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EXPOSURE TO MICROORGANISMS AND HEALTH EFFECTS OF WORKING IN UK MATERIALS RECOVERY FACILITIES - A PRELIMINARY REPORT*

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Abstract: The aim of this research was to identify issues concerning air quality and health effects associated with organic dusts and related to household waste recycling within two Materials Recovery Facilities (MRFs) in the UK. MRFs receive household and commercial waste collected for recycling and prepare them as secondary raw materials by sorting and baling marketable categories. Air quality monitoring for viable fungi, bacteria and Gram-negative bacteria and total dust was carried out over a year at two MRFs in the UK. Peak flow measurements and questionnaires to detect symptoms of organic dust exposure were also used. Initial air quality results showed levels of bacteria and fungi up to 2.0×10^5 cfu/m^3 with the Andersen Sampler, and personal sampling reached 3.8×10^5 cfu/m^3 with total dust levels up to 18 mg/m^3. Of 39 operatives 10 participated in peak flow monitoring. Almost all of these individuals showed some variability, particularly when changing jobs within MRFs, and two operatives showed decreases of more than 100 l/min in relation to their work. Of 39 operatives questioned at two MRFs 51% reported nasal irritation, 38% throat irritation, 21% of eye irritation, 38% dry cough, 31% joint pains and 38% complained of tiredness. However, it is difficult to attribute these results to the working environment, but it is thought they indicate operatives can experience effects on their health whilst working in MRFs, and that this is an issue which needs addressing by all management levels.

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INTRODUCTION

The UK produces approximately 120-130 million tonnes of Controlled Waste (industrial, commercial and household) per annum [3]. Household waste is estimated to be 20-25 million tonnes per annum (or 5% of the total of all waste generated in the UK), a 16% rise since the 1970s [7].

Important legislation has been introduced to the waste management industry in the UK in recent years. The Environmental Protection Act (1990) placed a 'Duty of Care' on producers and handlers of Controlled Waste, by introducing a notification system. The Environment Act (1995), the most recent piece of environmental legislation introduced into the UK, covered creation of the Environment Agency from April 1996, and included sections on contaminated land, urban air quality, waste strategy (policy statements, waste flows, techniques and waste streams) and packaging waste [3].

In 1990 the UK government set a recycling target of 25% of household waste to be achieved by the year 2000, and in 1995 a 40% 'recovery' target by the year 2005 of household and commercial waste. However, current reports indicate that local authority recycling rates in the

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UK average 6% (with some Councils recycling over 22%, and others not recycling) [2].

Materials Recovery Facilities (MRFs) receive materials collected for recycling and prepare them as secondary raw materials by sorting and baling marketable categories. They first appeared in the UK in the late 1980s, mainly as warehouses where material was handsorted, particularly more valuable materials such as aluminium cans. Increased materials for recycling in the UK from a combination of drop-off sites, kerbside collection programmes and commercial sources have led to the need for central processing activity. The first purpose built MRF, with a capacity at 100,000 tonnes per annum, opened at the end of 1993. There are now an estimated 30-50 recycling facilities of various types and sizes in the UK, collecting a variety of different materials. These figures include a small charity collecting 2-3 materials to large MRFs processing 12 or more materials. The probability is at least another 10 facilities will open within the next 12 months. MRFs are often a partnership between local authorities and private waste management companies. However, markets for recycled material in the UK are variable which has led to recycling rates falling, and the collapse of some programmes. There is little government support or intervention for recycling in the UK, although recycling credits are paid to reflect diversion of waste from landfill.

More recent developments include a new landfill tax, which began in October 1996, with price differentials for waste going to landfill, £2 per tonne for 'inactive' and £7 per tonne for 'active' waste. Revenues are due to go towards national insurance contributions, and environmental bodies to fund research into waste management. It is thought this will encourage recycling by penalising disposal options. Other targets in the UK include 80% of households to have access to recycling facilities, 40% of homes to carry out composting, together with new energy from waste plants, implementation of the EU packaging directive and priority waste streams.

MATERIALS AND METHODS

Two MRFs were examined as part of a 3 year research programme in the UK. Both MRFs were supplied by extensive kerb collection programmes, initiated in the late 1980s. One MRF was a large purpose-built facility with a capacity of 100,000 tonnes per annum (referred to as MRF A), whilst the other was a smaller MRF installed in an existing building, using older and less sophisticated equipment to sort and process materials of up to 500 tonnes per annum (referred to as MRF B). Both MRFs accept waste inputs from surrounding local authorities and private waste management contractors, consisting mainly of 'dry' recyclables, including newspaper, glass, metals and plastics. Storage of textiles from kerbside collection schemes and processing of commercial waste materials, mainly paper and plastic, are also undertaken at both sites. Both use handsorting techniques to separate these materials. These MRFs provided a good comparison between scale, investment and technological differences in sorting and processing recyclables, although they have similar inputs of waste materials and processing approaches. At MRF A approximately 16% of operatives had learning disabilities, with 75% at MRF B.

Initial research included a characterisation of both MRFs and waste inputs. Data was collected relating to all incoming waste and visual inspection was used to characterise 'cleanliness' of waste. This allowed a good understanding of the general characteristics of solid waste being disposed of in the study area, and were linked to site records and weighbridge data.

The design of the air sampling programme attempted to take into account current research on air quality in waste handling facilities [4, 6, 8, 9, 13], and was carried out in collaboration with Rothamsted Research Station. The Andersen Six Stage Sampler [1] was chosen to determine a size distribution of microorganisms in the atmosphere and levels of viable airborne particles. These samplers were operated at 25 l/min (at 1 minute for Gram-negative bacteria, and 30 seconds for all other samples) and were placed as close as possible to where the operatives were working at seven or eight sampling sites (seen in Tables 1 and 2), with duplication of samples at each site in both MRFs to minimise irregular levels. Sites were chosen to represent major processing functions within both plants, where waste is moved, compacted or otherwise processed for recycling, and where the greatest aerosolisation of microorganisms may occur, similar to Danish areas of concern [13].

Polycarbonate aerosol monitors (37 mm diameter, 0.8 µm pores) in filter cassettes pre-weighed to an accuracy of 10^{-5}g were used to measure personal bioaerosol exposure. These operated over a work shift for up to 7 hours, at 2 l/min. Two filters were kept as controls, and all filters and cassettes were re-weighed after 24 hours. They were then used for viable counts, using the same media as for the Andersen Samplers, shown below:

- Gram-negative bacteria - Violet Red Bile Glucose Agar, 37°C for 24 hours;
- Bacteria - Nutrient Agar, 25°C and 37°C for up to 1 week;
- Fungi - Malt Agar, 25°C and 40°C for up to 1 week.

To account for seasonal variations the programme of air sampling was broadly continued within the four seasons: summer, autumn, winter and spring. Andersen sampling took place once every three months. Aerosol Monitors were used twice, in late winter and again in summer. Weather conditions were taken into account, and temperature and relative humidity readings were taken. Fungi were identified to species level where possible. A non-parametric Kruskal-Wallis test was then carried out on each microbiological parameter to detect if there were differences between work stations.

Peak flow measurements were considered the most practical way of detecting changes in an operative's lung function, and show association of any changes related to work periods, including 'recovery' stages [12]. A portable

Table 1. Viable counts range (median) from Andersen Samplers (10^3 cfu/m^3).

MRF A	Bacteria[a] (N = 8)		Bacteria[c] (N = 8)		Gram-negatives[b] (N = 8)		Fungi[a] (N = 8)		Fungi[c] (N = 4)	
Lower Floor	1.3-6.1	(3.40)	0.6-4.8	(2.60)	u.d.-0.08	(0.03)	24.3-53.6	(44.60)	u.d.-2.8	(0.04)
Pre-sort Cabin	2.0-9.0	(3.16)	0.6-7.4	(2.20)	0.02-0.56	(0.18)	23.8-56.2	(37.00)	u.d.-1.1	(0.58)
Plastics Cabin	2.5-29.2	(19.80)	0.5-25.1	(5.36)	u.d.-1.52	(0.12)	11.8-208.7	(88.64)	0.08-33.2	(9.04)
Paper Cabin[d]	1.9-8.5	(5.32)	1.2-7.6	(6.56)	u.d.-0.04	(0.02)	18.8-149.9	(19.68)	u.d.-12.1	(5.86)
Upper Floor	1.7-19.6	(3.24)	0.4-17.9	(1.52)	u.d.-0.32	(0.03)	6.8-78.7	(23.40)	0.08-3.2	(0.76)
Offices	1.0-18.2	(4.08)	0.8-16.1	(3.16)	u.d.-0.08	(0.02)	2.4-13.8	(7.60)	u.d.-6.0	(4.38)
Rest Room	1.7-8.8	(2.68)	0.8-9.3	(1.68)	u.d.-0.04	(0.02)	1.6-21.6	(13.92)	u.d.-12.1	(2.22)
MRF B	**Bacteria[a] (N = 8)**		**Bacteria[c] (N = 8)**		**Gram-negatives[b] (N = 8)**		**Fungi[a] (N = 8)**		**Fungi[c] (N = 4)**	
Tipping Floor	0.8-69.6	(8.84)	0.6-2.7	(1.88)	u.d.-0.04	(0.02)	4.0-29.9	(9.72)	0.04-0.2	(0.16)
Tipping Pit	4.7-39.1	(19.60)	1.1-15.3	(5.16)	u.d.-0.40	(0.02)	6.4-134.3	(9.40)	0.04-2.0	(0.76)
Sorting	3.9-14.8	(6.60)	1.8-5.7	(2.16)	u.d.-0.08	(0.02)	7.3-102.0	(13.84)	u.d.-1.6	(0.54)
Residue Area	2.9-11.0	(4.60)	1.5-12.8	(2.16)	u.d.-0.04	(0.02)	4.4-32.1	(15.92)	u.d.-1.6	(0.50)
Baling Area	4.5-60.0	(20.24)	1.2-8.0	(3.44)	u.d.-0.04	(0.02)	2.4-44.0	(17.20)	u.d.-1.8	(0.66)
Offices	4.4-14.6	(12.88)	2.3-7.3	(5.04)	u.d.-0.08	(0.02)	2.3-7.6	(5.80)	u.d.-1.7	(0.62)
Rest Room	6.3-36.2	(13.92)	2.8-9.4	(5.76)	u.d.-0.40	(0.03)	4.7-47.3	(10.76)	0.04-4.4	(2.20)
New Baler[d]	3.0-45.2	(12.08)	1.7-13.8	(2.12)	u.d.-0.04	(0.02)	24.0-237.5	(39.76)	2.4-4.0	(3.24)

[a] At 25°C; [b] At 37°C; [c] At 40°C; [d] N=6 for bacteria at 25°C/40°C, Gram-negatives and fungi at 25°C; u.d. undetectable.

device, the Mini-Wright Peak Flow Meter, was used. Operatives were given instructions on how to use the peak flow meter according to the manufacturer's recommendations, and were given a visual demonstration. Recordings taken on the first day were discounted to take into account the effect of learning, and were carried out every third hour for 14 days at work and at home. Operatives were asked to record three readings five times a day, but repeat recordings if the difference between the two highest readings was over 10%. They were also asked to record their activity, for example paper sorting at work, or reading at home. Smokers were detected by questionnaires. Operatives with learning difficulties were not able to use peak flow monitors successfully over the required period. Further research into MRFs employing operatives with learning difficulties will need to address this.

Questionnaires to detect symptoms of organic dust exposure were also used. The questionnaire chosen was adapted from a proposal for a standardised questionnaire to detect symptoms related to organic dust exposure developed by a working group [11]. Questions on atopy were added as this was not covered by other aspects of the study. The questionnaire was administered by short interview in conjunction with an Occupational Health Nurse. It was necessary to simplify questions for operatives with learning difficulties for clearer understanding. A control group undertaking light packing work was asked the same questions using the same format for later comparison. This group had 63% of individuals with learning difficulties.

RESULTS AND DISCUSSION

Waste entered both MRFs from three main sources:

- Source separated kerbside programmes;
- Drop-off sites;
- Commercial sources.

Items in the waste stream thought to create air quality problems included recyclable items not accepted, such as some plastics; non-recyclables, such as large lumps of steel scrap; hazardous wastes, such as medical materials; and cross-contaminants, such as putrescible items. Up to 70% of plastics contained a residue. Often these problems are due to over-enthusiastic recyclers - they think all materials can be recycled if a programme accepts some types. It was concluded that, at present, both recyclables and waste come from numerous uncontrolled sources with varied quality at both MRFs.

At present there are no standardised monitoring protocols for measuring bioaerosols, and there is a large degree of uncertainty over the types of method available [4, 5, 12]. Factors considered when designing an air sampling methodology here included: type of sampling (static or personal); expected contaminant (bacteria, actinomycetes or fungi); concentrations of likely airborne microorganisms; importance of particle size separation; whether microorganisms were prone to dehydration or overgrowth by others; and flow rate of air.

Table 1 shows median and range of viable counts (cfu/m^3) obtained throughout 1 year at MRF A and B. Levels of bioaerosols were below those reported in other literature, particularly in composting [8]. Use of the Kruskal-Wallis test revealed a highly significant difference

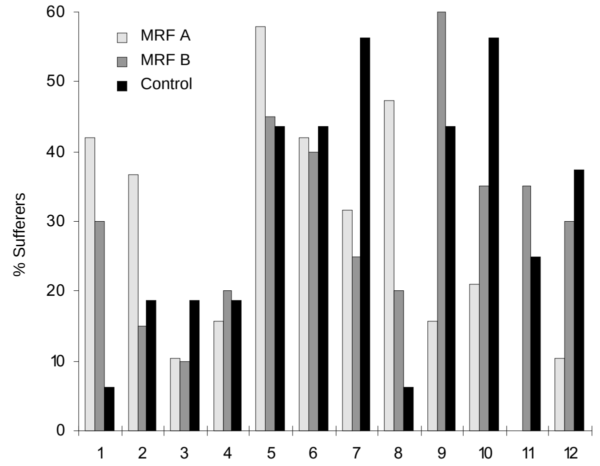

Figure 1. Frequency distribution of symptoms among workers in two materials recovery facilities and in the control group. Symptoms: 1, Dry cough; 2, Cough + phlegm; 3, Wheezing; 4, Chest tightness; 5, Nasal irritation; 6, Throat irritation; 7, Headache; 8, Nausea; 9, Tiredness; 10, Joint pains; 11, Skin problems; 12, Eye irritation.

($p = 0.001$) within microbiological parameters between sites at MRF A with fungi at 25°C. Significant differences ($p = 0.05$) were also recorded for Gram-negatives at MRF A, and for bacteria at 40°C and fungi at 25°C at MRF B. Tests for differences between work stations were borderline significant for bacteria at 25°C in both MRF A and B ($p = 0.055$ and $p = 0.078$, respectively).

At MRF A the highest counts of bacteria and fungi were obtained during plastic and paper sorting within enclosed cabins. At MRF B tipping, sorting and baling operations showed the highest counts. For species of fungi, approximately 80-95% were *Penicillium* spp., although *Aspergillus fumigatus* and *Cladosporium* spp. were also present. Most particles (up to 90%) were deposited among stages 3-4 of the Andersen Sampler. Levels of Gram-negative bacteria were low throughout both MRFs, and were almost non-existent on personal samplers. Endotoxin still remains to be measured as part of a European BIOMED2 Programme.

Table 2. Profile of individuals questioned.

Category	MRF A	MRF B	Control Group
No. Individuals	19 (1 female)	20 (3 females)	16 (10 females)
Age Ranges	20–55	19–54	19–72
Work History	2 months–2 yrs	1 month–6 yrs	2 months–11 yrs
Smoking History	42% smokers	25% smokers	6% smokers
	37% history	35% history	19% history

Personal sampling results (not listed in full here) recorded levels of fungi up to 3.8×10^5 cfu/m^3 and 3.4×10^5 cfu/m^3 during plastics sorting at MRF A and MRF B respectively. Total dust levels were high when paper sorting at MRF A (up to 18 mg/m^3), and the plastic cabin and tipping floor recorded 16.3 and 15.5 mg/m^3 respectively. At MRF B total dust levels were highest when sweeping tipping floors at 12.5 mg/m^3, and the sorting conveyor recorded a level of 10.6 mg/m^3.

Corrected results from peak flow monitors showed a majority of the 10 individuals who took part had some variability, in the region of 13-19%. Two operatives decreased by 100 l/min during a 24 hour period, possibly due to a reaction when changing jobs within MRFs, and four had in excess of 20% variability over the two week period. However, this data remains to be examined in more detail.

Previous questionnaires used in the UK to identify health effects associated with waste handling include one developed for use at landfills and transfer stations [4]. This included questions on work, smoking habits and

Table 3. Percentage of symptoms at MRF A, MRF B and in the control group.

Symptoms (%)	MRF A			MRF B			Control Group		
	Yes[a]	NW[b]	DK[c]	Yes[a]	NW[b]	DK[c]	Yes[a]	NW[b]	DK[c]
Dry Cough	26.3	10.5	5.2	5	10	15	0	6.2	0
Cough & Phlegm	26.6	0	10.5	5	0	10	0	18.7	0
Wheezing	10.5	0	0	0	5	5	0	18.7	0
Chest Tightness	15.8	0	0	10	0	10	6.2	12.5	0
Nasal Irritation	57.9	0	0	15	5	25	12.5	31.2	12.5
Throat Irritation	42.1	0	0	10	5	25	18.7	12.5	12.5
Headache	31.6	0	0	10	5	10	6.2	50	0
Nausea	47.4	0	0	5	5	10	6.2	0	0
Tiredness	10.5	0	5.2	25	15	20	18.7	25	0
Joint Pains	5.2	0	15.8	15	10	10	18.7	25	0
Skin Problems	0	0	0	25	5	5	0	25	0
Eye Irritation	10.5	0	0	20	5	5	6.2	31.2	0

[a]Yes, symptoms are related to work; [b]Yes, there are symptoms but they are not related to work; [c]Yes, there are symptoms but it is unknown if they are related to work.

symptoms such as coughing, breathing and chest difficulties, headaches, irritations and skin disorders. Certain drawbacks were recognised from this questionnaire, such as phrasing, and conclusions indicated problems would need further examination. A questionnaire used by the UK Health and Safety Executive for operatives working with known respiratory sensitisers, intended as part of a health surveillance programme, was also considered [6]. However, questions were too brief, and did not allow for symptoms such as those known when exposed to organic dusts.

In total 55 individuals were questioned, and their profile can be seen in Table 2. Results from the surveys are shown in Figure 1. In many categories the control group seems to exceed both MRF A and B in symptoms, such as throat and eye irritation, headache and joint pains. However, when these figures are grouped according to whether the individual believes their symptoms are attributable to work or not (see Table 3) it can be seen that these apparent anomalies are further explained. Figures for MRF A are not much changed, operatives here are quite certain their symptoms are related to work, apart from a small percentage with cough and phlegm and dry cough (thought due to smoking) and tiredness and joint pains. Operatives in MRF B were more uncertain as to the cause of their symptoms. Tiredness, at 60%, falls to 25% certain it is related to work, with 15% believing it was not related to work and 20% uncertain. In fact all reported symptoms at MRF B are reduced, with many operatives unsure of their origin. It is possible this is attributable to a higher percentage of operatives with learning disabilities. With the control group it can be seen that many of the symptoms experienced were not thought linked to work, many of these individuals believed other causes to be the source of their symptoms, such as hot weather, sinus trouble, migraine or arthritis. This may account for raised percentages relating to headache, nausea, tiredness and joint pains. These issues are currently undergoing further investigation as it is thought self-reporting may have affected results, with individuals at MRF A over-reporting and at MRF B under-reporting.

CONCLUSIONS

Issues such as waste inputs, their origin and MRF operations and design remain to be examined in more detail and linked with health effects within MRFs. Although peak flow monitoring and questionnaires have revealed a variety of health issues, more research is needed in this important area. Longitudinal studies, to monitor operatives before they start work and during the course of their employment are also needed.

Management and mitigation issues also need to be addressed, including development of information, education and training for the employees, and adoption of these practices. Currently, development of an approach to provide comparable data between different types of MRF is being considered. Employer investment as well as issues such as liability and health care for MRF operators within the EU also need to be evaluated. The concept of risk assessment, risk minimisation and employee protection already in EU health and safety directives needs to be further examined in this context.

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