. The current (2009) standard rate of landfill tax is £40/tonne.[5] This rate only applies to active wastes (i.e. those that give off emissions) and will increase to £48/tonne in 2010/11. The increase in landfill tax has already had a significant impact on the amount of waste going to landfill, which fell from 96 million tonnes in 1997/98 to 72 million tonnes in 2005/06 - a reduction of 25%, representing a saving of 0.7 million tonnes of carbon dioxide equivalent emissions a year.[5,6] The Climate Change Act (2008) will encourage investment in sustainable alternatives to landfill and in the 2009 budget the Government announced that it would assess the case for introducing further restriction on the landfilling of biodegradable wastes.[7] A consultation paper about modernising landfill tax legislation to act as a better driver for change was produced in April 2009.[5]

## RATIONALE FOR EU DIRECTIVE

Households, commerce and industry in the UK produce approximately 100 million tonnes of waste each year.[1] The majority of this waste is deposited in landfill, where the biodegradable (organic) component is attacked by bacteria and fungi, leading to the production of a mixture of greenhouse gases; and in particular, methane and carbon dioxide.[1] Methane is of concern because it has twenty three times the global warming potential of carbon dioxide ($CO_2$).[8] In modern landfill practice, specialist heavy machinery is used to compact the waste, driving out most of the oxygenated air around it. If the organic material in the waste such as paper, food and green material decomposes in the absence of oxygen, anaerobic digestion ensues leading to the production of considerable quantities of methane. Landfills released 25% of the UK's methane emissions in 2003, representing about 2% of UKs total greenhouse gas emissions.[9] The decomposition of organic material in landfill sites is the primary source of methane in the atmosphere.[10] The aerobic decomposition (i.e. in the presence of oxygen) of organic waste produces far less methane and therefore has less impact on global warming with all its negative consequences, both for the environment and health.[11] As well as greenhouse gases, the percolation of water through decomposing waste produces a noxious liquid - the leachate - which, if not controlled, can contaminate and seriously pollute both surface and ground water.[12]

Increased awareness of the positive environmental impact of recycling has resulted in the expansion of industrial processes including various forms of aerobic and anaerobic composting

for organic wastes as well as techniques for the recycling of glass, paper, metals, textiles and many other products.[13,14]

## RECYCLING STREAMS

This review will cover the recycling of the following materials or waste streams. Incineration is not included, since this is about recovering energy from waste and not recycling, although incineration may be the ultimate destiny of recycled products such as refuse derived fuel.

- Organic / biodegradable materials using composting (including anaerobic digestion) and mechanical biological treatments (MBT) and / or pyrolysis / gasification
- Rubber tyres
- Textiles
- Glass
- Paper
- Aluminium and other metals

## ORGANIC BIODEGRADABLE MATERIALS

Organic biodegradable waste materials such as paper, green waste and food release considerable quantities of greenhouse gasses as they decompose in landfill, making them eminently suitable for recycling by a composting process.

### AEROBIC PROCESSES

Composting is the biological decomposition and stabilisation of organic material under conditions that allow development of thermophilic temperatures (i.e. 45°C – 75°C) as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds and can be beneficially applied to land.[15] It is a process that facilitates the recycling of life sustaining elements such as nitrogen and carbon, and in nature occurs primarily through aerobic decomposition of organic biodegradable waste by the action of microscopic organisms such as bacteria and fungi, assisted by insects and earthworms that inhabit the soil.[16] Life on earth as we know it would cease if this natural recycling process failed. In the presence of

oxygen, aerobic decomposition breaks organic matter down into fine particles; with the microbes using the released nitrogen and carbon as their primary food source. Aerobic composting has dual benefits, since it contributes to sustainable waste management by reducing the amount of organic waste sent to landfill and generates a product that enhances the structure and fertility of soil.[8]

## COMMERCIAL COMPOST PRODUCTION

In 2005-06, approximately 27% of waste was recycled or composted, representing a quadrupling of this activity since 1996-97. Less waste continues to be landfilled, with a 9% fall between 2000-01 and 2004-05. The total amount of waste being produced is still increasing, but the rate at which waste is growing is coming down, with municipal waste growing less quickly than the economy.[1] The Association for Organics Recycling (previously known as The Composting Association) estimates that in the UK, total compost production is 2.1 million tonnes and current capacity is 3.4 million tonnes, but this could be relatively easily increased to six million tonnes if needed.[17] This indicates that there is the capacity to divert substantially more organic waste to compost than is currently occurring.

Large scale commercial production of compost from waste can only be carried out under licence and with an environmental permit or an exemption. The Environment Agency regulates larger scale/industrial composting facilities under the Environmental Permitting (England and Wales) Regulations 2007, while the medium and smaller scale sites must register but are usually exempt from the need for a licence or permit.

There are two main technologies used in commercial composting, open windrow and in-vessel composting. Properly managed open windrows, where the maturing material is regularly turned or aerated by other means are ideal for composting green waste. This process requires less technology, but more land and there would normally be strict restrictions on location of sites due to the level of odour and bioaerosols produced. In-vessel composting facilities are enclosed and many use sophisticated technology to minimise odour and reduce bioaerosol emissions. Where food or animal by-products are involved, in-vessel composting must be used.

Ideally, composting facilities should be located as near as possible to the source of the biodegradable waste to reduce transportation costs and associated air pollution. However, difficulty in gaining planning permission and licensing are major barriers to the development of any new composting facility and this can lead to environmental health injustice. Distrust of regulatory bodies and nimbyism (not in my backyard) is commonplace; and public opinion of

waste management practices is often low. People living in more deprived neighbourhoods often have less political power and are less able to practise the 'politics of exclusion' that can be employed to prevent the development of a new waste management facility; as a result new composting plants are located more frequently in areas of relatively high deprivation.[18,19,20]

The Compost Quality Protocol was finalised during 2007 and this, together with the BSI PAS100 specification for recycled compost has reassured customers of the quality of the compost they are buying, which has helped to grow the market. Certified quality compost that conforms to the BSI PAS100 specification can only be produced from source segregated waste, which ensures that it does not contain potentially harmful shards of glass or heavy metals. High standards of quality assurance are considered essential for the sustainability and growth of effective markets for commercially produced compost.[21] Quality control is important, because maximum benefit from diverting organic waste from landfill to compost production can only be achieved and sustained if customers want to buy and use the compost that is produced.

Provided compost has achieved the quality standard, it is no longer classified as 'waste' with all the restrictions this entails and instead becomes a commercial product. Horticulturalists and farmers are increasingly using commercially produced compost in place of chemical fertilizers. Concerns about the nitrification of water courses still exist, and restrictions on the amount of compost that can be spread on land are in force. However, risks of pollution are lower because the nitrogen and other nutrients in compost are released more slowly.[22]

Commercial recycling of food waste has also been successfully piloted in several local authorities. An incredible 6.7 million tonnes of food is thrown away each year. This waste of perfectly good food costs UK consumers a total of £10 billion a year (£610 a year for the average family).[21] Questions must be asked about whether this waste of resources and the impact it has on the environment can be afforded not only individually but also nationally.

## SMALLER SCALE / COMMUNITY COMPOSTING

There are several small in-vessel composters available that use innovative but simple technology to produce compost from waste in about fourteen days and are suitable for any organisation that produces between 50 and 7000 litres of food waste, or a mix of food waste and garden waste per week. However, there is only one of these small in-vessel composters that has been given animal by-product regulations approval to treat food waste containing meat and fish or woodchip based animal bedding and is increasingly popular in universities, schools, conference centres, community composters, hospitals etc.[23]

## GARDEN COMPOSTING

Neighbourhood composting is being encouraged by local authorities and many offer composting receptacles for home or community use at a reduced price.

The process of home composting takes longer; and green waste is slowly broken down by worms and other animals rather than by the mechanical shredding that takes place in commercial processes. Temperatures do not necessarily reach the heights achieved in commercial production, which may potentially affect health, since the sanitisation of compost is only achieved if a high temperature of between 45°C – 75°C is maintained for sufficient length of time.

## MECHANICAL BIOLOGICAL TREATMENT (MBT) AND ANAEROBIC DIGESTION

Municipal solid waste (MSW) is the term used to describe the general household waste that ends up in the bin, and includes packaging, defunct pieces of equipment, clothing, food scraps disposable nappies etc. Some of this waste is biodegradable and can be treated to reduce its ability to cause environmental harm. Mechanical biological treatment (MBT) covers a range of technologies that involve combinations of sorting, shredding, and treating the waste biologically by using an in-vessel composting type of process or by anaerobic digestion. In the mechanical stage, the waste is sorted and useful items that can be reused or recycled in other ways are removed. The remainder is broken down into smaller pieces, often by shredding, then in the biological stage, the waste is either broken down to produce a biologically stable compost like material or 'digested' anaerobically to produce methane, which can be used as a fuel to generate electricity and heat. The process of anaerobic digestion replicates what happens in traditional landfill, where the organic material is broken down by bacteria in the absence of oxygen and produces a biogas that is about 60 per cent methane and 40 per cent

carbon dioxide. The difference being that when produced through a controlled process, the gas is collected and used.

MBT also reduces the mass and volume of the waste. The main distinction between different MBT systems is the sequence of the steps and whether the biological treatment is designed to produce methane, stabilised waste in the form of a compost like material or a refuse derived fuel.[24,25]

The left over material from an MBT plant looks very similar to 'compost' but in the UK, it cannot be called compost to avoid confusion with the material produced from source segregated waste that meets BSI PAS100 quality criteria. However the same is not true in many other countries and much of the research does not distinguish between the processes. In the UK, the product from an MBT plant is still categorised as 'waste' and at the moment it cannot be spread on farmland but can only be used for land reclamation and landfill restoration. One of the concerns about using compost like stabilised waste material produced from MBT plants in agriculture or horticulture is that it could be contaminated with heavy metals and that these might contaminate food produced on the land. Trials are underway to test whether the stabilised waste from MBT plants can be used as a soil enhancer without significantly increasing risks to human health or the environment. Risks of contamination are reduced if as much non-compostable material as possible, such as batteries is removed during the mechanical stage.

An alternate use of the stabilised waste is to produce a refuse derived fuel that can then be burned to produce heat or electricity. However, a report for 'Friends of the Earth' produced by independent consultants supported MBT in general, and found that MBT processes that extract both the metals and plastics prior to land-filling the remaining waste have a lower impact on climate change than those producing refuse derived fuels for incineration or incineration of waste without MBT.[26]

## PYROLYSIS/GASIFICATION

These are thermal processes that use high temperatures to break down carbon based waste such as paper, plastics and food scraps in the presence of very little or no oxygen. The techniques are similar to those used to make charcoal from wood, so they can be classified as recycling since they result in the production of a physically altered new product. However, these processes are also classified as incineration in the European Union's Waste Incineration Directive.

In the pyrolysis process, waste is broken down in the absence of air. Gasification is a process in which materials are exposed to some air, but not enough to allow combustion to occur.

The main product in either case is 'syngas', composed mainly of carbon monoxide and hydrogen (85 percent), with smaller quantities of carbon dioxide, nitrogen, methane and various other hydrocarbon gases. The syngas can be burned to produce heat or electricity, or combined heat and power. A pyrolysis plant may use refuse derived fuel from an MBT plant or mixed waste that has been sorted to remove recyclables and materials that have no calorific value such as grit.

Although this process is widely used in Japan, there are very few operating in Europe, and the health effects of this process are not well understood, so cannot be considered in depth.

## TYRES

Mountains of used tyres are an all too common site. In the past the only disposal options available were landfill or incineration, and neither is popular. One use that has been widely promoted is to shred the tyres and use them as mulch, either in horticulture, or for children's play areas. This causes concern because tyres are made from crude oil and naturally contain heavy metals such as cadmium, chromium, lead and mercury, as well as arsenic and an array of hydrocarbons.[27]

## TEXTILES

If textiles are disposed of in landfill, the synthetic (man-made fibres) products do not decompose. Cotton and woollen garments do decompose but they produce methane, which as mentioned above contributes to global warming.

The fabric from clothing and other textiles that cannot be reused can be recycled. The fabric is sorted according to type, colour and grade, and then shredded into fibres. The resulting product, is known as 'shoddy'. High grade shoddy can be mixed directly with new fibres and then used to knit or weave new fabrics. The increasing awareness of the benefits is making recycling trendy and creating a generation of consumers who take pride in wearing clothes made from recycled materials. Lower grade shoddy can be used as carpet underlay, padding for mattresses and stuffing for cushions etc.[28]

As well as reducing the amount of material going to landfill, the recycling of fibre reduces the pollution and associated health risks of the dyeing and colour fixing processes applied to new,

raw cloth. Recycling in this way also saves large quantities of water, an increasingly limited vital resource.

## GLASS

Glass for recycling is first sorted manually into different colours and then taken to a glass recycling plant where it goes through a complex series of crushing, screening and sieving to remove any debris, stones, ceramic material and metals. All processes are generally automated and the processed glass cullet drops off the end of the conveyor system into a loading bay to await transportation to a glass factory to be reused.

The manufacture of glass products uses 300kg less $CO_2$ per tonne of glass produced when recycled glass cullet is used rather than raw materials, mainly because manufacturing virgin glass involves a carbon-intensive furnace process called calcination.

## PAPER

In 2008, the UK paper industry produced slightly less than five million tonnes of paper and cardboard. However, the total consumption of paper and cardboard was more than 11 million tonnes, indicating most paper used in the UK is imported.[29,30]

Levels of paper and cardboard recycling in the UK are high and in 2008, nearly 8.7 million tonnes of paper and cardboard was recovered for recycling.[29] It has been estimated that almost 70% of the paper and cardboard used annually in the UK is collected and sent for recycling. Once the used paper and cardboard is collected, graded, and any contaminants removed, it becomes 'recovered paper', and this represents 78% (over 4.0 million tonnes) of the raw material used by the UK papermaking industry in 2007, making the paper industry one of the UKs most successful recyclers. In Europe, the average utilisation rate is only 49.1%.[30] The average corrugated box made in the UK contains 76% recycled material and many boxes are made from 100% recycled material.[30] Paper can be classified as ‘recycled’ if it contains less than 25% virgin wood fibre.

Wood fibre is the main raw material used for the manufacture of paper products, although a wide variety of other materials can also contribute, such as rags, cotton, grasses, sugar cane and straw. If paper is recycled, the fibres can be used several times, but they eventually lose their papermaking qualities so fresh fibre needs to be constantly introduced into the process. Only 12% of the UK is forested, compared with a European average of 44%, so raw materials are in relatively short supply and recycling is therefore important.

Waste paper that is not used by the UK papermaking industry is exported for recycling. In 2007, the UK exported more than 4.6 million tonnes of paper and cardboard, mainly to China.

The UK paper collection rate is comparatively high, and currently stands at 76.7% of the amount used, compared to an average of 68.3% in Europe (2008). Most of the recovered paper and cardboard in UK comes from the graphic and packaging sectors.[30]

Essentially, waste paper is picked up through roadside recycling collections, sorted, baled and transported to a paper mill for recycling. Water is added to create a pulp and the ink on the printed paper is removed by washing or flotation. Sometimes the pulp is bleached with hydrogen peroxide or chlorine. Hydrogen peroxide breaks down into water and oxygen on disposal; whereas chlorine is potentially more toxic and can combine with organic matter to produce dioxins.

## ALUMINIUM AND OTHER METALS

Aluminium drinks cans are collected by almost all local authorities, and increasingly aluminium foil, such as clean take-away meal trays, chocolate foil wrapping and cooking foil is also collected.

Aluminium is an ideal material to recycle, since it can be recycled time and time again without loss of properties, and creating a product from recycled aluminium uses only around five percent of the energy and emissions needed to make it from the raw material bauxite.

One of the world's largest 'closed-loop' aluminium drinks can recycling plants is situated in Warrington, northwest England and this turns used cans into slabs of aluminium of exactly the right specification to make new cans. Used cans can be recycled, made into new cans, filled and put back on the shelf in just six weeks.

The process involves:

- Shredding the whole cans, removing any coloured coating
- Melting the shreds in a huge furnace
- Pouring the molten metal into ingot casts to set. Each ingot can then be made into around 1.5 million new cans.

Aluminium foil is a different alloy, and is usually recycled with other aluminium scraps to make cast items such as engine components, where it makes a big contribution to making vehicles lighter and more energy efficient.

Aluminium is one of the most cost-effective materials to recycle, because of the huge energy savings of up to 95% compared to creating a new product from raw materials. Aluminium is one of the few materials that has been recycled by large industrial processes for many years, and around 75% of all the aluminium ever extracted is still in circulation.

There are two sorts of recycling used for aluminium depending on the scrap used as feedstock. New scrap generated during production and fabrication is usually totally recycled and this is termed remelting. Old scrap, recovered from articles at the end of their useful life, such as drinks cans, scrap from motor vehicles and aluminium windows, is recycled where it is economically profitable, and this is termed refining. Old scrap needs more pretreatment and is more likely to be contaminated with organic material. Most scrap is sorted and may be shredded before being baled or sent directly into a melting furnace. Preliminary cleaning should remove oils and organic coatings by heating and drying in rotary driers at temperatures high enough to vaporize or carbonize organic materials but below the melting point of aluminium (660°C) or its alloys.[31]

In its natural state, iron ore is combined with oxygen, carbon or sulphur. After mining, the ore has to be stripped in a blast furnace to reduce it to pig iron that can then be used in steel production.

According to 'waste-online' about 11 Million tonnes of iron and steel is sent to scrap every year. About 70% of this scrap is recovered, but of the remaining material, two thirds is landfilled.[32]

## WHO IS AT RISK WHEN WE RECYCLE?

Recycling primarily affects two groups of people: those who work in the recycling industry and those who are affected by the emissions or other products from recycling processes. In general the latter will be people living in close proximity to a recycling plant, although if ground water or food crops are polluted, almost anybody in the wider population can be affected.

## HEALTH IMPACTS – RECYCLING BIODEGRADABLE ORGANIC MATERIAL

Most research about the health impacts of recycling biodegradable organic material come from Europe or the USA where many processes have been mainstreamed for longer.

Huge quantities of other materials for recycling are sent from the UK to India and China, and there is limited research from these countries to provide strong evidence about the health impacts of these processes.

### WORKERS IN THE RECYCLING INDUSTRY

Recycling of waste on an industrial scale often involves physically demanding work and the use of large heavy machinery. So it is not surprising that the UK waste industry reports between 4,100 to 4,300 accidents per year, with overall accident rates at four times the national average; around 2,500 per 100,000 workers. The major accident rate is 330 per 100,000 (three times the national average) and the fatal injury rate over ten times the national average at 10 per 100,000. Sprains and handling injuries account for 85% of absences lasting longer than three days. The majority of these are caused by heavy and awkward loads or sharp objects. Fatal and major injuries are significantly related to low falls and trips, falling objects and being struck by refuse collection vehicles with around 60% of waste industry injuries being caused by transport vehicles.[33]

A review of the international literature published by Englehardt et al in 2000 summarises the main health and safety risks to waste workers as; injury and musculoskeletal problems; health effects due to exposure to significant levels of chemical and biological toxins; skin problems and both acute and chronic respiratory health effects.[34] Skin disorders are a frequent problem with one cross sectional study by Malmros et al referred to in Englehardt's review reporting a significant odds ratio for skin itching of 14.7 (95% CI 1.5-132.2) among recycling workers compared to the general public. However, the picture is changing rapidly, and the research has

not had time to catch up with the health and safety improvements including the increased use of wheelie bins and significant modifications in lifting machinery.

There have been several pieces of work examining the health of people who work in the waste industry or at recycling facilities. Many are relatively small, relate to self reported symptoms or do not control for confounding factors such as smoking or exposure to vehicle exhausts so are of limited use as evidence.

A cross sectional study of upper airway inflammation and respiratory symptoms in workers collecting domestic waste in the Netherlands found an increased prevalence of self reported respiratory symptoms.[35] This was supported by increases in inflammatory markers measured via nasal lavage. The inflammatory changes were considered to be caused by exposure to organic dust, mediated by neotrophils resulting in the respiratory symptoms. In this study 47 waste workers were compared to 15 office workers at the same plant. Numbers were relatively small and there were differences between the two groups in factors such as length of time employed, sex and smoking habit that could have acted as confounding factors.

An article by Hansen et al. (1997) reported on a cross sectional study comparing Danish waste collectors with park workers.[36] This was a larger study and concluded that waste collectors have moderately increased prevalence of several respiratory problems such as cough, itching nose, wheeze and chronic bronchitis. This study attempted to control for confounding factors and concluded that the main causes for the observed differences were probably exposure to vehicle exhaust and bioaerosols.

The health of workers at nine materials recycling facilities in England and Wales was examined and found that exposure to organic dust, endotoxins and glucans from waste is dose response related to health, and particularly to self-reported respiratory and gastrointestinal health. The analysis controlled for smoking, age and gender. The study did not show significantly elevated amounts of pollutants such as mercury or cadmium.[37,38]

A small study conducted by Gladding and Coggins in 1997 at two materials recycling facilities in the UK both of which accepted waste from private contractors and local authorities concluded that levels of respiratory symptoms were no higher in workers at the materials recycling facilities plants than control groups, although it was interesting that they did find there was a perception amongst materials recycling facilities workers that their symptoms were work-related.[39]

## COMPOST PRODUCTION AND MBT

Most of the research does not distinguish between source segregated and MBT processes and indeed the in-vessel processes are the same, so they will be discussed together here.

Most people support the notion of recycling of waste and are happy to comply, but before quality compost production can take place, separation of green and/or food waste must take place. It is often this initial sorting stage that many households find a nuisance or distasteful.[40] The most common reasons given for not participating relate to concerns about separating food waste and the potential hygiene, odour or vermin issues (24% of non-participants combined). However, these issues were considered less important by residents who were actually involved in the food waste collections (6% of participants), indicating that these are perceived issues rather than problems experienced by people who engage with this activity. An evaluation of the schemes found that provided bins were kept outside and out of the sun they did not cause any undue problems or odour.[40]

There are many potential pathogens associated with the various stages of composting. These are outlined in an Environment Agency report 'Health impact assessment of waste management: methodological aspects and information sources'.[44] The main potential source of health problems comes from the bioaerosols and the volatile organic compounds (VOCs) that are released during the composting process. Benzene is one of the common volatile organic chemicals identified in waste. From toxicological and occupational studies, it 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.[41] But VOCs are ubiquitous in the environment and there is no evidence that compost workers or those living in close proximity to a compost plant experience an increased risk of these comparatively rare problems.

Bioaerosols are particles of microbial, plant or animal origin and are often referred to as organic dust.[42] This can include live or dead bacteria, fungi, viruses, allergens, bacterial endotoxins (components of cell membranes of Gram-negative bacteria), antigens (molecules that can induce an immune response), toxins (toxins produced by microorganisms), mycotoxins (toxins produced by fungi), glucans (components of the cell wall of many moulds), pollen, plant fibres etc. However, bioaerosols exist naturally in the ambient air and their concentrations are difficult to measure, since they are affected by the external environment and vary naturally with topography, strength of the wind and season of the year. Although the presence of these materials in the air does not necessarily correlate with risk of disease, bioaerosols do have the

potential to produce health effects such as aspergillosis, hypersensitivity pneumonitis, skin complaints and exacerbation of asthma. However, the ability to cause disease depends on the concentration of viable organisms, their virulence and the susceptibility of the exposed person. A review of occupational exposure to bioaerosols concluded that there is little published evidence of serious/chronic disease in compost workers, although there is evidence of early health responses to bioaerosol exposure.[43] At high doses, or in susceptible individuals at lower doses, there is evidence of a causal link between some of the micro-organisms present in the bioaerosols and adverse effects in humans.[44] Since there is no agreed 'safe' value and information about bioaerosols is limited, the Environment Agency has adopted a precautionary approach that requires a site specific risk assessment where there is a dwelling or workplace within 250m of a composting site boundary.[45] Most research suggests that under normal conditions, beyond 250m, bioaerosol concentrations are similar to those in the background.

If the composting process is not managed properly, strong unpleasant odours can occur, but this is often categorised as a nuisance rather than a health risk. Although people living near a composting facility reported higher levels of somatic symptoms generally, the type of self reported symptoms was not influenced by odours and bioaerosol concentrations, except for nausea which was clearly linked to annoying odours.[46] However, strong odours can create the public perception that compost production is a hazardous process and this may lead to psychological distress.[44]

Several health impact assessments of composting were uncovered during this review. In most cases the evidence about negative health impacts was limited; and although positive health impacts such as ‘feelings of satisfaction’ and ‘raising awareness of environmental health issues’ were anticipated, all lacked strong scientific evidence.[47] Most research to date has been conducted on the occupational risks for waste industry workers, but many of the studies mentioned below rely on self reported health problems; are cross sectional studies, including some that have no control group for comparison so provide relatively weak evidence; or they may be biased in other ways.

One older (1997) and three relatively recent literature reviews exploring the human health impacts of composting were examined.

The 1997 work concluded that there was no information about risks to households living in close proximity to a composting facility, but none was expected. However, exposure of organic waste collectors and compost workers to bioaerosols was high and health risks may exist.[48] The (1997) report suggested the need for more work to explore possible exposure related effects and how waste collection and compost processing might be carried out to reduce potential risk.

The 2003 review conducted by Saffron and colleagues found that the association between bioaerosols and health outcomes was biologically plausible and the most important route of exposure was inhalation, but that there was insufficient evidence to link residence near a centralised composting facility with health problems.[49]

Harrison's review of 2007 found that acute and chronic respiratory health effects, mucosal membrane irritation, skin diseases and inflammatory markers were all raised in compost workers[50]. They also showed a response to elevated exposure to bioaerosols despite the fact that there was a "healthy worker" effect (compost workers' general health apart from potential compost-related illness was better than average). Harrison also found an association between the distance an individual lived to an outdoor composting facility, and respiratory symptoms and general health complaints, but not allergies or infectious disease.

The most recent review conducted by Domingo and Nadal (2008) explored human health risks in domestic waste composting facilities only, but it was less categorical about the conclusions and essentially found that information relating to occupational risks was scarce. The authors suggested adopting a precautionary approach and the development of surveillance systems for those working with compost.[51]

Examples of the specific pieces of work that these reviews depended on are considered below. Many come from the Netherlands, Denmark or Germany where recycling and industrial composting has been undertaken for considerably longer than in UK, but application of the findings to the UK should be undertaken with care, since waste collection techniques may well be dissimilar and bioaerosol concentrations in particular are known to be affected by local weather patterns.

In a double blind cross sectional study by Herr et al., self reported irritative airway complaints were associated with residency in an area with high bioaerosol exposure, and with a composting facility in the neighbourhood.[52,53] The study found that self reported health complaints such as 'waking up due to coughing' odds ratio 6.59 (95% CI 2.57 – 17.73), 'coughing on rising or during the day' odds ratio 3.18 (95% CI 1.24 – 8.36), and 'bronchitis' odds ratio 3.59 (95% CI 1.40 – 9.40), 'excessive tiredness' odds ratio 4.27 (95% CI 1.56 – 12.15), were higher in people living in areas with highest bioaerosol exposure, 150 – 200m away from a large scale composting site. The health complaints were not accompanied by increased self reports of disease diagnosed by a doctor. The model for the logistic regression included age, odour annoyance, period of residence as fixed co-variates, and additional confounders were gender, composting in own garden, collection of organic waste in the home, distance of home from a busy street, smoking, and exposure to passive smoke. The same study found that storage of organic waste indoors for more than two days was associated with skin-related complaints, and people with a history of an atopic condition (e.g. hay fever, eczema or other allergies) were at greatest risk.

Cobb et al. (1995) administered a health questionnaire to people living near a mushroom composting facility and a comparison group living further away, but no significant differences in health complaints were found.[54]

Workers at a composting facility in Denmark reported more diarrhoea than other waste workers.[55] The adjusted prevalence proportion ratio was 2.8 (95% CI 0.90 – 8.80) but results were not significant.

Another cross sectional study comparing compost workers to drinking water supply workers in Denmark found a slightly increased risk of self reported vomiting and diarrhoea with an odds ratio of 7.51 (95% CI 1.17 – 48.10).[56] Although a control group was used, several possible confounding factors were not controlled for in this study.

A similar cross sectional study in Germany found that compost workers had significantly more symptoms and disease of the airways and the skin than controls.[57] The high exposure to bioaerosols among compost workers was significantly associated with higher frequency of minor health complaints as well as higher concentrations of specific antibodies against moulds and actinomycetes. There was no control of potential confounding factors undertaken in the analysis.

The most important health problem identified that might also be a potential problem for home composters is aspergillosis, a lung disease caused by inhalation of spores of Aspergillus, a fungus that grows on dead plant or animal matter and is commonly found in compost. The Daily Telegraph headline of 12th June 2008 read 'gardener killed by fungus in his compost.' This followed publication earlier in the week of a case report 'Gardening can seriously damage your health' in the Lancet.[58] The man in the case study had opened a bag of compost and mulch which had been left to rot. Although a smoker and a welder by trade, he had previously been regarded as healthy. The man became ill 24 hours after exposure and died about a week after being admitted to hospital. This case was extraordinary, since severe illness and death only usually occurs in people with weakened immune systems or who have damaged lungs. Cases of hypersensitivity pneumonitis due to Aspergillus in compost have been reported, but again are rare.[59]

## MAIN HEALTH BENEFITS ASSOCIATED WITH COMPOST AND MBT PRODUCTION

Essentially no scientifically measurable health benefits are associated directly with composting. However, in several health impact assessments that were reviewed, it was acknowledged that separation of green waste or home composting creates a 'feel good' factor. People who engage in composting feel that they are doing their bit for the environment and this in turn increases their sense of wellbeing and health.

Many of the health benefits derived from composting come indirectly and are difficult to quantify.[8] For example, the application of compost to agricultural land increases its water holding capacity. This in turn helps to reduce the risk of flooding and saves water, both of which are clearly good for health. The use of compost in agriculture and horticulture decreases the need for artificial fertilisers, saves money and energy associated with their manufacture as well as reduces the pollution of waterways and associated health risks. The application of compost to land leads to carbon sequestration, and appears to act as a carbon sink, thereby reducing the risk of health effects associated with carbon emissions and global warming.

For home gardeners, composting is one aspect of contact with the natural environment which many believe benefits health. It is possibly easier to appreciate how a walk in the park, or the sound of birdsong could contribute to 'complete mental, physical and social wellbeing'[60] but if composting is acknowledged as an essential element in the production of sustainable green landscapes, then maybe we can 'stretch' the evidence sufficiently to include this natural recycling process. Wilson's 'biophilia' hypothesis[61] suggested that humans are innately

attracted to other living organisms and this has been expanded of late to include a bond with nature [and presumably composting] more generally.

Horticultural therapy has long been recognised as salutary.[62] It is used effectively to promote health and wellbeing in community groups, and for programmes with older people, those with disabilities and special education needs and in prison settings.[63,64,65]

Whilst this work is primarily exploring recycling and composting, the links between this and the health benefits from gardening cannot be completely ignored, because home or community composting facilitates the related physical activity and the production and increased consumption of fruit and vegetables all of which are linked to better health.[66] Researchers in the USA have shown that gardening can offer enough moderate physical activity to keep older adults healthy.[67]

Obesity and cancer rates are higher in deprived urban areas where home gardening could have greatest impact and reduce the effect of the 'food deserts'* commonly found in these areas.

School gardening and composting schemes are increasingly popular, and one study in the USA (2004) found that as well as helping to increase children's interest in eating fruit and vegetables which is linked to reducing the risk of obesity in later life, the composting of the organic waste produced a gross saving of $6,230 in disposal fees alone.[68]

The development of a school based food garden in Australia resulted in pupils showing greater attention to origins of produce (garden grown and fresh), as well as increased consumption of vegetables and fruits, and enhanced confidence in preparing fruit and vegetable snacks.[69]

* A food desert is an urban district with little or no access to foods needed to maintain a healthy diet, but often served by plenty of fast food restaurants

## HEALTH IMPACTS – INDUSTRIAL RECYCLING OF OTHER MATERIALS

Recycling happens in many ways, but the major industries operating on a commercial scale only will be examined. The health impacts of the specific processes on those who work in the industry will be considered, but many industrial recycling processes also result in pollution of the environment that may impact on human health. It is clear from researching the literature that the scientific evidence about the health impacts of these processes on the public's health is scarce. Many of the risks to human health, from chemicals such as Bisphenol A (BPA), commonly found in paper recycling facilities are hypothesised from animal experiments rather than proven.

The problem for those working in public health is what approach to take. A precautionary approach may seem the best, but communication with the public needs to be handled with a great deal of care, since there is evidence to suggest that alarming messages can actually invoke undue anxiety and cause more health problems than the exposure itself.[70] On the other hand, pollution of the wider environment exposes large numbers of people, and even when there is a relatively small increased risk, this can have serious effects. It is now accepted for example that the current decline in male fertility is related to the increased amount of oestrogenic pollutants in the general environment.[71,72] In most cases the environmental pollution and consequent health impacts resulting from recycling process are less than would occur if the products were made from raw materials.

Recycling is a growing industry that employs increasing numbers of people and contributes to economic growth. The dilemma arises, because when there is a lack of clear evidence about health impacts, is it right to stipulate the use of procedures to reduce the risk of environmental pollution if they are expensive and make the industry less competitive or possibly no longer economically viable?

### RUBBER TYRES

The development of crumb-rubber modified asphalt has led to the development of several rubber recycling industries including tyre shredding. As a relatively new industry little is known about the occupational health impacts of tyre shredding. Exposure to rubber fumes in the tyre manufacturing industry has been strongly linked with chronic and acute respiratory effects, and an increased risk of bladder, lung, laryngeal and skin cancers and leukaemia. In a study of two tyre shredding facilities in Taiwan the main health risks related to sound levels that were found to universally exceed the recommended 85db daily exposure level. As a result four workers had

suffered a loss of hearing (although it must be noted that neither plants implemented the recommended hearing procedures). Emissions of volatile organic compounds were not found to be significant although workers did complain of the rubber odour. [73]

Two studies from the USA were found that explored risks associated with the use of recycled tyre crumb which is now commonly used as an alternative to sand or woodchips in children's playgrounds.

Anderson et al (2006) reviewed the literature as well as any specific reports of health problems after parents raised concerns about exposure of children to recycled tyre crumbs in playgrounds.[74] They found no reported symptoms or adverse health effects in exposed children. They acknowledged however that the literature available on the safety and risk of exposure to crumb rubber constituents was limited and they could not quantify safe levels of exposures associated with the product. They suggested that although there were gaps in the evidence, no evidence exists suggesting harm.

Another extensive report was undertaken for the California integrated waste management board to evaluate playground surfaces for the release of chemicals that could cause toxicity in children following ingestion or dermal contact. [75] Three routes of child exposure to chemicals in the rubber were considered: ingestion of loose rubber tyre shreds; ingestion via hand-to-surface contact followed by hand-to-mouth contact and skin sensitization via dermal contact. Playground surfaces constructed from recycled tyres were also tested for their ability to attenuate fall-related impacts. The potential of these rubberized surfaces to impact on the local environment, including the local ecology, was also addressed through a discussion of the published literature. The report concluded that there was no significant increased risk in most areas. The one area where there was most uncertainty and possibly a slightly increased risk related to the chronic ingestion of rubber tyre chips by children over several years.

On the 22nd June 2009, The Ecologist reported that the US Environmental Protection Agency has launched an enquiry into the health risks of tyre chippings, following claims that government bodies were issuing contradictory advice on the safety of the tyre chippings.[27] The new report will examine whether children are at risk of either inhaling or ingesting dangerous possibly carcinogenic or mutagenic material from tyre chips.

## MAIN HEALTH BENEFITS ASSOCIATED WITH RECYCLING TYRES

Most health benefits relate to the diversion of used tyres away from more 'unhealthy' forms of disposal, such as landfill. Other health benefits mentioned above include its effectiveness in reducing the risk of injury in children's playgrounds. The California report mentioned that to achieve an adequate level of protection the tyre chips had to be laid thickly, and that most recorded injuries related to situations when manufacturer's recommendations about thickness had not been followed.[75]

## TEXTILES

There is comparatively little textile manufacture or recycling taking place in the UK. However there do not appear to be any specific health impacts of textile recycling, which tends to take place alongside primary manufacture.

## MAIN HEALTH BENEFITS ASSOCIATED WITH RECYCLING TEXTILES

Most health benefits of textile recycling relate to the diversion away from the use of potentially carcinogenic dyes and other noxious chemicals commonly used in the primary textile manufacturing industry.

## GLASS

Much of the general literature on occupational and health hazards associated with recycling cite cuts from glass breakage and handling as one of the main occupational concerns within the glass recycling industry.[34] However, a survey of local authorities undertaken by British Glass on behalf of the Waste and Resources Action Programme (WRAP) concluded that injury from broken glass did not seem to be a safety issue if the correct equipment was worn and that the main health and safety concern was repetitive strain injury due to heavy lifting.[76]

In British Columbia, (Canada) people are encouraged to return used glass bottles to the store from which they were purchased. The returned bottles are broken and stored, eventually being returned to the factory for recycling. One study found a strong association between respiratory and skin irritation symptoms and exposure to airborne particulates, since glass breaking equipment was installed in the stores. Following installation of the machines, employees complained of mucous membrane irritation, respiratory irritation, breathlessness and skin rashes. The study found that there was a significant association between breaking the bottles

and self reported respiratory symptoms and that this was most likely to be due to the fungal spores released when mouldy bottles were broken, rather than small glass particles or dust.[77]

A risk assessment undertaken by the Health and Safety Executive in 2008 found that workers involved in kerbside glass collections were likely to exceed the daily upper noise exposure limit of 85db set by the Noise at Work Regulations 2005.[78] In some cases personal noise exposure was as high as 100db. Workers who are exposed to these daily high levels of noise exposure are at risk of developing serious hearing damage. The main source of this noise tended to be through the transfer of glass to receptacles and troughs on side loader vehicles. The levels of noise exposure for each individual depended upon the amount of glass handled and the speed of working. A study in 2007 by Shanks found that simply tipping the glass slowly into a polythene lined trough could reduce noise exposure by up to 2.9 db.[79] The Health and Safety Executive (2008) recommends the use of slow-collection bins (which can reduce noise levels by 70-85%), ear protection (which will reduce noise levels to below 80-85db) and rotated work shifts to reduce the risk to workers health.

### MAIN HEALTH BENEFITS ASSOCIATED WITH RECYCLING GLASS

Most health benefits are indirect and relate to the diversion away from using raw materials and the energy intensive production of new glass. Once collected, glass recycling is highly mechanised and fully automated.

## PAPER

Most research relates to the occupational health of individuals working in the paper recycling industry rather than any pubic risk. The main health risks appear to revolve around the chemicals used to process or de-ink the paper during recycling.

Workers handling sorted cardboard and paper waste do not appear to be at any particular risk due to dust, bioaerosol and bacteria exposure provided standard protective industrial protocols are employed.[13,44]

Cancer risks were perceived to be comparatively high among paper mill workers and in 1997, a Danish study investigated the cancer risks among 5377 workers in five paper recycling plants.[80] The survey carried out on male workers found significantly more pharyngeal cancer, with seven observed cases, producing a standardised incidence ratio (SIR) of 3.33 (95% CI 1.34 to 6.87) and slightly more lung cancer in the production sector, although this was not statistically significant, with 39 observed cases and a standardised incidence ratio of 1.21, (95% CI 0.86 to 1.65). There

was also an increased risk of Hodgkin's disease among production workers, but again this was not statistically significant, with a standardised incidence ratio of 1.90 (95% CI 0.51 to 4.85). Potential confounding factors, such as smoking and alcohol intake, which can be linked to lung and pharyngeal cancer, were not accounted for.

A 2007 study of 8 workers in the UK paper recycling industry revealed two cases of occupational asthma that had only developed in the two years after aerosolised hydroxylamine was introduced in the plant to de-ink the paper. [81] The two individuals had worked at the same plant for 11 and 20 years respectively without any problem previously, suggesting (but not proving) a link between exposure and outcome.

A 1998 Croatian study on 101 workers employed in the paper recycling industry found a significantly higher prevalence of chronic respiratory symptoms in these workers compared with a similar group of control workers ($P < 0.01$). [82] A logistic regression analysis performed on chronic respiratory symptoms of paper workers indicated significant effects of smoking and exposure, with the smoking effect being the most important. Among 101 tested paper workers, 16 (15.8%) had positive skin-prick (allergy) tests to at least one of the paper extracts; none of the control workers reacted to these extracts. Increased serum immunoglobulin E (IgE) levels were found in 21% of the paper workers and in 5% of control workers ($P < 0.05$). Paper workers with positive skin-prick tests to any of the paper and/or other tested extracts had higher prevalence of chronic respiratory symptoms and lower measured lung-function tests compared with predicted than did those with negative skin-prick tests, but the differences were not statistically significant. The measured concentrations of total and respirable dust in this industry were higher than those recommended by Croatian standards. This study suggests that working in the paper-recycling industry is associated with respiratory impairment if dust is not controlled and that sensitive workers employed in this industry may be at risk of developing chronic respiratory abnormalities.

Some older studies referred to the problem of noise, but in the UK this is strictly regulated under the Noise at Work Regulations 1989.[83]

Bisphenol A (BPA) is a common chemical used in the plastic industry as well as in the production of special types of paper such as thermal paper and carbonless copy paper. BPA, in particular chlorinated and polychlorinated BPA, is widely detected in wastewater from paper recycling plants.[84,85,86]

There is limited evidence of the effects of BPA on human health. Most toxicity studies involve laboratory experiments on mice; and the effects of exposure on humans are only estimated.

The human studies that have been conducted tend to explore correlations or are based on small sample size observational studies without adequate control for any potential confounders. Since BPA products are ubiquitous in our environment attempts to observe the effect of this as single exposure are difficult. Many laboratory studies have linked BPA to endocrine disruption and reproductive system problems.[87,88,89,90] Although it does not appear to be carcinogenic on its own, BPA is thought to be oestrogenic and to increase susceptibility to prostate and breast cancers.[91,92] BPA can also induce inflammatory or allergic responses and has recently been linked to an increased risk of cardiovascular diseases and diabetes.[93]

BPA and other organic chemicals can bioaccumulate, indicating that they can be passed up the food chain to humans, but how this might happen after they are discharged in wastewater effluent is not known. The German Environmental Agency is concerned about possible risks and has recommended surveillance of BPA concentrations in and around paper recycling factories.[94]

A recent (2007) Japanese chromatography study found a range of other organic chemicals such as aryl hydrocarbons and ethers and other non-ionic surfactants in the effluents from paper recycling plants. Theoretically these chemicals can affect human health, but again the evidence is weak, and further investigations are clearly needed.[95]

A study on the effluent from an industrial paper recycling mill in China identified a range of possible toxicants, mainly heavy metals. Some of them may impact on human health or affect aquatic organisms. However, given the low concentrations of the metals detected, their impact does not appear to be significant.[96]

## MAIN HEALTH BENEFITS ASSOCIATED WITH RECYCLING PAPER

The recycling of paper saves huge quantities of carbon dioxide and trees. Forests act as carbon sinks, so the recycling of paper has significant indirect effects on health by mediating climate change.

## ALUMINIUM AND OTHER METALS

Recycling of aluminium, iron, magnesium and zinc involves melting the scrap and casting to form new ingots. The presence of even small quantities of materials such as PVC and other contaminants such as oil or grease, as well as the fluxes that are used in the recycling process provide a source of organic material and chlorine that can lead to the creation of dioxins. These are a group of chemicals that have been linked to male infertility, cancer and can cause a skin condition called chloracne.[31] Dioxins are found naturally in the environment – in the air, soil

and food, so again it is difficult to evaluate the effect of those coming from aluminium or other metal recycling, but ideally any extra exposure should be avoided, so that the total intake remains below recommended levels.

The Health and Safety Executive has released guidelines on how to minimise dioxin exposure among workers recycling aluminium, zinc, and copper and its alloys such as brass and bronze. [97].

## MAIN HEALTH BENEFITS ASSOCIATED WITH RECYCLING ALUMINIUM AND OTHER METALS

As with previous sections, the main health benefits relate to the reductions in carbon dioxide and energy used in recycling plants compared with primary production. A recent paper (2007) reviewing the environmental management of airborne metal particulate emission in the recycling industry in the USA found that ambient air quality is improving. The major hazardous air pollutants are total particulates, particulate metals and volatile organic compounds even though these are reported at low concentrations. The primary metals industry is the major source of these total bioaccumulative particulate metals in the air and metal recycling contributes to reducing these and other emissions and to reducing energy consumption by 65-95% compared to primary metal production.[98] There is a need to further reduce airborne particulate metal emissions and this can be achieved through the application of technology that has been tested in other industries. Compliance with HSE recommendations and standards should improve health and safety in the workplace.[97]

## RESEARCH GAPS AND RECOMMENDATIONS

The Landfill Directive and government policy will shift the emphasis away from landfill and towards an increase in composting and other forms of recycling as part of a more integrated waste management strategy over the next few years. To avoid undue transport and associated costs, recycling facilities need to be located in close proximity to the urban areas where the waste that feeds them is produced. This will inevitably lead to an increase in planning applications and large public consultations. The lack of research evidence about the health impacts of recycling will be problematic when public health or local authority professionals are asked for advice on planning applications. Research into risk perception to assist the understanding of people's fears and concerns will help the development of effective communication strategies and encourage informed debate and acceptance of composting and other recycling facilities.

Local authorities and public health professionals will need to work hard to win the hearts and minds of their communities to encourage more households to separate waste materials for collection and/or engage in home composting.[99] Better evidence about the health benefits of recycling to underpin these appeals will undoubtedly help this struggle.

Clinical and environmental health disciplines to date have tended to address the same question: Is there an association between exposure and outcome? Despite having a sixty year old definition that endorses health as a positive concept, a resource for life and 'not merely the absence of disease,' the research agenda has remained firmly fixed and focused on disease outcomes caused by potentially unhealthy exposures. "Research and teaching … have centred on the hazardous effects of various environmental exposures, such as toxic chemicals, radiation and biological and physical agents … However some kinds of environmental exposures may have positive health effects. As we learn more about the health benefits of contact with the natural world, we need to apply this knowledge in ways that directly enhance the health of the public."[100] If we are to achieve the levels of recycling required to reach government targets and ameliorate the effects of climate change, research to support positive messages about the health benefits of recycling is urgently needed.

Since an independent review by the National Consumer Council in 2006 established its effectiveness, the use of a social marketing approach to encourage healthy behaviour has become a key feature of government policy and is now widespread.[101] Social marketing is an adaptable approach used to achieve and sustain behaviour goals on a range of social issues and would be an ideal approach to employ to encourage recycling. One of the problems that local

authorities face is the need to change the image of recycling from something that eccentric individual do (and local authorities and public health professionals encourage), to it being a regular, normal activity that everyone can and should do as much as possible.

Social marketing for health uses traditional marketing strategies to tailor a campaign to identified needs. The key to good marketing is finding out what the customer wants or values, and might be prepared to offer in exchange. Research to gain insight into the barriers and motivating factors for different sections of the public and to inform social marketing approaches to recycling is needed.

For example, there is a growing interest in organic gardening, and several schools in the UK are participating in gardening (which includes composting) in an attempt to tackle the growing obesity crisis. This not only provides physical activity, but also education about the nature of food and where it comes from. Very few of these schemes have been going long enough to be able to say with any certainty that they can create sustainable behaviour change in physical activity and eating habits. So there is a clear need for better evaluation to improve the quality of evidence for health impact assessments or social marketing programmes.

Obesity levels in children are rising and are a great cause for concern. [102] It is interesting to note that in the USA, Candice Shoemaker recently received a $1.04 million grant from the U.S. Department of Agriculture's National Research Institute to study whether gardening [including composting], particularly in schools can promote a healthier lifestyle and combat childhood obesity. Is something similar needed for recycling in the UK?

Planners also have a role and can encourage more sustainable local food production, and encourage home and community gardens. It would be useful to explore how public land, could be used for gardening and composting activities and thereby contribute to improving the public's health.[103]

There have been interesting and very successful developments in some of the large cities of India and Bangladesh, relating to the decentralised composting of urban organic waste.[104,105] In both cases, communities took responsibility for the collection and composting of green waste, and were able to sell the compost that was produced. The benefits included community control and therefore acceptance, reduced need for transportation of waste, increased local employment and a small financial profit. Key to the success of both schemes was municipal support and in the case of Bangladesh, approval from the Bangladesh Agricultural Research Council, and policy support from the Ministry of Agriculture. Would there be any benefit in exploring the possibility of setting up similar small scale schemes in the UK?

## USEFUL WEB SITES

www.defra.gov.uk/environment/waste/index.htm

www.environment-agency.gov.uk/business/topics/waste/35411.aspx

www.wrap.org.uk/composting/

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