Final Report

Scoping study of potential health effects of fortnightly residual waste collection and related changes to domestic waste systems

This report presents a review of international research into waste collections commissioned by WRAP and the Chartered Institution of Wastes Management (CIWM). The report's findings have confirmed existing advice for councils and householders on avoiding risks to public health. No evidence was found that changing to a fortnightly collection creates risks that cannot be dealt with by following the good practice guidance already available.

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

CIWM is a non profit-making organisation dedicated to the promotion of professional competence amongst waste managers.

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Written by: Dr. Toni Gladding, Integrated Waste Systems, Open University

Front cover photography: Waste Operative pushes a garden waste wheelie bin towards collection lorry

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1.0 Introduction

The Open University was commissioned to undertake a scoping study regarding fortnightly collection of waste by the Chartered Institution of Wastes Management (CIWM) and the Waste & Resources Action Programme (WRAP). Input and advice was provided by Cranfield University and Enviros Consulting Ltd. during the formulation of this report.

By its very nature, waste collection has the propensity to cause adverse health impacts if not properly managed. The purpose of this study was to identify the range of potential health impacts that could be associated with fortnightly waste collections, evaluate existing scientific knowledge, establish if there are any gaps that require further study and identify good practice in the mitigation of known risks. The format of the report is a thorough literature review of published information, followed by an evaluation of the information to provide the conclusions of the report and offer recommendations for further research based on the findings.

This scoping study was not intended to reproduce earlier work funded by Defra on fortnightly collection as part of the Waste Implementation Programme (Defra 2007b). This work was intended to expand the original literature search regarding public health issues and specifically to include potential occupational health issues.

1.1 Background

Fortnightly waste collection schemes are defined, for the purposes of this report, as schemes which collect **residual** waste fortnightly. This is the key defining feature of such schemes. Beyond this there are many variations including how this key feature interacts with other collection services provided, such as those for dry recyclables, garden waste and food waste.

The concept of limiting residual waste collection capacity is that it will encourage recycling and composting by restricting the ease with which recyclables can enter residual waste disposal routes, as long as this is done in tandem with facilitating recycling opportunities for householders (WRAP 2007). As a result, there may be reductions in vehicles and staff required to collect residual waste, but with concurrent investment in recycling programmes this should not lead to a reduction in total collection capacity for the householder (WRAP 2007). Residual waste capacity can be restricted whilst retaining weekly collections by limiting numbers of sacks or reducing the size of bin provided. One of the reasons that many councils have opted for fortnightly collection of waste is that they already have 240 litre wheeled bins in place and thus changing the collection frequency is seen as the simplest approach.

European Landfill Directive targets are driving a reduction in the amount of biodegradable waste that is sent to landfill, and statutory recycling targets have been set by Defra (2007a) in the English Waste Strategy published in May 2007 (from 40% by 2010 to 50% by 2020). Therefore local authorities are exploring a range of approaches to improve their recycling rates. Additionally, the EU Waste Framework Directive requires separate collection of paper, glass, metals and plastic by 2015 where this is technically, environmentally and economically practicable (Defra 2008). Hence it is clear that collection systems throughout the UK will be required to adapt to these requirements in the future if they have not yet done so.

The introduction of fortnightly collection schemes has been shown to significantly improve recycling rates, providing they are well designed and implemented. As of March 2009, 216 out of 434 UK waste collection authorities were using fortnightly collections. All of the 20 statistically highest performing authorities in England in 2007/08 were using fortnightly collection. The Best Value Performance Indicator (BVPI) for combined recycling and composting rates of these authorities ranged from 45.08% to 51.72% (Defra 2007a). Some of these headline figures can be misleading without detailed analysis and the mechanisms responsible for improvement are not always clear. It could be due to the operational aspects of the system, the information, guidance and publicity that accompany the change in collection scheme, or an increase in the range of materials collected. However, the effect is generally to improve the participation, set out and capture rates and it is now clear that capacity is a key driver – restricting the capacity for residual waste whilst enhancing the capacity for diversion.

1.2 The Scoping Study

This research is intended to explore the potential impacts that could be associated with the switch to fortnightly collection of residual waste and may need further research. A number of nuisances have been reported in relation to fortnightly collection and it has been implied that these nuisances could represent a public health hazard. Some reports have also suggested potential increased occupational risks to waste collectors.

Whilst there is no direct evidence of actual ill health arising from a change in service frequency, the possibility has not been separately researched. Given the increase in fortnightly collection schemes throughout the UK then, if there appear to be risks, either to the public or occupationally to collectors, these need to be identified and managed.

The majority of the concerns raised about fortnightly collection schemes focus on the extended storage of wastes that contain an organic fraction, e.g. garden and food wastes, and on residual wastes that are collected fortnightly, particularly where food wastes are not separately collected on a weekly basis.

There are also important occupational issues to be understood. Bomel (2004) estimated that some 43,000 workers were working mainly as collectors in local authorities, with evidence that some crews can service up to 7,000 properties in a weekly round. This report also estimated that a further 9,000 jobs in waste collection would be created to meet national recycling targets between 2004 and 2010. In the latest Bomel report (2009), this data had been further refined, with 61,955 waste-related employees being reported in the public sector. Although the number of collectors has not been updated, an 11.6% increase in employment is reported from 2005 to 2007 across the industry as a whole, from around 176,452 to around 196,920.

Given the nature of the work, collectors are likely to have greater exposure to a wider range of potential risks than householders. Therefore, one of the aims of this work is to examine the published literature to determine if there are studies relating to occupational risks and fortnightly collection, to evaluate any data and to identify any areas that require further research.

2.0 Literature Review

In 2007, a Defra–funded report included a thorough literature review as part of a broader study looking at the public health impacts of fortnightly collection of biodegradable waste (Defra 2007b). It is not intended to repeat the previous review here. This scoping study targets relevant papers identified in the initial review, and also examines additional papers containing information on potential public health risks and occupational health and safety.

Relevant papers are individually summarised in Appendix 1 Tables A1.1 to A1.7 and are listed in date order, to reflect the progression of the research with time (all articles are also listed alphabetically in the bibliography).

2.1 Odour

There is a large amount of scientific literature examining odours at waste treatment facilities, but this is not reviewed here as the odour generation and exposure characteristics will be very different to those related to the storage and collection of household waste at the kerbside.

Odour consists of a complex mix of chemicals in gaseous form that can be detected by the olfactory sensors of the nose. In waste management, production of odours is linked to microbial decomposition of the organic fraction (Ivens et al 1997, Mayrhofer et al 2006), although packaging materials and household products such as detergents have also been associated with odour in kerbside waste containers (Statheropoulos et al 2005).

Within this mix are volatile organic compounds (VOCs). VOCs are organic compounds which easily vaporise in normal atmospheric conditions. Typical odorous compounds including VOCs which are associated with waste include chloro-organics, hydrogen sulphide (rotten eggs), mercaptans (rotten vegetation e.g. cabbage) and amines (fishy smells) (Wilkins 1997, Gostelow et al 2003). In kerbside waste containers, high levels of alkanes, alkylbenzenes and terpenes have been reported as being responsible for undesirable odours (Statheropoulos et al 2005). However, there is little evidence linking odours to actual health outcomes.

In terms of frequency, offensive odours from residual wastes and breakdown of organic materials have been reported as an issue in fortnightly collection of waste (Gellens et al 1995). The 2007 Defra-funded study on fortnightly collection of biodegradable waste reported that the perception that odour is linked to adverse health outcomes may influence the tolerance of householders to change in collection frequency. This study also indicated that more odours may be experienced by householders on a fortnightly collection scheme, particularly in summer (the study reported an OR of 3.45, which means the experience of odour was three and a half times more likely with a fortnightly scheme) (Defra 2007b). Defra (2007b) also reported that collectors noticed an increase in odours on introduction of fortnightly collection from garden waste bins and from percolate (liquid) produced by compressing waste, but did not investigate whether this was linked to health effects.

Many studies report that odours produced by waste were offensive (Kamiya et al 1984, Krajewski et al 2002, Mayrhofer et al 2006). A few also investigated production of odorous compounds in relation to time, e.g. simulating a 14 day collection cycle (Nielsen et al 1998, Heldal et al 2001, Mayrhofer et al 2006). These determined that VOCs generally peaked at one week whilst other compounds such as ammonia continued to increase over a 14 day storage period. Weather (temperature) and storage conditions were also found to affect odour production (Statheropoulos et al 2005, Mayrhofer et al 2006). Overall, the research indicates that some compounds may diminish between 7 and 14 days, but that others will continue to increase. However, in all cases this will depend on storage conditions and temperature.

Human response to odours is highly subjective; different people find different odours offensive, and at different concentrations (Gostelow et al 2003). Odours are also quite difficult to quantify as they consist of many different individual components and the complex mix cannot be easily predicted (Gostelow et al 2003). There is a large body of research indicating that, where odour is present, there is an associated perception that health risks are increased. Some authors report that individuals may develop an odour hypersensitivity that is not accompanied by an enhanced ability to discriminate different odours (van Thriel et al 2008) and that if an odour is perceived as a 'negative' odour, it is more likely to be associated with health effects than a 'positive' odour (Smeets et al 2008). Indeed, it has also been reported that individuals may ascribe health symptoms (which they may be experiencing) to odour even when none would be expected based on toxicological dose-effect relationships (Bulsing et al 2009).

On the subject of waste containers, various studies have identified the production of odours from the breakdown of organic materials during storage (Kamiya et al 1984, Wilkins et al 1996, Nielsen et al 1998, Leach et al 1999, Statheropoulos et al 2005). This has been linked to sulphur and organosulphide compounds (Kamiya et al 1984, Wilkins et al 1996, Leach et al 1999), a variety of other VOCs including alkanes, alkylbenzenes and terpenes (Leach et al 1999, Statheropoulos et al 2005), and ammonia (Nielsen et al 1998, Heldal et al 2001).

In terms of occupational health effects, Wilkins et al (1996) suggested that mucous membrane irritation and nausea could be linked to odorous compounds produced by garden wastes, and in a later paper linked organic sulphur compounds to gastrointestinal problems in waste collectors (Wilkins 1997). Ivens et al (1997) related gastrointestinal symptoms to odours in questionnaires on waste collectors. Kiviranta et al (1999) found small amounts of VOCs when carrying out personal sampling within the breathing zone of waste collectors (330 $\mu g/m^3$). However, this was thought to be related to vehicle exhaust exposure during general collection and is not linked to collection frequency. This paper quoted a comfort range of < 200 $\mu g/m^3$, with a range of 200-3,000 $\mu g/m^3$ for when airways-related symptoms might occur. Krajewski et al (2002), meanwhile, found no occupational symptoms in relation to odour.

2.1.1 Odour: Summary of Research

2.1.1.1 Householders

Increased odours are linked to longer storage of waste (Kamiya *et al* 1984, Nielsen *et al* 1998, Heldal *et al* 2001, Defra 2007b). However, only a minority of odorous compounds appear to increase consistently with longer storage (Nielsen *et al* 1998, Heldal *et al* 2001, Mayrhofer *et al* 2006).

There are no specific studies on whether odour and VOC production are linked or whether any odorous compounds have elicited health effects in householders. Although many may exceed the odour threshold and hence be detectable, there is no clear evidence linking these to health outcomes, particularly given the transient exposure likely to be experienced. However, the perception that unpleasant odours are linked to adverse health outcomes is reported (Bulsing *et al* 2009, Defra 2007b, Smeets *et al* 2008, van Thriel *et al* 2008) and, in some cases, storage and temperature conditions can result in odours that could represent a nuisance, particularly given the types of odorous compounds that have been found in waste containers (Statheropoulos *et al* 2005).

2.1.1.2 Occupational

In terms of occupational issues, some studies have reported that odorous compounds are linked to possible health outcomes, particularly gastrointestinal symptoms in collectors (Wilkins *et al* 1997, Ivens *et al* 1997). As some VOCs have been shown to increase with longer waste storage intervals (Kamiya *et al* 1984, Nielsen *et al* 1998, Heldal *et al* 2001, Defra 2007b), it is possible that in waste collectors a cumulative effect may occur e.g. over time from several hundred containers. These issues would benefit from further research to investigate odour concentrations and health outcomes and, as a precautionary measure, should be considered in an occupational risk assessment.

2.2 Rodents and Other Vermin

Rodents and other vermin, as well as birds such as seagulls, are known disease vectors. However, there are many factors that affect vermin populations and very few studies have been carried out on the direct relationship between rodents and vermin and waste collection activities.

Poor waste management practices and public health issues regarding vermin have been generally discussed (Pond 1968, Mayr 1983, Milke 2004), as has the presence of rodents and vermin on landfill sites: Mikkonen *et al* (2005), for example, comments on rat proliferation and parasites on a landfill site and Cook *et al* (2008) reports on seagulls and their association with landfill sites. Birds, such as gulls, have been reported as potential carriers of *Escherichia coli* O157 (albeit intermittently in samples from a single landfill site) (Wallace *et al* 1997). Mayoral *et al* (2005) examined rat prevalence during home composting and found no increase of rodents with backyard composting in Spain.

In the absence of any more specific literature, Defra (2007b) outlines various health issues associated with rats, and reviews rats in waste management, in particular the issues associated with rats in composting facilities and landfill sites (in many cases, these were old landfill sites before modern engineering controls).

Sharp (2007) reports an increase in the UK rat population of up to 39% since 1998, a trend that is identified as being independent of improved standards of human living. The study speculates that the increase may be related to bird feeding and possibly to composting if the process is carried out inappropriately. It also speculates that fortnightly collection of residual waste may be a contributory factor. However, in a local authority context, Quirk (2007) reports a review of rat complaints within a borough after the introduction of fortnightly collection using wheeled bins, and no higher prevalence was found. Defra (2007b) also surveyed waste collectors after the introduction of fortnightly collection and reported that no increase in rodents was seen. There are no similar reviews or reports relating to other vermin such as birds.

2.2.1 Rodents and Other Vermin: Summary of Research

2.2.1.1 Householders

There are no studies that specifically link particular collection methods or frequency to the proliferation of rats (and/or other vermin such as birds) or assess the risks of any health impacts on householders. As observed by Defra (2007b), many factors may impact on rat populations, e.g. property condition, drains etc. and it is difficult to single out any particular factor such as waste collection. However, issues such as bad storage practice may have an impact.

2.2.1.2 Occupational

There are also no studies assessing potential health impact from rats and other vermin for waste collection workers. However, a good risk assessment should include good hygiene practices as this will take the possibility into account.

2.3 Flies

One of the most commonly reported issues associated with fortnightly collection appears to be flies and maggots. There are several species of fly that are associated with breakdown of organic materials, including the house fly (*Musca domestica*), blowflies (e.g. bluebottles *Calliphora vomitoria* and green bottles *Phaenicia sericata*) and fruit flies (*Drosophila spp*.). As well as being a nuisance, flies can be a vector for bacterial transmission and can be associated with pathogens that cause disease in humans and animals. A review of flies, their role in the environment and their potential as carriers of disease, was previously published by Defra (2007b) and will not be re-visited in great detail here.

In terms of public health, there are several publications in the literature relating to the relationship between flies and waste management. One of the first was published in 1967 by the Ministry of Housing and Local Government (MHLG 1967). This publication states that flies and waste are a public health issue, and that household refuse is a breeding place for flies. Flies were regarded as potential disease vectors with the potential to breed in dustbins all year round. MHLG (1967) reported that in the summer flies become mature adults in two to three weeks, though blowflies could take as little as nine days. From seven to twelve days they were thought to migrate from their food (i.e. the waste). Therefore, weekly collection of general waste was recommended, with cleaning of bins if necessary. With regard to separated food wastes, the publication stated that in exceptional circumstances blowfly larvae may become fully grown and seek to migrate only three days after eggs are laid. The study concluded that if a bin is full or the inside wall moist, then flies would find no difficulty in escaping, and a twice weekly collection was recommended for this type of material, alongside research into fly control and storage hygiene. These recommendations should be seen in the context of the poor containment practices prevalent at that time. Containment is much improved in modern society.

The principles of the MHLG (1967) reasoning for a weekly collection were revisited by IWM in a 1997 publication on collection, where it stated that weekly waste collection was established to take into account the life cycle of the fly. A later update (IWM 2000) reported that the collection frequency for residual waste had in some cases changed to 14 days to take recycling services into consideration, as well as changes in the weight and volume of materials.

Flies as a problem in household food waste storage were also reported by Gellens *et al* (1995) as part of a fortnightly 'biowaste' collection system. In a study looking at fly populations associated with landfill and composting sites, Goulson *et al* (1999) indicated that adult flies may have emerged prior to waste being delivered to waste sites on a fortnightly cycle. Diggleman *et al* (2003) reported that changing frequency of collection generated nuisance complaints regarding flies, and Goulson *et al* (2005) also reported that warmer weather could increase numbers and hence nuisance. Defra (2007b) identified several studies that highlight household waste as an important breeding medium for houseflies, sometimes even in tightly closed waste containers. Ali *et al* (2007) demonstrated a 13 day lifecycle in initial trials using wheeled bins containing a 'typical waste content' and stored outside. This mimicked common storage and collection conditions but without mitigation measures being taken.

In terms of health, Mayr (1983) and Rozendaal (1997) identified flies as disease carriers associated with waste. Nazni *et al* (2005) indicated that flies moving from waste to food areas made them a candidate for disease transmission. Boadi *et al* (2005) linked poor waste storage in the home with fly populations and childhood diarrhoea.

In Brazil, a study associated the spread of *Aedes aegypti* (the mosquito) to poor waste collection practices (Medronho *et al* 2009), and recommended regular waste collection to control the spread of disease (in particular dengue which is found in the tropics). Obviously, conditions such as weather and frequency of collection are very different to the UK, but this study does illustrate the importance of correctly storing waste materials.

2.3.1 Flies – Summary of Research

2.3.1.1 Householders

It is clear from the published literature that household waste is a breeding medium for flies, and that the nuisance to householders is potentially greater on a fortnightly residual waste collection compared to a weekly collection due to the 7-14 day lifecycle.

While there is no clear evidence of actual health impacts, flies are disease vectors and are linked to the transmission of microorganisms from waste material to food areas, a potential risk that could be exacerbated if fly populations increased. However, this would depend on storage and hygiene as much as collection frequency, particularly whether mitigating measures, such as wrapping food waste and keeping containers clean, are followed (Cox 1999, Defra 2007b).

2.3.1.2 Occupational

Although there are various studies examining flies at waste sites (Imai 1986, Goulson *et al* 1999, Howard 2001, Lole 2005), there appears to be very little information and a lack of research regarding the potential occupational health impacts associated with waste collection and flies or maggots. However, this does not preclude a precautionary approach, particularly regarding hygiene, and provision of an occupational risk assessment taking this information into account.

2.4 Microorganisms in waste

Microorganisms will grow on any material where there is sufficient supply of nutrients and water, their role being to aid the breakdown of organic materials, including those that end up in the household waste stream.

As the organic materials break down, a wide range of yeasts, fungi and bacteria species may be present, and it should be noted that the composition of food waste material e.g. whether cooked, whether containing meats etc. is very different from raw and plant-based materials which may be composted in the garden. Typically, fungal growth is linked to species such as *Penicillium* spp. or *Aspergillus* spp., often seen as a blue/green fluffy mould. The various bacterial food spoilage microorganisms that are likely to be present include pathogenic bacteria such as *E. coli* O157:H7, *Campylobacter*, and *Salmonella*, and, potentially, *Clostridium botulinum.*

In terms of public health, these microoganisms could be an issue where organic wastes, particularly separated and cooked food wastes containing animal proteins (e.g. meat, fish and dairy) are stored at or above room temperature (if the container is in the sun, for instance) for an extended period. It is likely that various moulds and food spoilage bacteria will multiply on such material, which, if left uncovered, could in turn be handled and accidentally ingested. In addition, spores could also potentially be inhaled (inhalation will be dealt with in the section on bioaerosols).

An informal small scale survey of 102 UK households using food waste containers (Blenkharn 2007) found that only 23 of 89 respondents washed their hands everytime after handling the container, 53 admitted to infrequent washing and 12 never washed their hands. An increase in foodborne infection with the introduction of food waste recycling was also reported. Although a very small snapshot, this does indicate the potential for cross contamination and risk of ingestion to the householder, and the importance of education when introducing such a scheme.

There are also issues to consider with regard to the presence of mycotoxins from mould growth in older wastes. Mycotoxins are secondary metabolites produced by fungi. They are toxic and are known to occur in areas such as grain storage, and therefore have limits imposed in terms of ingestion and food. The European Food Safety Authority (EFSA), for example, has imposed limits for mycotoxins such as ochratoxin A, which is known to be produced by *Aspergillus* spp. and *Penicillium* spp. These fungi grow with poor food storage, e.g. in damp conditions and ochratoxin A is thought to be a potent renal toxin (EFSA 2006). Rundberget *et al* (2004) found that mycotoxins were present in food wastes from private households as a result of *Penicillium spp*. mould growth in the order of 10^5 colony-forming units of Penicillium per gram of sample. Previous studies have also demonstrated that a wide range of food spoilage microorganisms and toxic metabolites will grow on vegetable material as it breaks down (Tournas 2005).

Tremorgenic mycotoxins, meanwhile, have been linked particularly to 'fermented meats' (Sabatar-Vilar *et al* 2003). Tremorgenic mycotoxins cause muscle tremors and convulsions and have been associated with illness and death in pets if ingestion of mouldy foods has taken place (Boysen *et al* 2002, Naudé *et al* 2002, Walter 2002). However, there are no studies on incidental exposure and the risk to humans from handling mouldy food wastes.

Finally, the issue of viral contamination also needs to be considered. Some vaccines, such as the oral polio vaccination, utilise the live virus for immunisation (polio injections utilise the dead version of the virus and do not carry the same risk). Primomo *et al* (1990) reported that some 100 enteric viruses are excreted in human faeces, including hepatitis and polio. They went on to state that viruses can live for months 'creating risks to both sanitation workers and contamination of groundwater in landfills'. Indeed, there are reported cases of individuals who are not immunised contracting polio from nappies six weeks after vaccination (Mauel *et al* 1998). There is a potential risk that a susceptible individual, e.g. a waste collector with no immunisation, could come into accidental contact with this material if adequate hygiene measures are not followed. The change from weekly to fortnightly collection would not significantly affect the risks posed by viral contamination.

2.4.1 Microorganisms in Waste: Summary of Research

2.4.1.1 Householders

The literature review has shown that there are few studies on hand-to-mouth exposure to microoganisms linked to household waste, to food waste in the kitchen or to frequency of collection. It is likely that this type of exposure is rare, as such material is usually disposed of prior to or in the early stages of decomposition, is subsequently contained and is not extensively handled by the householder after storage within the waste container. However, evidence suggests that householders may not always wash their hands if contact with this material occurs and, if hygiene practices are poor, there remains a small possibility of hand-to-mouth contact and potential ingestion of pathogenic bacteria and moulds and their metabolites. There is also a small potential risk factor where unintended contact with the material may occur, e.g. for pets and children.

2.4.1.2 Occupational

The potential risk of incidental exposure is multiplied for the waste collector, particularly if hygiene measures are not adequately followed. The occupational health impact risks of the incidental handling of mouldy food wastes, in particular animal proteins, has not been researched, and there remains the possibility of accidental consumption of mouldy food remnants if poor hygiene practices are followed. This unintended exposure could lead to illness, and the risk may be increased with longer storage of wastes containing a biodegradable component as a result of fortnightly collection. There also remains a potential risk factor related to hand-to-mouth viral contamination linked to vaccination, but this is not related to collection frequency.

2.5 Airborne Dust and Bioaerosols

Bioaerosols have many components, and can be airborne solid or liquid particles of biological origin, which may contain microorganisms ranging in size from 0.5 to 100+ microns (adapted from Cox & Wathes 1995). They may be present as clumps, aggregates or as single cells, all of which may or may not be attached to particles of other material. As outlined in section 2.4, microorganism growth is associated with waste due to the breakdown of the organic fraction within the waste stream. These become bioaerosols once aerosolised, usually as a component of dust, although direct correlations between concentrations of dust and bioaerosol components are not always found (Gladding *et al* 2003).

The risk of exposure to aerosolised dust and therefore to bioaerosols is a growing research area within waste management. The potential health implications of bioaerosols in relation to waste have been acknowledged for some time (Pahren 1987). The composition of bioaerosols released from waste facilities has been previously discussed by Swan *et al* (2003) and Defra (2007b) amongst others, and they have been found to contain (but are not limited to) bacteria and fungi (viable e.g. live and dead), endotoxins and glucans (cellular wall components with toxicological properties), viruses, yeasts, and also, potentially, secondary metabolites including mycotoxins.

In terms of direct health effects, little research has been carried out to establish 'safe' levels of bioaerosols to which an individual can be exposed, and Wheeler *et al* (2001) observed that the dose-response relationships remain unclear. This is partly due to the fact that there are many different species of viable (live) bioaerosols, but also because there are many components, such as endotoxins, glucans and mycotoxins that can have immunotoxic effects. Bioaerosols and their components have been linked to infection (via pathogens in viable microorganisms), allergic type reactions, such as mucous membrane irritations, respiratory complaints such as chronic bronchitis and asthma, and skin irritations. They have also been linked to systemic toxic effects, with the term 'Organic Dust Toxic Syndrome' referring to exposure to certain components such as endotoxins and glucans and specific effects such as fever, chills, headaches, excessive tiredness and flu-like symptoms that resolve on removal from exposure (Swan *et al* 2003, Gladding *et al* 2003).

In considering the potential health impacts, however, it should be remembered that bioaerosols are present constantly in the air around us. It is important, therefore, to comment on exposure concentrations. Measurement of bioaerosols is often carried out by monitoring for the presence of viable microorganisms (bacteria and fungi), which are quantified as colony forming units based on their ability to grow in the laboratory (expressed as cfu/m^3).

For environmental exposure from waste sites, Wheeler *et al* (2001) used a conservative concentration of 1000 cfu/m^3 for bacteria and fungi (100 cfu/m^3 for *A. fumigatus*), which is effectively a 'no-observed effect level' or NOEL. A NOEL is a concentration at which no observable health effects are found in an exposed versus an unexposed population. These concentrations were also further reviewed and agreed with by Swan *et al* (2003) in a report for the Health and Safety Executive.

However, given that natural concentrations could be regularly expected to exceed this, that farming regularly generates concentrations in excess of this (Swan *et al* 2003), and that these NOELs are not supported by dose-response data, they can serve as a guideline only. Indeed, the Environment Agency, in its guidance on particulates emitted from waste facilities in 2004, took a risk-based approach rather than imposing emission standards on facilities that may not have a solid scientific basis (M17, Environment Agency 2004). The latest guidance (Environment Agency 2009) restates 1000 cfu/m^3 for bacteria and 500 cfu/m^3 for *A. fumigatus*, based on the latest information on background values. These concentrations are, however, to be elicited using an agreed standardised method for measuring their concentrations (AfOR 2009).

In terms of occupational health, Lavoie *et al* (1997) proposes a conservative concentration of 10^4 cfu/m^3 as a guidance level for waste management facilities, based on a review of the literature by a variety of authors, but again this is not supported by dose-response data. The Danish Working Environment Service proposed that levels in excess of 1 x 10^6-10^9 cfu/m^3 could cause respiratory problems (Wurtz 1996) and Lacey *et al* (1994) reports that concentrations of viable microorganisms above 10^6 cfu/m^3 have been linked to hypersensitivity pneumonitis (allergic alveolitis) complaints, e.g. Farmers' Lung.

In terms of other bioaerosol components, such as endotoxins, the Dutch Expert Committee on Environmental Standards proposed a health-based occupational exposure limit of 50 EU/m^3 (it should be noted 'EU' are Endotoxin Units which are used to measure the lipopolysaccharide action of endotoxin; as an approximation, 10 EUs equal 1 ng). This was later revised to a temporary legally binding limit of 200 EU/m^3 due to feasibility difficulties when meeting the lower limit (the economic effects of meeting this standard were prohibitive for industry) (Douwes *et al* 2003, Spaan *et al* 2008). However, it has had a history of review and has recently been reported as being due for further revision (Spaan *et al* 2008).

Dose-response relationships of bioaerosols, focusing specifically on waste management, have been further reviewed in a Defra-funded study (Searl 2009), which looked at dust, bacteria, fungi, endotoxin and glucans. The study found that bioaerosol concentrations are typically below 1000 cfu/m^3 for viable bacteria/general fungi and 1 EUm^3 for endotoxin at background. It also reported difficulties in determining clear threshold levels of effect for different bioaerosol components due to individual susceptibility, previous sensitisation and the fact that many studies were on varied human populations which had a range of different parameters to take into consideration. Other authors have also commented that the difficulty with setting limits for bioaerosols is due to personal susceptibility and individual exposure settings, which result in non-consistent health effects (Liebers *et al* 2008).

Searl (2009) identified that perhaps up to 10% of the population could belong to a particularly sensitive sub-group, for example atopic individuals (with a history of allergy or asthma), those with cystic fibrosis and transplant and cancer patients. However, no specific risks were identified for the elderly or children and the study concluded there was insufficient information to set bioaerosol 'limits' for exposure, and that a 'best practice' approach should prevail (Searl 2009). However, it is clear from other research that consistently high concentrations in an occupational context can elicit health effects (Lacey *et al* 1994, Swan *et al* 2003, Gladding *et al* 2003, Wouters *et al* 2006, Lavoie *et al* 2006).

Focusing specifically on waste management, there are many studies investigating dust and bioaerosols. This review focuses on those where householders and waste collectors were considered within the scope of the study, unless a finding at a waste facility was directly relevant.

For householders, there are a few studies examining the potential effects of storage of materials for separate collection. For instance, van Yperen *et al* (1997) indicated that the separation of 'garden waste' could be a risk factor for householders and Weinrich *et al* (1999) reported that fungi and other microorganisms develop within a few hours of storage of such material. Wouters *et al* (2000) measured microorganisms in homes storing separated organic materials (such as fruit, vegetables and food remnants) and found higher counts in the home if the waste was stored for more than one week. From this, the study concluded that susceptible individuals could be at a higher risk if this occurred. Two papers by Herr *et al* (2004) indicated that longer (over 2 days) storage of separated organic waste (the composition of which was not defined, other than it was 'separated from other household waste') indoors could cause issues with skin problems and allergies, and linked complaints of irritated airways to higher bioaerosol exposure.

It should be noted that the general scientific literature cites that moulds should not be allowed to grow unchecked in the home (Hardin *et al* 2003), as their presence is likely to sensitize and produce allergic responses in some individuals. However, metabolites of moulds (e.g. mycotoxins) have been found in cultures of *Aspergillus* spp. in decomposing organic wastes at composting facilities (Fischer *et al* 1999, Fischer *et al* 2000) and also in food wastes from the home (Rundberget *et al* 2004) and old meat material (Sabatar-Vilar *et al* 2003). These demonstrate that exposure to mycotoxins is possible if waste food material is stored for prolonged periods in the home and becomes mouldy. However, for mycotoxins it has been reported that a toxic dose via the inhalation route is highly unlikely, even for vulnerable sub-populations (Hardin *et al* 2003). Other studies have stated that inhalation of mycotoxins is not related to proven human health effects (Nordness *et al* 2003). Indeed, Fischer *et al* (1999) found that colony counts would need to exceed 10^7 conidia/m^3 (a fungal component) to detect such compounds. A later paper acknowledges that this may be an issue in highly contaminated environments only (Fischer *et al* 2003). Additionally, a toxicological study found that there was an inefficiency of delivery of mycotoxins via inhaled spores, and suggests extremely high concentrations of spores and exposure would be needed to elicit a response (Kelman *et al* 2004).

Searl (2009) commented on the fact that the potential for exposure of waste collectors to bioaerosols and biologically-active liquid leachate might increase due to separating out food and green waste materials. This might require different handling options to traditional waste collection.

In summary, despite the possibility of cumulative exposure in collectors, there are no current studies linking inhalation of mycotoxin compounds with proven health effects. It should be noted, however, that longer lower level exposure has been investigated in relation to growth of *Stachybotrys chartarum* and mycotoxins in damp homes and linked to respiratory and related symptoms (Pestka *et al* 2007).

The impact of the type of containers used to store waste externally has also been investigated. Moulds are often reported as being present in waste containers, particularly linked to the presence of organic materials (Weinrich *et al* 1999, Reiss 1995, Defra 2007b). Closed containers have been linked with 'percolate', that is a wet residue laden with bioaerosols (Malmros *et al* 1993, Breum *et al* 1997), and higher exposures (Heldal *et al* 1997, Heldal *et al* 2001). Conversely, paper sacks and open containers are reported as being dustier, which can also be linked to higher exposure (Breum *et al* 1997, Smedlund 1999). Therefore, there appears to be no decisive indication of which type of container (paper or enclosed plastic) would result in lower bioaerosol concentrations.

In terms of collection frequency, van Yperen (1997) suggested that older waste may be a risk factor for waste collectors and the presence of *Aspergillus fumigatus* (a pathogen) has been thought to be linked to fortnightly collection (Martens *et al* 1999). Neumann *et al* (2002) reported they found lower concentrations of fungi in a weekly collection. The amount of 'percolate' generated has been found to be unaffected by storage over one or two weeks (Nielsen *et al* 1994 and 1998), but endotoxins and fungal concentrations have been found to be higher with a fortnightly collection of organic materials (Ivens *et al* 1999, Lavoie *et al* 2002, Lavoie *et al* 2006). Ryckeboer *et al* (2003) indicated that microorganisms in organic materials within bins may be at their highest 27 days after deposition. The same paper also found that yeast and fungi were not present in the thermophilic phase which was dominated by bacteria. Interestingly, bacterial concentrations were found to be higher in bins after one week rather than two (Haughey *et al* 2006) and another study found exposure levels of dust and endotoxin for waste collectors to be higher in weekly collection rather than fortnightly (Wouters *et al* 2006). This research could indicate an initial colonisation by bacteria of the organic materials (within a residual fraction or as a separated garden waste collection) in a container, changing to a larger population of fungi by the second week. This is supported by Neumann *et al* (2002), which found that fungi concentrations were lower with a one week collection interval.

In some studies, weather conditions were thought to be important, with Weinrich *et al* (1999) reporting that the intensity of mould spore emissions correlates closely with climatic conditions. Additionally, waste collectors have been shown to experience higher bacterial concentrations in summer (Nielsen *et al* 1997, Thorn 2001, Neumann *et al* 2002, Nielsen *et al* 2000, Widmeier *et al* 2007).

In terms of occupational impacts and collection, there are several studies demonstrating concentrations of bioaerosols of 10^4 cfu/m^3 and above of viable microorganisms, and endotoxins or glucans in excess of 10 EU/m^3 (Kiviranta *et al* 1999, Neumann *et al* 1999, Neumann *et al* 2002, Lavoie *et al* 2002, Krajewski *et al* 2002, Heldal *et al* 2004, Lavoie *et al* 2006). Some studies link exposure to the type of job carried out, where waste loaders experience higher concentrations than drivers (Nielsen *et al* 1995). Type of collection vehicle has also been investigated and higher level loaders and automated side loaders have been found to reduce exposure (Nielsen *et al* 1997, Neumann *et al* 2005, Lavoie *et al* 2006). Neumann *et al* (2005) specifically investigated vehicle design and refuse collection and determined that some vehicles may generate more bioaerosols than others, e.g. rotating drum compaction produced higher fungal counts than packer plate compaction. Additionally, a hinged lid and remote lifting required a suction effect to produce a positive effect in reducing exposure, and a higher rave rail height was recommended to assist this (2m rather than 1.4m in current standards).

Vehicle cleanliness has also been investigated. Lavoie *et al* (2002) reported that cleaning of a truck in isolation appears to make little difference to exposure, with no significant difference in the fungi found in a 'dirty' vs. 'clean' truck. They concluded the main source of bioaerosols was waste type, particularly the 'leachate' generated by organic materials, although it was recognised if trucks were allowed to dry completely before use this may be beneficial. Neumann *et al* (2005) in a study on weekly residual waste collection reported that cleaning of the vehicle at intervals of not more than 14 days was recommended as it was found that if this was not carried out, a recognisable mat of fungi formed in the guide plate area and on the sides of the lifting device, and higher bioaerosol exposures were associated with vehicles cleaned less often.

However, independent of job or vehicle design, type of waste is the most often reported factor regarding waste collection and exposure to bioaerosols, with garden waste often generating the most concern (Breum *et al* 1996, Heldal *et al* 1997, van Yperen *et al* 1997, Nielsen *et al* 1997, Thorn 2001, Lavoie *et al* 2002, Lavoie *et al* 2006, de Meer *et al* 2007).

In a summary of the research in this area, Wouters *et al* (2006) reported that exposure to waste collectors was determined by task (e.g. driver or loader) and collection regime, which were more important than the truck, container or waste composition. Collection techniques and collection frequency were closely linked and hence discriminating factors could not be discerned. In a further review of these studies, Searl (2009) concluded the factors affecting worker exposure during waste collection may include vehicle design, domestic waste storage arrangements and collection regime, and that delay should be minimised between collection and treatment.

In terms of health, a number of studies have investigated a range of symptoms experienced by waste collectors and have linked these to bioaerosol exposure. These include gastrointestinal complaints such as diarrhoea and nausea (Malmros *et al* 1993, Ivens *et al* 1997, Thorn *et al* 1998, Ivens *et al* 1999), and systemic effects such as tiredness and fever (Malmros *et al* 1993, Heldal *et al* 2004). Respiratory symptoms were often reported (Hansen *et al* 1997, Allmers *et al* 2000, Yang *et al* 2001, Issever *et al* 2002, Wouters *et al* 2002, Heldal *et al* 2003a and 2003b, Steiner *et al* 2005), particularly in susceptible individuals (de Meer 2007). Weinrich *et al* (1999) also reports that immunocompromised individuals should not handle organic waste, but that it is harmless to healthy individuals. More recently, it has been reported that higher concentrations of actinomycetes and moulds, rather than endotoxin, are more likely to play a role in health effects, such as mucous membrane irritation, linked to bioaerosol exposure in compost workers. These could be relevant to green waste collection (Liebers *et al* 2008).

Regarding specific issues, Allmers *et al* (2000) reported a case of Aspergillosis in a waste collector associated with the separate collection of organic waste. Heldal *et al* (2003b) found a link between exposure and recruitment of neutrophils (white blood cells linked to inflammation) and swelling in the nasal mucosa in waste collectors. Interestingly, Müller *et al* (2006) found exposure of healthy, previously unexposed volunteers to compost facility dust increased neutrophils. Recruitment of neutrophils and inflammation has also been shown in waste recycling workers by Gladding *et al* (2003).

Other studies, however, have reported that there are no significant health complaints in collectors (Bunger *et al* 2000 in organic waste collection on a two week schedule, Widmeier *et al* 2007 in general waste collection). However, in the Bunger *et al* (2000) study the 'healthy worker selection' effect was thought to be in operation, where more hardy workers stayed in the industry and those that became unwell left. Liebers *et al* (2008) also commented that work-related studies of endotoxin exposure are complicated by the 'healthy worker effect' and some workers may, in fact, develop a tolerance.

Steiner *et al* (2003) found no prevalence of asthma or lung disease in general waste collectors, but found their health was potentially poorer than the general population. For example, 50% were hypertensive and many smoked or were overweight. In a later study, no relationship was found between bioaerosol exposure in waste collection workers and markers of lung epithelial injury (CC16) or effects on respiratory health, though it should be noted low exposure to bioaerosols in waste water workers was linked to 'sub-clinical' toxic pneumonitis (Steiner *et al* 2005). Perez *et al* (2006) indicates there are no definite conclusions regarding exposure and health effects in waste management and that further research is needed in this group.

In terms of potential airborne viral contamination, very few studies have been carried out. Enteroviruses have been reported in air samples from a waste management facility (Pfirrmann *et al* 1994) but were not linked to actual health outcomes.

2.5.1 Airborne Dust and Bioaerosols: Summary of Research

2.5.1.1 Householders

In summary, in terms of bioaerosols the main exposure risk for householders is related to separated organic materials (presumed to be fruit, vegetable peelings and food waste), storage time, storage conditions (temperature) and the type of storage container in the home. Therefore, longer term indoor storage of such wastes – over two days (Herr *et al* 2004) or longer than one week (Wouters *et al* 2000) – to the point of mould growth (which may be container and/or temperature dependent) should be avoided. Searl (2009) stated that waste collection regimes could affect the exposure of the public to bioaerosols, and that emissions indoors can be minimised by ensuring that waste is stored in closed containers that are kept in cool conditions. External storage of organic materials and/or residual wastes does not appear to represent a similar risk factor for the householder. The research does indicate, however, that even indoors, it is unlikely that toxic metabolites such as mycotoxins represent a respiratory risk.

2.5.1.2 Occupational

For collectors, the presence of organic materials appears to drive the likely bioaerosol exposure. This has been recognised by existing HSE guidance on garden waste collection and potential risks to health (Health and Safety Executive 2007). A longer storage interval associated with further fungal growth appears to be linked with potential for higher exposures to endotoxins and fungi in collectors. Indeed, Wouters *et al* (2006) and Searl (2009) both agree that collection regime/technique and interval are amongst the most important factors regarding exposure to waste collectors.

From this literature review, other issues that appear to be significant include handling (e.g. how a vehicle is loaded which may include vehicle design), truck cleanliness where there is visible mould growth, and also time of year, with summer showing higher exposures. A variety of symptoms and effects on the immune system have also been demonstrated in collectors. These are not dependent particularly on frequency, but do appear to be linked to the separate collection of organic materials, a practice that often accompanies a change to fortnightly collection of residual waste. There do not appear to be any specific studies on the collection of residual waste on a fortnightly basis or the collection of separated food wastes.

Other issues such as type of container do not appear to be a significant factor, though it should be noted that paper bags were shown to produce dustier material and enclosed containers resulted in 'percolate', although neither appear to be particularly time dependent. Finally, no particular concern was demonstrated for airborne viruses or mycotoxins which are unlilkely to easily become airborne in significant concentrations.

2.6 Other issues associated with fortnightly waste collection

It is recognised that waste collection is a relatively hazardous occupation. The Bomel (2004) report for the Health and Safety Executive (HSE) highlighted that the waste industry has an accident rate of five times the national average at 2,500 per 100,000 in 2001/02. Indeed, Bomel (2004) points out that waste collection is responsible for the highest number of accidents in the waste industry and this has not changed in updated figures. Waste collection is still identified as the activity within waste management that generates most accidents and is the most risky over a ten year period covered by both Bomel reports (Bomel 2004, Bomel 2009). The 2009 report also highlighted that the accident rate was falling, but still had an injury rate of 2,207 reportable injuries per 100,000 workers. This is still more than four times the 'all industry average' rate of 518. It is also more than twice the reported injury rates for the manufacturing industries and construction. The majority of these are related to weight and lifting, or slips and trips, and the serious accidents and fatalities are related to vehicles and traffic.

High risk of accidents has been reported many times in scientific research (Cimino 1975, Gellin 1985, Malmros 1990, Poulsen *et al* 1995, Ivens *et al* 1998, An *et al* 1999, Englehardt *et al* 2003, Bomel 2004, Bomel 2009). Indeed, in the period 1993-1998, the Working Environment Service in Denmark initiated a five year programme to investigate the risks associated with waste collection and with changing practices as recycling initiatives became more common. This programme was entitled CORE (Waste Collection and Recycling) (Jonsson 1996). It is from this initiative that many of the Danish papers outlined in Appendix 1 originate (e.g. Poulsen *et al* 1995, Wilkins *et al* 1996, Wilkins 1997, Breum *et al* 1997 (both papers) etc.).

These health and safety concerns have been recognised by the CIWM, which commissioned a report to determine ways in which this could be improved (Entec 2007). The European Agency for Health and Safety at Work (2007) has also identified waste collectors as an 'at risk' group which may be exposed to various bioaerosols, toxic components, mycotoxins and oncogens and that an ongoing expansion in the industry will increase the numbers that are potentially exposed.

In terms of specific occupational health impacts, as early as 1970 Gellin theorised that these workers were a high-risk group, and reported that dog and rat bites, and bee and wasp stings were an occupational hazard. In terms of general waste collection, Krajewski *et al* (2003) reported that workers regarded noise, dustiness, odour, physical effort and changeable atmospheric conditions as the most strenuous factors in their jobs. Englehardt *et al.* (2003) identified that municipal solid waste workers were exposed to more occupational health and safety risks than workers in many other industries and reported that waste collectors are susceptible to musculoskeletal injuries due to the amounts of waste they handle per day. Englehardt also reported collectors are also exposed to sharp objects, glass, razors, bioaerosols, infectious materials and volatile compounds. They suffer from a variety of respiratory and gastrointestinal insults and are subject to extremes in temperature and humidity. More recently, Anjos *et al* (2007) reported that waste collection consisted of walking, running and lifting variable weight loads whilst under stress due to traffic and the public. This article reported the physiological workload placed on waste collection workers can be excessive, with demands placed on the collector similar to an athlete in training. However, these risks exist whether a collection is weekly or fortnightly.

The possibility of a range of health effects in general waste collection has been raised several times (Malmros 1990, Gladding 1993, Poulsen *et al* 1995, Ferreira *et al* 2001, Rogers *et al* 2002), including exposure to diesel exhausts (Malmros 1990, Poulsen *et al* 1995). More recently, RPS (2008) indicated that waste collectors are exposed to carbon monoxide, carbon dioxide, nitrogen oxides, particulate matter, dioxins, PAHs and VOCs, as well as bioaerosols and noise from refuse collection vehicles. General gastrointestinal problems (discussed earlier) were highlighted by Kuijer *et al* (2004) and lung function/respiratory issues by Zuskin *et al* (1996) and An *et al* (1999). A single article highlighted the risk of testicular cancer in waste workers due to degrading polymers (Dumble 1998). Additionally, hearing issues have also been highlighted by British Glass (2002) for separate collection of glass, and even with general waste collection (Kuijer *et al* 2004).

It must be noted that the majority of the studies identified did not specifically link these potential health impacts to any particular collection frequency. However, one area where collection scheme design and frequency could have potential manual handling impacts relates to the redistribution of the waste into different containers for the purpose of increasing and improving recycling. Musculoskeletal impacts linked to handling during general waste collection and recycling schemes are highlighted in a number of studies (Malmros 1990, Gladding 1993, Dorevitch 2001, Yang *et al* 2001, Rushton 2003). The HSE has produced several publications regarding handling issues, in part related to new recycling initiatives (Pinder *et al* 2002, Oxley *et al* 2006). Kiviranta *et al* (1999) reported that workers were most concerned about heavy containers and poor accessibility causing musculoskeletal issues rather than potential exposure to dusts and health.

The impact on householders related to handling different containers and container weights also needs consideration. Pinder *et al* (2002) make reference to fortnightly collection increasing the weight of containers. Gladding (1993) highlighted that the choice of container and where it is stored or placed for collection may be issues that affect the householder and recommended that risk assessments of new schemes for separate collection of recyclables be implemented.

2.6.1 Other issues: Summary of Research

2.6.1.1 Householders

Additional potential issues identified for householders may be related to type and weight of containers in a fortnightly collection scheme.

2.6.1.2 Occupational

This section has demonstrated that waste collection is a physically demanding occupation with known hazardous components and an existing high accident rate. The issue is whether fortnightly collection of residual wastes changes these existing risks significantly, e.g. with material weight or container design and currently there are no published studies on this particular issue. Limited research exists on collection of waste, containers (Pinder *et al* 2002) and material types (British Glass 2002), with some risks identified.

2.7 Combined Occupational Exposures

In terms of the perception that odours can be associated with exposure to bioaerosols, the literature review does not provide any evidence of a relationship in terms of waste management. Swan *et al* (2003) noted that the dispersion behaviour of odorous compounds is different from bioaerosols and, although there may be the assumption that a detectable odour is synonymous with exposure to bioaerosols, this is not necessarily the case.

Wilkins (1997) suggests that odour and VOC concentrations may show a more direct relationship to waste collection activities; Kiviranta *et al* (1999) reports that the risk of exposure to VOCS and airborne microorganisms will be higher due to working outdoors in close proximity to vehicles. Proximity to the collection vehicle may also expose workers to diesel exhaust particles (DEP), which may be drawn into vehicle cabs through open windows, doors or inefficient cab filters (Malmros 1990). DEP is known to cause irritation of the upper respiratory tract (Scheepers and Bos 1992) and it has been recognised that this may contribute to health risks for waste handlers, both on its own and as an immunostimulant (Poulsen *et al* 1995). Previous studies on waste collectors have demonstrated exposure to VOCs from vehicle exhausts (Kiviranta *et al* 1999) and have indicated that, due to the increased respiratory rate during collection (25-40 l/min instead of the normal 6 l/min), particles may travel further down the respiratory tract. Indeed, various studies have emphasised the physical demands on waste collectors which would increase respiration (Anjos *et al* 2007, various Canadian studies) and hence potential exposure.

Some in vitro and animal model studies (Dong *et al* 1996, Yang *et al* 1999) have also indicated that there may be an adjuvant effect (increased response of the immune system) of DEP on pulmonary inflammation response, caused by exposure to endotoxins. Higgins *et al* (2000) demonstrated that an increase in aeroallogens (such as spores) in combination with a high ozone exposure could potentiate (worsen) bronchial hyperactivity in susceptible individuals. Liebers *et al* (2008) also comment that further research is needed regarding synergistic effects of endotoxin and other environmental factors. As endotoxins and DEP may both be present together in the air in the vicinity of collectors, a combined effect from the two respiratory insults may be possible. Recent research has also illustrated that asthmatics may be particularly susceptible to diesel exhaust particulates (Zhang *et al* 2009), hence the health status of the worker may also affect outcomes.

The possibility of 'mixed' exposures related to skin problems were first identified by Gellin (1970), Gellin (1985), and latterly by Dorevitch *et al* (2001). However, for collectors, the additional issues regarding combined exposures relate mainly to VOCs/odours, diesel exhaust and bioaerosols. These exposures may be exacerbated due to the physical demands of the job and potentially by any existing health conditions a worker may have. There is little published literature in this area of joint exposures (occupationally or environmentally).

There is relatively little research on the potential for mixed exposures to increase health risks for waste collectors. This is an area where further research would be useful to inform occupational risk assessments and health and safety practices.

2.8 Occupational research into waste collection and recycling in Canada

Since the early 1990s, there has been a significant body of research on waste management and health issues in Quebec, Canada. This research has been carried out by the Institut de recherche Robert-Suavé en santé et en sécurité du travail (IRSST), an organisation that has been established, in Quebec, since 1980.

As in the UK, research is linked to priority needs and the most important problems. One such problem has been identified as waste collection and recycling, and this coincides with another important identified area, namely bioaerosols in the workplace. The main projects related to waste collection are outlined below (undertaken between 1992 to the present day):

- 090-009 : Reduction of hazards associated with domestic waste collection;
- 099-187 : Study of the biological agents and ergonomic risks involved when trucks with articulated arms are used for household waste collection;
- RR-077 : Accident hazards associated with domestic waste collection;
- 099-383 : Optimal layout of trucks with articulated arms for household waste collection;
- 098-057 : Control of garbage collectors' exposure to bioaerosols; and
- 097-123 : Research on protective equipment used by domestic waste collectors.

This list is not exhaustive, but it does illustrate the importance given to this priority area. This has led to a number of publications and reports regarding waste and/or bioaerosols, including:

- Initial review of waste collection (Bourdouxhe *et al* 1993);
- Scientific papers published on waste collection and fortnightly collection (Lavoie *et al* 2002, Lavoie *et al* 2006);
- Summary paper on utilising trucks with articulated arms for municipal waste collection (Lavoie 2007);
- Papers published on materials recovery facilities (MRFs) and recycling and a technical guide on prevention of occupational health and safety risks in MRFs (Lavoie *et al* 2005);
- Technical guide on bioaerosols in the workplace (Goyer *et al* 2003); and
- Technical guide on respiratory protection against bioaerosols (Lavoie *et al* 2007).

Only those in relation to collection are shown below. Several of the more important conclusions are already reported in the literature review, but more detail is added regarding the whole research programme below.

The physical hazards of waste collection have been extensively researched by IRSST. One such project investigated the risk of accidents in waste collectors (Bourdouxhe *et al* 1993). Identified themes ranged from working in traffic, to 'efficiency' scenarios that assumed waste collectors were involved in a task and finish type operation. It was identified that different areas had such different ways of collecting material that every situation may well be different. The IRSST also investigated whether the 'behaviour of the waste generator' may affect worker health. Significant risks were found with:

- amount of work per collector, 500 collections and walking 11km per day with frequent mounts and dismounts, riding on platforms over a period of 6-9 hours);
- the diversity and weight of objects collected (many very heavy or potentially hazardous);
- climatic conditions (frozen bins and bins in large snow drifts);
- nature of objects transported (wet paper bags containing green materials that tear);
- problems related to use of public thoroughfares (pavement quality, traffic, behaviour of the public);
- different vehicles (side/top loading);
- personal protective equipment (particularly boots and demands made on the feet);
- work organisation (task and finish scenarios); and
- residents' behaviour (hiding hazardous items for instance).

Indeed, the report highlighted that 8 out of 10 collectors would be injured once per year. These mainly included back or shoulder pain, slips and trips, crushing injuries and cuts. Workers also reported abuse by residents and residents' frustration tended to be focused on the collectors. Major recommendations included management of health and safety, training, reviews of work organisation, review of vehicles, management of the generators of the material and reviewing how contracts were awarded (Bourdouxhe *et al* 1993).

IRSST have also extensively researched exposure to bioaerosols, with papers related to waste collection discussed earlier in the literature review section (Lavoie *et al* 2002, Lavoie *et al* 2006). In the 2002 paper, it was reported that an empty but dirty truck did not affect the exposure of collectors (who were experiencing up to 10^4 cfu/m^3 of bacteria and fungi, and 100 EU/m^3 of endotoxins), but that the liquid produced by organic materials was one of the main issues with regards to bioaerosol exposure. Emphasis in the conclusions of this paper was that certain types of waste collected could increase bioaerosol exposure, particularly during summer months. It concluded that increasing the frequency of collection of compostable material and implementing strong hygiene measures were needed to reduce risk of exposure (Lavoie *et al* 2002).

In a later paper, Lavoie *et al* (2006) reported that the highest personal exposures to bacteria were observed for urban compostable waste collectors (median = 50,300 CFU/m^3) but fungal counts collected on an 'every-other-week cycle' were highest among a group of rural compostable waste collectors (median = 101,700 CFU/m^3). Warm temperatures (24-30°C) and longer time intervals were thought to be 'worse case scenario' conditions. This paper was extensively reported in the UK press during April 2007 as potentially highlighting increased risks to collectors during fortnightly collection (for example, Sunday Times, April 2007).

Since this research, IRSST (Lavoie 2007) has investigated the mechanisation of collection to reduce such exposures. Trucks that automatically 'grab' wheeled bins by use of a guiding camera and empty into a hopper behind the cab without the worker having to come into contact with either the container or waste have been designed. Again, the worst conditions are assumed to be in summer, with maximum temperatures and number of days before collection. It was found that trucks with mechanised arms significantly reduced such exposures (endotoxins reduced to 50% of guidelines) (Lavoie 2007). It also reduced accident risks by 91% (Lavoie 2007). However, issues remained with cleaning and maintenance and 'side waste' which were addressed by improving truck design and implementing certain work procedures (Lavoie 2007). Hence this system is seen as an improvement, as waste collectors no longer have to leave the truck and accidents are reduced, as well as respiratory and skin exposure. Clearly, such a vehicle would reduce the risk of exposure and accidents to waste collectors, but unfortunately requires a large amount of space in which to operate; in Canada, the vehicle is utilised in suburbs with little parking. It may, therefore, be of limited use in the UK.

In summary, an ongoing programme of research studies by IRSST had identified a number of concerns regarding waste collection, both regarding accidents and injury as well as potential for ill-health. In terms of accidents, 'task and finish' scenarios and risk from residents were highlighted. In terms of bioaerosols, of particular concern was collection of organic materials on a fortnightly basis during the summer months (comprising of garden waste). In conjunction with collection interval, summer temperatures of up to 30°C (averaging at 25°C in July/August, whereas the UK averages at around 20°C according to www.metoffice.gov.uk data) were thought to be one of the main reasons this occurred. As a result, moves have been made to remove collectors from the potential source of exposure where possible, including promoting trucks with articulated arms. However, in all of the publications presented, the importance of health and safety management has been highlighted, particularly in relation to hygiene.

Clearly some of these issues are specific to Quebec: frozen bins in winter and very hot temperatures in summer for instance. However, there are also many similarities, e.g. Bomel (2004 and 2009) identified many similar concerns in terms of accident hazards (traffic, task and finish operations). There are also many lessons which authorities in the UK can consider, such as the impact of fortnightly collection of putrescible materials in warmer weather and the provision of adequate containers and guidance to reduce any potential risks.

2.9 Summary of literature review

The results of the literature review indicate that there is much less research targeted specifically at the collection of waste than there is at waste management facilities. Of those studies that have taken place, there are many different variables that could have affected the results but these are often not clearly defined, e.g. storage arrangements, frequency, type of container, composition of the material collected, type of collection vehicle, etc. It is, therefore, difficult to draw definitive conclusions regarding fortnightly residual waste collection and any potential impacts or risks from the literature alone.

However, the literature review has highlighted several potential issues. Those related to householders are summarised below:

- the potential for fly/odour nuisance;
- the potential risks associated with allowing mould growth on separated organic material if stored in the home;
- a small possibility of incidental hand-to-mouth ingestion of microorganisms due to poor hygiene; and
- possible handling concerns regarding the type and weight of container.

In summary, the review has demonstrated that, in general terms, householder risk is little changed from traditional waste collection, where hygiene, container type and storage have always been important. Fortnightly collection may introduce a requirement to store separated organic and residual wastes with an organic content for a longer period than previously, but as with traditional waste collection it is how and where they are stored that is the issue. Much of the potential increase in risk is relatively easily mitigated by wrapping and storage care, e.g. regularly taking organic materials to outside containers. If good practice is not followed, this can lead to nuisance issues such as flies and odour and a potential increase in the risk of microorganism transmission. There is evidence that a change in nuisance levels can elicit feelings of increased risk in householders, and these findings illustrate the importance of good communication and guidance for householders on good storage practice when introducing such a scheme.

The review has also confirmed that general waste collection is a high risk occupation irrespective of frequency of collection. Depending on collection scheme design and frequency, collectors could potentially be at an increased risk from cumulative exposure to:

- VOCs and odours;
- bioaerosols linked to separated organic waste collection;
- ingestion of microorganisms and their components; and
- handling impacts related to increased weight of containers.

There is more evidence relating to separated organic materials than to collection frequency. It appears that some of these issues are also more prominent in summer and there is obviously an important hygiene component to the ingestion risk. There is also evidence that combined exposure to exhaust emissions and the bioaerosols generated by organic materials may increase risk. However, what is not clear from the literature is whether a change in collection frequency substantially alters existing risks associated with waste storage and collection.

3.0 Recommendations for future research needs

Many of the papers reviewed related to general waste collection or separation of the green waste component. Although some extrapolations can be made from this data, it is clear that there are some gaps in knowledge that would benefit from further research.

In terms of risks to householders, further research in the following areas is recommended:

- how to effectively communicate good practice regarding the storage of food waste in the home; and
- the relationship between bioaerosol species and residence time in containers, e.g. bacterial vs. fungal populations over time.

In terms of risks to collectors, further research in the following areas is recommended:

- assessment of bioaerosol exposure and related health outcomes in those waste collectors who operate food waste collections and fortnightly garden waste collections, incorporating seasonal factors;
- mycotoxins associated with waste and risk of transmission for collectors;
- cumulative issues regarding odour and health effects for collectors; and
- the potential for mixed exposures to increase the health risks for collectors.

The lack of information in these areas should not preclude a precautionary approach with regards to any change in collection scheme design or frequency, which should be covered by revised risk assessments.

4.0 Guidance for Local Authorities

It has long been recognised that waste collection and disposal activities can be hazardous and result in potential health issues. These issues can be addressed if local authorities ensure that a thorough risk assessment has been undertaken and appropriate hygiene measures and guidance are in place to ensure that good practice is followed.

The potential health impacts that are flagged up in this report, whether for weekly or fortnightly collection, are concerns that a local authority and collection contractor should be specifically considering as part of its risk assessment process. Areas highlighted by this research include:

- adequate risk assessment regarding inhalation of bioaerosols and mitigation measures where separated organic material is collected (this has already been recognised by the HSE which has produced separate guidance on green waste collection (HSE 2007);
- enforcement of strict hygiene measures for collectors;
- an updated assessment in respect of the weights of containers being handled; and
- specific guidance to householders on the storage of separated organic waste in the home.

It should also be stressed that a risk assessment must be undertaken for each activity and that risk assessments need to be reviewed if operational methods change. It is also important to take into account the existing health of waste collectors when undertaking a risk assessment.

It should also be noted that, if a contractor is carrying out collection on behalf of the local authority, the authority retains a responsibility for ensuring that health and safety matters are appropriately managed.

5.0 Guidance concerning mitigation

Extensive guidance is available to local authorities operating fortnightly waste collections; (WRAP 2007) and the Defra (2007b) reports outline various mitigation measures to limit nuisance to the householder and potential health impacts related to the collector. In terms of the communications and advice given by local authorities to residents, it is worth reiterating the main points here:

- keep containers outdoors;
- wrap food waste;
- advise the householder to maintain hygiene of the container through washing and/or disinfecting;
- ensure a container with a tight-fitting lid is used for organic materials;
- place paper within the bin to soak up wet residues;
- keep containers lidded and closed for organic materials; and
- store waste out of direct sunlight.

For householders, mitigation measures should be focused on containers and storage arrangements; the likelihood of odours and transmission of disease by vectors such as flies can be significantly reduced if organic wastes are wrapped and food in the home is always covered.

The key process for the mitigation of risk to the workforce is the risk assessment process. Risk assessments need to be undertaken for each activity and need to be reviewed when methods change. A starting point may be to consider each of the categories highlighted in this report within the context of the planned programme, and then to consider how each of these could be mitigated. Suggestions for mitigation measures include:

- consideration of vehicle and container design at programme inception;
- guidance for householders on storage and presentation of the materials to be collected;
- removing workers from the potential exposure where possible e.g. mechanisation of lifting and emptying;
- adequate information and training for workers, particularly regarding hygiene risks and truck cleanliness; and
- personal protective equipment (PPE) provision where necessary.

PPE should not be considered in isolation, and should only be considered after all other measures have been taken. The effects of wearing PPE should, themselves, be assessed. For instance, basic paper dust masks will not be adequate for screening out bioaerosols. Additionally, cleaning a truck could in turn increase risk of bioaerosol exposure to workers if carried out without an adequate assessment. The risk assessment process should always be undertaken by competent persons who understand the range of issues involved.

Finally, whatever collection arrangements are in place and whatever mitigation measures are adopted, the importance of a good quality communications programme explaining the scheme and providing clear advice and contact details cannot be over-emphasised.

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Appendices

Table A1 Odour

Author(s)	Publication details	Relevance	Comments
Kamiya A., Ose Y., (1984)	Study of odorous compounds produced by putrefaction of foods. V. Fatty Acids, sulphur compounds and amines. *Journal of Chromatography* 292, 383-391	Collector	An investigation was made of the relationship between odour and odorous compounds in solid waste. A variety of foods were kept separately in polyethylene bottles at 23°C for three months and chemical analyses of the headspace gas and leachate were performed at regular intervals. In addition, the offensive odours were characterised by sensory tests. It was found that fatty acids and sulphur compounds were the main components producing the offensive odour of domestic waste.
Gellens V., Boelens J., Verstraete W. (1995)*	Source separation, selective collection and in reactor digestion of biowaste. *Antonie Van Leeuwenhoek* 67(1):79-89	Householder	Compares weekly and fortnightly collection of biodegradable waste. Odour problems reported. Including paper waste helps to overcome these problems.
Wilkins C.K., Larsen K. (1996)	Volatile organic compounds from garden waste. *Chemosphere* 32:10, 2049-2055	Collector	About 170 compounds were identified in the headspace or liquid exudate from garden waste. Typical for microbiological growth were branched and straight chain alcohols, carboxylic acids and esters C_2–C_8. Several of the substances have been identified in early studies of compost. For some waste samples the organosulfur compound concentration (C_1 and C_3 mono-, di- and trisulfides) was ca. 10 mg/m^3 which suggests that these substances may contribute to mucous membrane irritation or nausea reported by waste collection personnel.
Wilkins C.K. (1997)	Gaseous organic emissions from various types of household waste. *Ann. Agric. Environ. Med.* 4, 87-89	Collector	Closed 'garbage cans' or containers could contain concentrations of organic sulphur compounds, which could contribute to gastrointestinal problems in collection personnel.
Ivens U.I., EbbehØj N., Poulsen O.M., Skov T. (1997)	Season, equipment, and job function related to gastrointestinal problems in waste collectors. *Occup Environ Med.* 54(12):861-7	Collectors	Denmark. Questionnaires on collectors. Reported symptoms of gastrointestinal problems linked to rotting organic waste smells. More prevalent in waste loaders and during summer. Blamed on microbial compounds released during breakdown.
Nielsen B.H., Wűrtz H., Breum N.O. (1998)	Microorganisms and endotoxins in stored biowaste percolate and aerosols. *Waste Man & Res* 16, 2:150-159	Container Frequency	Simulated closed containers of waste. Maximum emission of hydrogen sulphide and methyl mercaptan after one week of storage, whilst concentrations of ammonia increased throughout the two week storage period.
Heldal K.K., Breum N.O., Nielsen B.H., Wilkins K. (2001)	Experimental generation of organic dust from compostable household waste. *Waste Manag Res* 19(2):98-107	Container Frequency	Different storage systems evaluated over 14 days for organic wastes simulating collection frequency. Aerated containers lost more weight (39%) over closed containers (9%). Ammonia increased in both systems to 140ppm - higher at 14 than seven days and was still increasing.

Krajewski J.A., Tarkowski S., Cyprowski M., Szarapinska-Kwaszewska J., Dudkiewicz B. (2002)	Occupational exposure to organic dust associated with municipal waste collection and management. *Int J Occup Med Environ health* 15(3):289-301	Collector exposure	Repugnant odour but no claim of occupationally related symptoms.
Leach, J., Blanch A.; Bianchi A.C. (1999)	Volatile organic compounds in an urban airborne environment adjacent to a municipal incinerator, waste collection centre and sewage treatment plant. *Atmosp Environ* 33, 4309–25	Collector	Most abundant VOC classes consisted of aromatic, chlorinated and organosulphide compounds, with smaller proportions of alkanes, alkenes and cycloalkane compounds contributing to odour.
Statheropoulos M., Agapiou A., Pallis G. (2005)	A study of volatile organic compounds evolved in urban waste disposal bins. *Atmospheric Environment* 39 4639–4645	Collector	(VOCs) evolved in urban waste disposal bins in different situations. High levels of alkanes, alkylbenzenes and terpenes responsible for undesirable odours. Variety and concentration of VOCs depends on conditions e.g. time of waste exposure, load and weather. Claimed waste could accumulate in bins with some compounds exceeding olfactory and safety thresholds representing a source of potential health impact.
Mayrhofer S., Mikoviny T.,Waldhuber S., Wagner A.O., Innerebner G., Franke-Whittle I.H., Märk T.D., Hansel A., Insam H. (2006)	Microbial community related to volatile organic compound (VOC) emission in household biowaste. *Environmental Microbiology* 8(11), 1960–1974	Container	Austria. From point of view that microorganisms generate nuisance odours (VOCs), measured over 16 days. Found high temps (40°C) and relationship between certain microorganisms and emission patterns. Intention to find ways of reducing these organisms and so odour. Highest cell counts to seven days decreasing by day 16.

Articles on odour from various waste sites not included as evaluated as not relevant.

Table A2 Rodents/Vermin

Author(s)	Publication details	Relevance	Comments
Pond M.A. (1968)	Role of the Public Health Service in housing and urban life. *Public Health Reports* 83(2), 101-107	Householder	General public health comments.
Milke M. (2004)	Plague in Sydney and its solid waste lessons. *Waste Management* 24, 321-323.	General	Refers to plague in 1900s from poor sanitation.
Mikkonen T., Valkama J., Wihiman H., Sukura A. (2005)	Spatial variation of Trichinella prevalence in rats in Finnish waste disposal sites. *The Journal of Parasitology* 91(1), 210-213	Collector	Trichinellosis is one of the most widespread parasitic zoonoses in the world and hazardous to humans. *Trichinella* spp. were found to be a common parasite in trapped rats (overall prevalence, 19%) detected in 12 of 13 dumps, more often on female rats and not related to their physical condition.
Mayoral J., Sánchez A. (2005)	Backyard Composting in Catalonia. *Biocycle* 46,4:75-78	Householder	Spain. Trials of home composting. Did not find increased problems with rodents.
Quirk D. 2007	Rushmoor Council: Directorate of community and Environmental Health *Report No: ENH07047* September 2007	Householder	Review of complaints of rats Borough wide and in fortnightly collection trial area, no extra prevalence found. (Wheeled bins used).

Table A3 Flies

Author(s)	Publication details	Relevance	Comments
Ministry of Housing and Local Government (1967)	'Refuse storage and collection' *HMSO*	Householder Frequency	Blowflies (bluebottles and green bottles) and in smaller numbers houseflies as hazards, and state they have been found to breed in dustbins all year round. In the summer they become mature adults in two-three weeks, though blowflies can take as little as nine days. From 7-12 days they are thought to migrate from their food (the bin).
Imai C. (1986)	A new method to control houseflies, *Musca domestica*, at waste disposal sites. *Researches on Population Ecology,* 27(1), 111-123.	Destination	1300–1500 flies emerged/m^2 of landfill surface in one month following deposition.
Gellens V., Boelens J., Verstraete W. (1995)	Source separation, selective collection and in reactor digestion of biowaste. *Antonie Van Leeuwenhoek* 67(1):79-89	Householder	Compares weekly and fortnightly collection of biodegradable waste. Infestation with flies and maggots reported. Including paper waste helps to overcome these problems.
Rozendaal J.A. (1997)	Houseflies. Vector Control. Methods for use by individuals and communities. *(WHO)* 302-323	Frequency	In temperate climates waste collection should be weekly, flies can breed even in tightly closed containers and waste should be covered to prevent breeding.
Goulson D., Hughes W.H.O., Chapman J.W. (1999)	Fly populations associated with landfill and composting sites used for household refuse disposal. *Bulletin of Entomological Research* 89, 493–498	Frequency	The suitability of household waste for the development of calyptrate Diptera was confirmed in a controlled trial: a mean of 0.43 adults emerged per kilo of one-week-old waste. Significantly more flies emerged from one week- old than from two-week-old household waste at the site - this is thought due to the fact adult flies had already emerged by the time the waste arrived on the landfill site with two week old waste.
Cox J. (1999)	Preventing Housefly Problems. *Journal of Pesticide Reform* 19(1), 22-23	Householder	Advised that waste should be tightly wrapped and waste containers tightly covered. Further advice included removing the organic material that is needed for the development of the egg, larvae and the pupae.
Howard J. (2001)	Nuisance flies around a landfill: patterns of abundance and distribution. *Waste Management & Research* 19(4), 308-313	Frequency	Regular supply of organic waste, combined with above-ambient temperatures present immediately below the surface layers, helps promote the rapid proliferation of many fly populations throughout much of the year.
Diggelman C., Ham, R.K. (2003)	Household food waste to wastewater or to solid waste? That is the question. *Waste Management & Research* 21(6), 501-514	Collector	General comments that changing frequency of collection of waste can lead to nuisance complaints flies (odour etc.).

Boadi K.O., Kuitunen M. (2005)	Environmental and health impacts of household solid waste handling and disposal practices in third world cities: the case of the Accra Metropolitan Area, Ghana. *J Environ Health* 68(4):32-6	Householder	Storage of open containers and plastic bags in the home associated with presence of houseflies in the food ($r=.17$ $p<.0001$) and so with childhood diarrhoea.
Lole M.J. (2005)	Nuisance flies and landfill activities: an investigation at a West Midlands landfill site. *Waste Management & Research* 23(5), 420-428	Frequency	Importation of flies onto landfill site highest in July, but relatively low survival rates compared to what was delivered to site. Populations highest May-July with another peak Aug-Sept (also peak emergence time for common housefly).
Nazni W.A., Seleena B., Lee H.L., Jeffery J., Rogayah T.A., Sofian M.A. (2005)	Bacteria fauna from the house fly, *Musca domestica* (L.). *Trop Biomed* 22(2):225-31	Householder	Movement of fly from garbage to food makes then candidate for disease transmission.
Goulson D., Derwent L.C., Hanley M.E., Dunn D.W., Abolins S.R. (2005)	Predicting calyptrate fly populations from the weather, and probable consequences of climate change. *J of Applied Ecology* 42, 795–804	Householder	*Musca domestica* often associated with waste, high nuisance value. Suggested fly populations driven by the weather rather than any biotic factor. Prediction for higher numbers with general warmer temperatures in the future, and so increase in fly-borne disease.
Ali S., Phillips P.S., Bates M., Phillips C.A. (2007)	Development of comprehensive microbiological methods to assess the possible impact of biweekly kerbside collection of MSW on human health in England. *Proceedings of 22nd International Conference on Solid Waste Tech and Management* Philadelphia, PA USA	Householder Frequency	Findings have indicated that, as the average lifecycle of a housefly is up to 13 days, collections of bins only once every two weeks could allow flies to lay more eggs.
Medronho R.A., Macrini L., Novellino D.M., Lagrotta M.T., Câmara V.M., Pedreira C.E. (2009)	Aedes Aegypti immature forms distribution according to type of breeding site *Am J Trop Med Hyg.* 80(3):401-4	Householder Frequency	Investigation of the production of the mosquito in different types of containers. 747 containers in 300 dwellings examined. Containers used to store waste enclosed 90.2% of the larvae and 88.9% of the pupae. Wider covering of water and regular garbage collection decisive factors in effective control of dengue vector.

Table A4 Microorganisms and Mycotoxins

Author(s)	Publication details	Relevance	Comments
Fischer G., Müller T., Ostrowski R., Dott W. (1999)	Mycotoxins of Aspergillus fumigatus in pure culture and in native bioaerosols from compost facilities *Chemosphere* 8:1745-55	Collector	Identified mycotoxins associated with *A. fumigatus* commonly found at composting facilities, e.g. Tryptoquivaline, which has tremorgenic properties. Concentrations found depended on colony counts, and must exceed 10^7 conidia/m^3 in the air to detect fungal metabolites or toxins. However, further research needed on detection limits identified.
Fischer G., Müller T., Schwalkbe R, Ostrowski R., Dott W. (2000)	Species-specific profiles of mycotoxins produced in cultures associated with conidia of airborne fungi derived from biowaste *Int J Hyg Environ Health* 203(2):105-16	Collector	Identified common species found within composting e.g. *Aspergillus spp.* and *Penicillum spp*. and from isolated strains attempted to identify presence of metabolites, e.g. mycotoxins which may be hazardous to health. Mycotoxins Fumigaclavine C, tryptoquivaline, and trypacidin and compounds such as cyclopenol, cyclopenin, and penitrem A were identified and thought possible they could occur in native bioaerosols and so be a hazard to health at waste facilities.
Fischer G., Dott W. (2003)	Relevance of airborne fungi and their secondary metabolites for environmental, occupational and indoor hygiene *Arch Microbiol.* 179(2):75-82	Collector	Review. Argues respiratory risks of mycotoxins have not been fully evaluated, but acknowledges only highly contaminated environments relevant. Recommends identification of species as some are more likely to contain mycotoxins likely to cause health effects than others. General comment on sources of anthropogenic bioaerosols and longevity of spores that may contain mycotoxins.
Rundberget T., Skaar I., Flåøyen A. (2004)	The presence of Penicillium and Penicillium mycotoxins in food wastes *Int J Food Microbiol* 15;90(2):181-8	Collector	Measured food waste collected weekly (purpose to ascertain mycotoxins in food wastes destined for animal feed). 25 *Penicillium spp.* identified. Of 48 summer samples, 36 contained more than 10^5 colony forming units (CFU) Penicillium/g sample. Mycotoxins in these samples ranged from 75–19000 Ag/kg mycophenolic acid, 40–920 Ag/kg roquefortine C, 35–7500 Ag/kg penitrem A, 20–2100 Ag/kg thomitrem A and 20–3300 Ag/kg thomitrem E. Of 49 winter samples, one contained mycophenolic acid (4800 Ag/kg) and roquefortine C (190 Ag/kg). Differences were thought related to storage temperatures and weather conditions. Concluded most samples containing mycotoxins had a mould count above $1x10^6$ CFU/g; some lower also contained significant amounts.

Table A5 Dust/Bioaerosols and Microorganisms

Author(s) / Date	Title / Details	Relevance	Comments
Pahren R. (1987)	Microorganisms in municipal solid waste and public health implications. *CRC Crit Rev in Env Control* 17(3):187-228	Collector	USA. Mentions risk. Evaluates microorganisms but also potential for viral exposure (nappies of infants). Discusses exposure not necessarily an issue, depends on dose-response. Discusses lower level exposure of people living around waste plants.
Malmros P., Pedersen L.F., Trøster K., Tønning K. (1993).	3-delt indsamlingssystem for dagrenovation. *Rapport fra et forsøg i Fåborg og Herning Kommuner. Miljøprojekt nr. 214*	Collector	Denmark. Enclosed containers generate 'percolate' which can increase exposure, organic waste collectors experience nausea, diarrhoea, tiredness, fever.
Nielsen B.H., Wurtz H., Holst E. (1994)	Endotoxins and microorganisms in percolate derived from compostable household waste. *Am J Ind Med* 25(1):121-2	Container Frequency	Denmark. Analysis of percolate after 14 days storage. Communication here: more fully reported in Nielsen *et al* (1998) and Heldal *et al* (2001).
Poulsen O.M., Breum N.O., Ebbehøj N., Hansen A.M., Ivens U.I., van Lelieveld D., Malmros P., Matthiasen L., Nielsen B.H., Nielsen E.M., Schibye B., Skov T., Stenbaek E.I., Wilkins C.K. (1995)	Collection of domestic waste. Review of occupational health problems and their possible causes. *Sci. Total Environ.*, 170(1-2):1-19	Collector exposure & health	Denmark. General including risk and musculoskeletal issues, but heavy emphasis on bioaerosols. Exposure evaluated in relation to dust containing bacteria, endotoxins, mould spores, glucans, volatile organic compounds, and diesel exhaust. Recommended needed data on dose-response, respiratory and MMI/skin issues, and interaction between exposures, e.g. exhaust and bioaerosols simultaneously.
Reiss J. (1995)	Moulds in containers with biological wastes. *Microbiol Res* 150(1):93-8	Container	Recommendations after a study of moulds in biological waste collection containers. Wrapping in newsprint reduced CFU 50-70%. Cleaning container after emptying with diluted vinegar reduced CFU up to 80%. Placing container in shade.
Nielsen E.M., Nielsen B.H., Breum N.O. (1995)	Occupational bioaerosol exposure during collection of household waste. *Ann. Agric. Environ. Med.*, 2, 53-59	Collector exposure	Average bioaerosol exposure for waste loader 10^5 cfu/m^3, higher than driver. Roof measurements significantly higher (10^6 cfu/m^3) probably due to waste compression, so workers may get higher peak levels.
Breum N.O., Nielsen E.M., Nielsen B.H. (1996)	Bioaerosol exposure in collecting garden waste, recyclable materials and waste for incineration. *An Agric Environ Med* 3:27-32	Collector	Denmark. Collecting dry recyclables, garden waste and residual (incinerator) waste in autumn and spring. Workers collecting garden waste more heavily exposed and seasonal differences.

Breum N.O., Nielsen M., Wurtz H., Ivens U.I., Hansen J., Schibye B., Nielsen B.I., Poulsen O.M. (1997)	A job exposure matrix related to bioaerosol exposure during collection of household waste. Ann *Agric Environ Med* 1997;4:53–61	Container Collector	Denmark. Paper bags no 'leachate' but most dusty and produced more total microorganisms, *A. fumigatus*, bacteria and Gram-negative bacteria. Collectors of compostable household free access waste had higher exposures to fungi than low access collectors, (5.4 x 10^4 compared to 3.1 x 10^3 cfu/m^3).
Breum N.O., Nielsen B.H., Nielsen E.M., Midtgaard U., Poulsen O.M. (1997)	Dustiness of compostable waste: a methodological approach to quantify the potential of waste to generate airborne microorganisms and endotoxins. *Waste Man Res* 15(2):169-187	Container Collector	Denmark. Waste stored for one-two week periods in containers allowing free access or low access to air. Free access equalled greater weight loss (up to 25% per week) and no percolate. Low access equalled only 3% weight loss and 0.1L percolate. Dustiness highly correlated to weight loss and greater concentrations of airborne microoganisms when agitated.
Heldal K., Eduard W., Bergum M. (1997)	Bioaerosol exposure during handling of source separated household waste. *Ann. Agric. Environ. Med.,* **4**, 45-51	Collector exposure	Norway. Closed bins for biodegradable waste considered to generate higher exposures, two times higher in summer than winter.
van Yperen H.R., Rutten A.L.M. (1997)	Health risks due to exposure to biological agents during removal of organic waste, a survey of gaps in knowledge. *Ann Agric Environ Med* 4, 39–43	Householder Collector Frequency	Netherlands. Highlighted potential risks to householders and so collectors with separation of biodegradable waste. Concluded low for householders, but could be significant for collectors, and that age of waste could be a factor (but no data). Recommended research directed towards reaching practical solutions and making choices in techniques, rather than towards collection of more numerical data.
Nielsen M., Wurtz H., Nielsen B.H., Breum N.O., Poulsen O.M. (1997)	Relationship between different bioaerosol parameters sampled from the breathing zone of waste collectors - identification of the most important parameters. *Ann Agric Environ Med* 4, 81–85	Collector exposure	Denmark. 199 collectors sampled, variability of samples purpose of study. Very little correlation between different parameters. Recommended total counts as most reliable way to measure exposure to collectors.
Nielsen E.M., Breum N.O., Nielsen B.H., Wurtz H., Poulsen O.M., Midtgaard U. (1997)	Bioaerosol exposure in waste collection: a comparative study on the significance of collection equipment, type of waste and seasonal variation. *The Annals of Occupational Hygiene* 41:3, 325-344(20)	Collectors	Denmark. Garden waste collectors frequently experienced concentrations exceeding 10^5 cfu/m^3 for mesophilic fungi and 10^4 cfu/m^3 for the thermophilic fungus *A. fumigatus*. Type of collection vehicle was important. Vehicles loaded from the top (approximately 3 m above the ground) caused lower exposure (by a factor of 25) to fungi than vehicles loaded level or the breathing zone of the workers. Exposure also affected by season.
Ivens U.I., Hansen J., Breum N.O., Ebbehoj N., Nielsen M., Poulsen O.M., Wurtz H., Skov T (1997)	Diarrhoea among waste collectors associated with bioaerosol exposure *Ann Agric Environ Med* 4, 63-68	Collectors	Denmark. Dose response relationship found for diarrhoea and exposure to fungi in waste collectors PPR 5.60, with a significant trend from high to low exposure.
Hansen J., Ivens U.I., Breum N.O., Nielsen M., Wurtz H., Poulsen O.M., Ebbehoj N. (1997)	Respiratory symptoms among Danish waste collectors. *Ann Agric Environ Med* 4, 69-74	Collectors	Denmark. Waste collectors exposed to bioaerosols and exhaust fumes. Significantly increased for cough PPR 1.3, itching nose 1.9, wheeze 1.4 and chronic bronchitis 2.3. Concluded waste collectors moderately increased prevalence of respiratory problems compared to park workers.

Thorn J., Beijer L., Rylander R. (1998)	Airways inflammation and glucans exposure among household waste collectors. *Am. J. Ind. Med.*, **33**, 463-470	Collectors	Sweden. Waste collectors have also reported a higher incidence of diarrhoea, congested nose and unusual tiredness compared to controls.
Nielsen B.H., Wűrtz H., Breum N.O. (1998)	Microorganisms and endotoxins in stored biowaste percolate and aerosols. *Waste Man & Res* 16, 2:150-159	Container Frequency	Denmark. Microoganisms and endotoxins sampled from containers over two weeks, finding no significant difference in percolate between one or two weeks. Some increase of ammonia over two week storage period.
Weinrich M., Vissiennon T., Kliche R., Schumann M., Bergmann A. (1999)	Nature and frequency of the existence of mold fungi in garbage cans for biological waste and the resultant airborne spore pollution. *Berl Munch Tierarzti Wochenschr* 112(12):454-8	Householder Collector	Reports that microorganisms develop within a few hours of waste being deposited. *A. fumigatus* and *A. niger* often found. Amount emitted depends on climatic conditions, e.g. temperature, relative humidity and sunlight (radiation). Risk harmless for healthy individuals, but those with weakened immune system or immunocompromised should avoid handling of biodegradable wastes, and possibly other wastes.
Ivens U.I., Breum N.O., Ebbehøj N., Nielsen B.H., Poulsen O.M., Wűrtz H. (1999)	Exposure-response relationship between gastrointestinal problems among waste collectors and bioaerosol exposure. *Scand. J. Work. Environ. Health,* 25, (3):238-45	Collector health	Denmark. 1747 waste collectors. Exposure-response relationship between nausea and endotoxins exposure (prevalence proportion ration (PPR) 1.60) and between diarrhoea and exposure to both endotoxins and viable fungi (PPR 5.60 and 4.59 respectively), with lower exposures related to a lower number of reports for nausea and diarrhoea.
Kiviranta H., Tuomainen A., Reiman M., Laitinen S., Nevalainen A., Liesivuori J. (1999)	Exposure to airborne microorganisms and volatile organic compounds in different types of waste handling. *Ann. Agric. Environ. Med.,* 6:39-44	Collector exposure	Finland. Small study of two waste collection workers (in wider study of waste facilities). 10^4 cfu/m^3 fungi, and 10^3 cfu/m^3 bacteria. No gram-negative bacteria found. Small amounts of VOCs (330 µg/m^3, Comfort range (< 200 µg/m3), symptoms might occur within the range (200-3,000 µg/m3), thought related to exhaust exposure. Concluded exposure in waste collection generally low, but it is possible that while opening a waste container the worker can be exposed to high levels of microorganisms and VOCs for a short period of time, and higher ventilation rate could exacerbate this.
Thorn J. (2001)	Seasonal variations in exposure to microbial cell wall components among household waste collectors. *Ann. Occup. Hyg.*, 45, (2):153-156	Collectors	Sweden. Household waste collectors handling compostable waste can be exposed to airborne (1-3)-ß-D-glucans, especially during the warm season, when more symptoms have been reported among waste collectors, according to previous studies. Not interpreted as a causal relationship as household waste may contain several agents of effect.
Smedlund Miljösystem Ab est (1999)	Source separation of compostable material – different handling lines. *Unpublished consultancy report*	Containers	Sweden. Review of storage conditions. Paper sacks show highest exposures when emptied up to 134 x 10^3 cfu/m^3, and higher glucans, but lower endotoxins.
Becker G., Mathys W., Neumann H.D., Allmers H., Balfanz J. (1999)	Risk to employees in garbage collection and transport from pathogen exposure. *Schriftenr Ver Wasser Boden Lufthyg* 104:551-9	Collectors	Germany. Reporting on an upcoming study and risks of potential bioaerosol exposure and effects on health in collectors, reported more fully in Neumann *et al* (2002).

Martens W., Bohm R., Fessel A., Fricke K., Haumacher P., Kenner-Aschenbrenner K., Kohler K.K., Mayr C., Philipp W., Strauss R., Witzigmann R., Zapirain R. (1999)	Microbial emissions in collection of residential garbage. *Schriftenr Ver Wasser Boden Lufthyg* 104:503-219	Collector Frequency	Germany. Emissions related to type of waste. Prevalence of *A. fumigatus* in residual and biodegradable wastes. In part thought due to collection frequency on a fortnightly basis.
Neumann H.D., Balfanz J. (1999)	Microbial exposure in collection of residential garbage – results of field studies. *Schriftenr Ver Wasser Boden Lufthyg* 104:533-45	Collector	Germany. 7.5 x 10^5 cfu/m^3 fungi during collection. Hot periods increased *A. fumigatus*. Type of refuse not important.
Wouters I.M., Douwes J., Doekes G., Thorne P.S., Brunekreef B., Heederik D.J. (2000)	Increased levels of markers of microbial exposure in homes with indoor storage of organic household waste. *Appl. Environ. Microbiol.,* 66, (2), 627-631	Householder Frequency	Netherlands. Increased microbial contaminant levels in homes associated with indoor storage of separated organic waste. Hence might increase the risk of bioaerosol-related respiratory and other symptoms in susceptible people/children. Higher counts if organic waste stored for one week or more than one week or less. Residual material no difference.
Bünger J., Antlauf-Lammers M., Schulz T.G., Westphal G.A., Müller M.M., Ruhnau P., Hallier E. (2000)	Health complaints and immunological markers of exposure to bioaerosols among biowaste collectors and compost workers. *Occup. Environ. Med.,* **57**, 458-464	Collector health	Germany. 53 garden waste collectors. No significant health complaints. Bad smells reported but not related to nausea. No significant symptoms compared to control group in waste collectors.
Nielsen B.H., Nielsen E.M., Breum N.O. (2000)	Seasonal variation in bioaerosol exposure during biowaste collection and measurements of leaked percolate. *Waste Management & Research*, **18**, (1), 64-72	Collector exposure	Higher exposure during the summer: total microorganisms 9.2×10^5 cells m^{-3}, culturable fungi (moulds) 7.8×10^4 cfu m^{-3}, *Aspergillus fumigatus* 2.9×10^{-3} cfu m^{-3}, mesophilic actinomycetes 9.0×10^2 cfu m^{-3}, bacteria 1.0×10^4 cfu m^{-3}, endotoxins 16 EU m^{-3} (1.0 ng m^{-3}) and dust 0.33 mg m^{-3}. Risks from 'percolate'.
Allmers H., Huber H., Baur X. (2000)	Two year follow-up of a garbage collector with allergic bronchopulmonary aspergillosis (ABPA). *Am J Ind Med* 37:438-442	Collector	US. Waste collector with allergic bronchopulmonary aspergillosis/asthma associated with mould from household waste, blamed on separate collection of organic waste.
Heldal K.K., Breum N.O., Nielsen B.H., Wilkins K. (2001)	Experimental generation of organic dust from compostable household waste. *Waste Manag Res* 19(2):98-107	Container Frequency	Norway. Different storage systems evaluated over 14 days for organic wastes simulating collection frequency. Aerated containers lost more weight (39%) over closed containers (9%), with higher microoganisms in closed containers and more 'percolate'. Both open and aerated systems had potential to generate similar concentrations of fungi.
Issever H., Gul H., Erelel M., Erkan F., Gungor G.Y. (2002)	Health problems of garbage collectors in Istanbul. *Indoor Built Environ* 11:293-301	Collector	Turkey. 228 collectors in five districts. Found statistically significant effects on the respiratory system. No significant reported health symptoms. 'Centres' sampled not personnel.

Wouters I.M., Hilhorst S.K.M., Kleppe P. (2002)	Upper airway inflammation and respiratory symptoms in domestic waste collectors. *Occup Environ Med*; 59: 106–12	Collector health	Netherlands. Prevalence of respiratory symptoms was higher in waste collectors than controls. Geometric mean exposure concentrations were dust 0.58 mg/m^3, endotoxins 39 EU/m^3, and 1.3 µg/m^3 for b (1-3)-glucans. Exposure to dust and endotoxins was associated with concentrations of IL8 after the shift ($p<0.05$). Increased concentrations of IL8 ($p<0.05$) and total cells ($p<0.10$) after the shift were associated with respiratory symptoms. Increased airway symptoms compared to controls.
Neumann H.D., Balfanz J., Becker G., Lohmeyer M., Mathys W., Raulf-Heimsoth M. (2002)	Bioaerosol exposure during refuse collection: results of field studies in the real-life situation. *Sci Total Environ* Jul 3;293(1-3):219-31	Collectors Frequency	Germany. 10^4 cfu/m^3 bacteria and fungi. Endotoxins 50 EU/m^3 in summer, more often below 10 EU/m^3 autumn/winter. Low exposures of fungi thought related to the prevailing one week collection interval. Type of refuse no significant difference.
Krajewski J.A., Tarkowski S., Cyprowski M., Szarapinska-Kwaszewska J., Dudkiewicz B. (2002)*	Occupational exposure to organic dust associated with municipal waste collection and management. *Int J Occup Med Environ health* 15(3):289-301	Collector exposure	Noise, dustiness, physical effort and changeable atmospheric conditions as the most strenuous factors concerning their jobs. 10^4-10^5 cfu/m^3 fungi during collection.
Lavoie J., Dunkerley C.J. (2002)	Assessing waste collectors' exposure to bioaerosols. *Aerobiologica* 18, 3-4:227-285	Collector exposure	Bacteria/fungi exposure to collectors of the order 10^4 cfu/m^3, endotoxins to 100 EU/M^3. Cleanliness of truck does not affect exposure. Exposure related to the liquids produced by the materials, especially if organic. Reference to increasing the collection frequency of organics in summer from fortnightly to reduce exposure, or improve hygiene measures.
Heldal K.K., Halstensen A.S., Thorn J., Eduard W., Halstensen T.S (2003a)	Airway inflammation in waste handlers exposed to bioaerosols assessed by induced sputum. *European Respiratory Journal*, **21**, (4), 641-645	Collector health	25 waste collectors in a community near Oslo. The study reported a rise in respiratory tract inflammation over the course of the workers' working week, based on short-term analysis of breathing trends and saliva; 22 of the workers collected organic waste and three workers collected paper waste. All waste was stored in closed containers.
Heldal K.K., Halstensen A.S., Thorn J., Djupesland P., Wouters I., Eduard W., Halstensen T.S. (2003b)	Upper airway inflammation in waste handlers exposed to bioaerosols *Occup Environ Med* 60:444–450	Collectors	Small study on a working week but results suggested that a moderate exposure to fungal spores (range 0–2.0 x 106/m^3), endotoxins (range 4–183 EU/m^3), and beta(1→3)-glucans (range 3–217 ng/m^3) during waste handling induced upper airway inflammation dominated by neutrophil infiltration (Monday (28%) to Thursday (46%)) and swelling of the nasal mucosa (particularly associated with the fungal spore and beta(1-->3)-glucans exposure ($r(S) = 0.58$-0.59, $p < 0.05$).
Ryckeboer J., Mergaert J., Coosemans J., Deprins K., Swings J. (2003)	Microbiological aspects of biowaste during composting in a monitored compost bin. *J Appl Microbiol* 94(1):127-37	Container	Belgium. Number of microorganisms generated by organic waste increases and decreases depending on the phase (mesophilic, thermophilic, cooling and maturation). Largest increases seen at 27 days after cooling. Yeast/fungi not present in thermophilic phase.

Herr C.E.W., Nieden A., Stilianakis N., Gieler U., Eikmann T.F. (2004)	Health effects associated with indoor storage of organic waste. *Int Arch Occup & Environ Health* 77, 2:90-7	Householders Frequency	Germany. Questionnaires. Longer indoor storage of organic waste associated with skin problems and allergy.
Herr C.E., Nieden Az A., Stilianakis N.I., Eikmann T.F .(2004)	Health effects associated with exposure to residential organic dust. *Am J Ind Med*. 46(4):381-5	Householders Frequency	Irritating airways complaints associated with higher bioaerosol exposure not linked to odour. Longer storage of organic waste indoors associated with skin issues but not to respiratory complaints.
Heldal K.K., Eduard W. (2004)	Associations between acute symptoms and bioaerosol exposure during the collection of household waste. *Am J Ind Med* 46:253–260	Collectors	Norway. 22 workers of separated organic and total waste. The median exposure levels of bacteria and fungal spores were 0.4 and 0.1x $10^6/m^3$, respectively. The exposure to rod-shaped bacteria (7% of the bacteria count), endotoxins (1.8 EU/m^3), and dust (0.2 mg/m^3) was low. Symptoms most often reported were unusual tiredness (24%), headache (22%), cough (15%), and irritation in eyes and nose (10 and 17%). MMIs thought related to waste collection (low level exposure).
Steiner D., Jeggli S., Tschopp A., Bernard A., Oppliger A., Hilfiker S., Hotz P. (2005)	Clara cell protein and surfactant protein B in garbage collectors and in wastewater workers exposed to bioaerosols. *Int Arch Occup Environ Health* 78(3):189-97	Collectors	Switzerland. This study was aimed at looking for increased lung epithelial permeability by determining CC16 and SPB in collection workers exposed to bioaerosols. No relationship found (but wastewater workers did show increased CC16 leading to hypothesis of 'sub-clinical' toxic pneumonitis at low bioaerosol exposures).
Neumann HD, Becker G, Lohmeyer M, Mathys W. (2005)	Preventive measures to reduce bioaerosol exposure during refuse collection: results of field studies in the real-life situation. *Sci Total Environ.* 1;341(1-3):1-13.	Collectors	Germany. Factors found to influence the bioaerosol concentration for refuse collectors: compaction method, lifting device control, rave rail height, hopper depth, design of intake area and dust control. Higher fungal counts were recorded with rotating drum vs. packer plate compaction. A hinged lid at the lifting device and a suction unit reduced exposure. Automatic lifting systems had a positive influence on rear-end loaders, as did loading operation control from the closed driver's cab on side loaders. Regular internal and external high-pressure cleaning of the lifting device every 14 days is recommended for vehicle hygiene.
Lavoie J., Dunkerley C.J., Kosatsky T., Dufresne A. (2006)	Exposure to aerosolised bacteria and fungi among collectors of commercial, mixed residential, recyclable and compostable waste. *Sci Total Environ* 370(1) 23-8	Collectors Frequency	Canada. Worker exposure counts were significantly ($p \leq 0.05$) higher than ambient levels measured upwind, with the highest personal exposures to bacteria for urban compostable waste collectors (median=50,300 CFU/m^3). On the other hand, fungal counts collected on an every other-week cycle were highest among a group of rural compostable waste collectors (median=101,700 CFU/m^3). Intimated fortnightly collection could increase exposures.

Wouters Spaan S., Douwes J., Doekes G., Heederik D. (2006)	Overview of personal occupational exposure levels to inhalable dust, endotoxins, β (1→3)-glucans and fungal extracellular polysaccharides in the waste management chain. *Ann. Occup. Hyg*. 50(1):39-53	Collector	Netherlands. 20% collectors showed EPS-Pen/Asp exposure. Mean exposure levels in domestic waste collection were 0.6 mg /m^3 for inhalable dust, 40.2 EUm^3 for endotoxins and 1.22 mg/m^3 for b (1-3)-glucans. Collecting waste once a week resulted in higher exposure levels than collecting waste once every fortnight (1.77 times higher for dust, 1.82 times higher for endotoxins and 1.51 times higher for glucans; $P < 0.05$). Reason could not be explained. Exposures slightly higher in collection of separated organic fraction compared to residual.
Perez H.R., Franka A.L., Zimmermanb N.J. (2006)	Health effects associated with organic dust exposure during the handling of municipal solid waste. *Indoor Built Environ* 15;3:207–212	Collector	USA. Review of work pointing out most is in Europe. Outlines limited nature of exposure assessment in research and need for further work regarding exposure levels and associated health effects. Concluded that the detailed characterisation of organic dust exposure experienced by municipal solid waste workers is necessary to improve understanding of health effects and develop strategies to improve health.
Haughey C., Manga H. (2006)	A bacteriological examination of Belfast City Council's household black 'wheelie' bins. *University of Ulster*	Container Frequency	Compared bacteria fortnightly/weekly in bins. Results indicated bacteria was higher in bins collected at the end of one week rather than after two weeks. Fungi not sampled.
Widmeier S., Bernard A., Tschopp A., Jeggli S., Dumont A., Hilfiker S., Oppliger A., Hotz P. (2007)	Surfactant protein A, exposure to endotoxins, and asthma in garbage collectors and in wastewater workers. *Inhalation Toxicology*, 19:351–360	Collectors	Switzerland. Attempt to find inflammatory mechanism in the immune system of collection workers, no correlation found. Endotoxins 8.14 EU/m^3 in winter, 11.03 EU/m^3 in summer (averages) for loaders.
de Meer G., Heederik D., Wouters I.M. (2007)	Change in airway responsiveness over a workweek in organic waste loaders. *Int Arch Occup Environ Health* 80(7): 649-52	Collectors health	Small study on organic waste loaders, 16 in all. Six exhibit regular respiratory symptoms, the remainder do not. Results indicated exaggeration of airways inflammation during the work week for those with pre-existing symptoms, linked to potentially higher endotoxins exposure (although this not measured during the course of this study).
Searl A. (2009)	Exposure-response relationships for bioaerosol emissions from waste treatment processes *Defra Project: WR0606: DRAFT*	General health	Review of dose-response relationships of bioaerosols focusing specifically on waste management incorporating dust, bacteria, fungi, endotoxin and glucans (Defra-funded UK study). Determined relationships between exposure and health were unclear due to susceptibility and sensitisation of exposed populations. Perhaps 10% of general population particularly susceptible. Ultimately insufficient data is currently available to set regulatory limits, hence recommended a 'best practice' approach.

*Repeat paper where covered more than one topic

Table A6 Other issues

Author(s)	Publication details	Relevance	Comments
Gellin G.A., Zavon M.R. (1970)	Occupational dermatoses of solid waste workers. *Arch Environ Health* Apr;20(4):510-5	Collectors	USA. Skin issues and waste collectors.
Cimino J.A. (1975)	Health and safety in the solid waste industry. *American Journal of Public Health,* 65(1):38-46	Collectors	USA. Discusses CO 'over-exposure' and possible heart disease, dusts, injuries, accidents, and examines illnesses and diseases associated with waste management. 'One of most hazardous occupations'.
Gellin G.A. (1985)	Dermatoses acquired by solid-waste handlers. *Am J Ind Med.* 8(4-5):363-70	Collectors	USA. Physical injuries to traditional waste collectors and skin problems.
Zuskin E., Mustajbegovic J., Schachter E.N., Kern J., Pavicic D., Budak A. (1996)	Airways Function and respiratory symptoms in sanitation workers. *J Occup Environ Med* 1996 38(5):522-7	Collectors	Croatia. Group of 81 workers. Higher levels of chronic respiratory symptoms in collectors compared to controls, and MMIs. Decreased lung function in collectors working 10+ years in the industry.
Dumble P. (1998)	Testicular cancer? Precautionary strategies for landfill operators and waste collectors. *IWM Proceedings*	Collectors	Discussion of potential threat of degrading polymers and handling/health.
Ivens U.I., Lassen J.H., Kaltoft B.S., Skov T. (1998)	Injuries among domestic waste collectors. *Am J Ind Med.* Feb;33(2):182-9	Collectors	Seasonal and weekly variation in injuries for collectors, more often on Mondays/Thursdays and in May/September. 17% experienced injury overall.
An H., Englehardt J., Fleming L., Bean J. (1999)	Occupational health and safety amongst municipal solid waste workers in Florida. *Waste Management Research* 17; 369	Collectors	USA. Injuries and accidents, reference to various symptoms and potential respiratory complaints with drivers and helpers being most at risk.
Dorevitch S., Marder D. (2001)	Occupational hazards of municipal solid waste workers. *Occup Med* 16(1):125-33	Collectors	USA. Musculo-skeletal injury, skin diseases and gastrointestinal issues. Emphasizes safety procedures.
Ferreira J.A., dos Anjos L.A. (2001)	Public and occupational health aspects related to municipal solid waste management. *Cad Saude Publica* 17(3):689-96	Collectors	Portugal. Protection of human health highlighted.
Yang C.Y., Chang W.T., Chuang H.Y., Tsai S.S., Wu T.N., Sung F.C. (2001)	Adverse health effects among household waste collectors in Taiwan *Environ Res* 85(3):195-9	Collectors	Waste collection a heavy job involving lifting, carrying, pushing and pulling (plus exposure to bioaerosols and 'toxic materials'). Questionnaire based. Data indicated risk of chronic respiratory symptoms, e.g. cough, phlegm etc. and musculoskeletal problems including lower back pain, and elbow/wrist pain. Also injuries by sharp objects.
Rogers J., Englehardt J., An H. (2002)	Solid waste collection health and safety risks: survey of municipal solid waste collectors. *J Solid Waste Technol Manag* 2002; 28:154–160	Collectors	USA. General overview of risks and hazards.

British Glass (2002)	Kerbside collection of glass - A brief study into the coverage and effectiveness of kerbside collection in the UK. *http://www.wrap.org.uk/downloads/Kerbside_collection_glass_printversion.a5c38dbe.pdf*	Collectors	Issue with noise identified when glass tipped. Reported otherwise that no major H&S issues. Minor complaints of dropped broken glass by the public, and food residues on collectors. PPE an important issue.
Steiner D., Jeggli S., Bernard A., Hotz P. (2003)	Lung diseases in persons exposed to waste disposal dust. *Schweiz Rundsch Med Prax*. 5;92(10):436-40	Collectors health	Germany. No elevation asthma or other lung diseases. 50% hypertensive, thought related to lifestyle choices.
Englehardt J.D., An H., Fleming L.E., Bean J.A. (2003)	Analytical predictive Bayesian assessment of occupational injury risk: municipal solid waste collectors. *Risk Anal*. Oct;23(5):917-27	Collectors	Traditional garbage collection. Injury rate 80 per 100 workers. Results, though subject to uncertainty in worker numbers and classification and reporting bias, agreed closely with a survey of 251 MSW collectors, of whom 75% reported being injured (and 70% reported illness) within the past 12 months. Mentioned VOCs and 'other respiratory insults'.
Rushton L. (2003)	Health Hazards and waste management. *Br Med Bull* 68:183-97	Collectors	UK. Increased risk of accidents and musculoskeletal problems. Health impacts of new waste management technologies need further evaluation.
Kuijer P.P., Frings-Dresen M.H. (2004)	World at work: refuse collectors. *Occup Environ Med* 61:(3):282-6	Collectors	Netherlands. General review of the hazards of waste collection, inc. risk and musculoskeletal issues, pushing/pulling and vibration, respiratory, gastrointestinal and hearing issues.
Anjos L.A., Ferreira J.A., Damião J.J. (2007)	Heart rate and energy expenditure during garbage collection in Rio de Janeiro Brazil. *Cad Saude Publica.* 23(11):2749-55	Collectors	Brazil. Reviews demands on collectors (physical) and stress. Measured heart rate and energy demands. Collectors had a low resting heart rate and so were quite fit, but exceeded 30% max individual daily load during work which is considered heavy, whilst burning 2800kcal, similar to an elite athlete.

Table A7 General issues related to collection and fortnightly collection

Author(s)	Publication details	Relevance	Comments
Institution of Wastes Management (1997) and (2000)	Refuse collection systems. *IWM*	Systems	1997 publication on collection stated that weekly refuse collection was established to take into account the life cycle of the fly. A later update (IWM 2000) acknowledged this had been often changed to 14 days to take into consideration recycling and changes in weight and volume of materials. Recommends risk assessment where changes implemented.
Enviros Consulting Ltd. & Cranfield University For Defra (2007b)	Health impact assessment of alternate week waste collections of biodegradable waste. *Defra Waste Implementation Programme. Defra/Wycombe District Council, London*	Householder Frequency	UK. Short householder survey, no significant issues identified. Questionnaires of householders and collection workers using fortnightly collection. Advice on wrapping and storage of materials to reduce nuisance to householders.
WRAP (2007)	Alternate week collections guidance. *Waste Resources Action Programme 13th July* ISBN: 1-84405-337-7	Systems	Outline of introduction of fortnightly collection systems, various case studies outlining experience and advice on introduction.
Entec (2007)	Health and safety initiative scoping study. *CIWM*	Systems	Good practice, competence, behaviours. Review of H&S in the industry including survey.
CIWM (2007)	Position statement	Statement	http://www.ciwm.co.uk/pma/3057
European Agency for Health and Safety at Work (2007)	Expert forecast on emerging biological risks related to occupational safety and health. *Luxembourg: Office for Official Publications of the European Communities* ISBN 92-9191-130-5	Review and risk	Waste collectors identified as an 'at risk' group leading to allergies, infectious diseases (bacteria, viruses), toxic diseases (endotoxins, mycotoxins) and cancers (oncogens). Increase in numbers exposed due to expansion of industry/recycling.

Table A8 HSE Publications

Author(s)	Publication details	Relevance	Comments
Pinder A.D.J., Milnes E. (2002)	Manual handling in refuse collection HSL/2002/21 *http://www.hse.gov.uk/research/hsl_pdf /2002/hsl02-21.pdf*	HSE Research	Covered ergonomics and safety risks of refuse collection. Recommended use of wheeled bins over bags, and timing recycling collections to even out volumes (only comment on fortnightly collection was regarding regulating volume). Also PPE to cover risk of sharp objects etc. from bags.
Bomel (2004)	Mapping health and safety standards in the UK waste industry. *Health and Safety Executive* Research Report 240	HSE Research	Health and safety overview for waste industry. Specifically looks at task and finish for collectors and risk of accidents, with potential for a high fatality rate. Waste collection among the riskiest of occupations.
Oxley L., Pinder A.D.J., Cope M.T. (2006)	Manual Handling in Kerbside Collection and Handling of Recyclables. HSL/2006/25 *http://www.hse.gov.uk/research/hsl_pdf/2006/ hsl0625.pdf*	HSE Research	Higher weights in kerbside boxes from fortnightly collection. Various ergonomic aspects identified with kerbside collection of recyclables. Recommended wheeled bins or reduction of boxes to 40L and use of a lid (to reduce water ingress). Also 10m lifting/carrying distance recommended with rests.
HSE (2007)	Green waste collection: health issues. *http://www.hse.gov.uk/pubns/waste02.pdf*	HSE Guidance	Refers to 'green waste dust' (garden waste) and bioaerosols. Recommends reviewing safe systems of work, and practices, and refers to other risks inc. rats, chemicals and potential for skin problems.
Bomel (2009)	Update to mapping health and safety standards in the UK waste industry – *Research Report 701* HSE	HSE Research	The waste and recycling industry are experiencing rapid growth (11.6% increase in employment from 2005 to 2007 from around 176,452 to around 196,920 employed), but accident statistics from 2003-4, shows the injury rate decreased by approximately 15 % (to 2007-8) compared to the first Bomel report. Waste collection still identified as among the riskiest of occupations over a 10 year period.

Waste & Resources
Action Programme

The Old Academy
21 Horse Fair
Banbury, Oxon
OX16 0AH

Tel: 01295 819 900
Fax: 01295 819 911
E-mail: info@wrap.org.uk

Helpline freephone
0808 100 2040

www.wrap.org.uk/healtheffectsstudy