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BIOAEROSOL EXPOSURE DURING HANDLING OF SOURCE SEPARATED HOUSEHOLD WASTE*

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Abstract: In this study the exposure level of microorganisms, endotoxins and dust among workers using different collection equipment for source separated household waste were compared to collection of unsorted waste. In addition, exposure levels among workers at composting plants were estimated. Municipalities that implemented full-scale source separation system using different equipment were selected: closed container with two wheels (Kristiansand), compostainer (aerated container with two wheels) (Innherred) and source separating cabinet (Senja). The collection systems for unsorted waste were closed containers and plastic sacks in sack holders. Samples were collected by personal sampling for eight hours each day during one week both in the summer and winter time. Measurements of sorted and unsorted waste collection were done on the same day. At the composting plant exposure levels were estimated during separate work operations. No significant differences were found between exposure levels of microorganisms during collection of biowaste and unsorted waste except for the compostainer/sack system in the summer. There was a significantly higher exposure level (total count 3.6×10^6 cells/m^3) using low loading (1 m) compared to loading at 1.8 m (0.8×10^6 cells/m^3). The residual fraction (collection frequency of 4 weeks) showed the same exposure level as biowaste (1.3×10^6 cells/m^3). Comparisons between the systems for biowaste indicated a higher exposure level for closed container (3.6×10^6 cells/m^3) than the compostainer (1.2×10^6 cells/m^3) in the summer, which decreased to (0.4×10^6cells/m^3) in the winter while the compostainer did not, probably due to the heat produced in the composting process. Exposure levels to endotoxins during waste collection were very low (< 8 EU/m^3). At the composting plant the endotoxin concentration was moderate, but reached 170 EU/m^3 in only one sample in which also the microorganisms concentration was high. Samples collected during work in closed cabins were substantially lower.

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INTRODUCTION

Problems concerning the continuously increasing waste production have initiated a great interest in efforts to reduce the current environmental pollution from landfills. The environmental government in Norway have therefore developed action plans aiming at increased recycling of domestic waste during the next decade.

Large investments are needed for establishment of new waste collection systems like source separation systems for household waste and recycling plants. The number of employees occupied with waste collection and recycling is also expected to increase because a larger part of the domestic waste will be source separated. It is of most importance to ensure a healthy work environment when such new systems and plants are implemented.

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Recent studies have shown that workers at waste-handling plants and composting plants may have more gastrointestinal symptoms, irritation of the skin, eye and throat, respiratory disorders including organic dust toxic syndrome (ODTS; toxic pneumonitis) than in other occupations [12, 13]. The knowledge of the cause of these health problems among waste collectors is limited however. The occurrence of these symptoms is also known to be high in other work environments where the workers are exposed to high levels of bioaerosols, containing mould spores, bacteria, endotoxin, volatile organic and inorganic compounds and gases produced by bacteria [15].

At present, only a few studies have reported bioaerosol exposure levels during collection of household waste [1, 2, 5, 9, 11, 14]. The purpose of the present study was to estimate the exposure levels of microorganisms and endotoxin among workers using different collection systems for source separated household waste. As many factors may be different between the systems, the levels were compared to collection of traditional unsorted waste in the same region at the same time. In addition, exposure levels among workers at composting plants were estimated.

The study is a part of the program «Source separation in Urban Areas and Rural Communities» initiated by the Norwegian Pollution Control Authority (SFT). The aim of this program is to evaluate the feasibility of full-scale source separation of household waste in eight different regions.

MATERIAL AND METHODS

Waste collection system. The following different systems for collection of source separated waste from regions participating in the full-scale project for at least one year were selected for the study: (1) closed container (from 120 l to 240 l) on two wheels in Kristiansand, a city at the south coast of Norway; (2) compostainer, an aerated container (120 l) on two wheels at Innherred, an inland community in the middle of Norway with a moderate population density; (3) source sorting cabinet containing four boxes with a volume of ca. 8 l at Senja, an island situated at the northern coast with low population density (Tab. 1).

The compostainer is based on an aerated decomposition of the waste and has ventilation holes at the top and sides. The purpose is to start a composting process. The households are asked to mix the waste with structure material. A grid in the bottom separates the waste from the draining. Microbial growth in the waste may lead to an increased temperature, and evaporation may to some extend dry out the waste.

Sampling strategy and procedure. There are many sources of variation that may affect the exposure level of microorganisms when waste is collected. The influence of the composition of the waste, region and weather condition was limited by a comparative design where conventional waste collection and collection of source separated waste were measured on the same days in the same region.

With the assumption of an exposure variability with a geometric standard deviation of 4, a difference between systems of a factor of 4 would be detected with 95% probability when 10 personal samples of each collection system for biowaste are collected. Samples were collected both in the summer and in the winter time in each area to study the seasonal differences. Personal samples were collected during a full working shift.

At the composting plants the exposure levels during separate work operations were estimated.

Table 1. Systems for collection of source separated waste and unsorted waste in three different regions of Norway.

		Region		
		Kristiansand, urban	Innherred, rural, moderate population density	Senja, rural, low population density
Waste collection systems:				
Biowaste		container with 2 wheels	compostainer	source-sorting cabinet
Residual waste		container with 2 wheels	container with 2 wheels	plastic sack
Mixed waste		container with 2 wheels	plastic sack	plastic sack
Collection frequency:				
Biowaste	summer	weekly	every fortnight	every fortnight
	winter	every fortnight	every fortnight	every fortnight
Residual	summer	every fortnight	every fourth week	every fortnight
	winter	-	every fourth week	every fortnight
Mixed waste	summer	weekly	weekly	weekly
	winter	weekly	weekly	weekly
Number of households		28 000	3 500	3 500
Collected biowaste (kg person $^{-1}$ year $^{-1}$)		60	80	50
Produced compost (10^3 kg)		4 500	875	355

Table 2. Exposure levels of microorganisms, endotoxin and dust during collection of waste in three different regions, using different waste collection equipment (summer time).

Region	Type of waste	Truck/ loading point	Collection equipment	Exposure level during working day in summer*				
				Total counts 10^6 cells/m^3	Fungal spores %	Endotoxin EU/m^3	Total dust mg/m^3	Significance
Kristiansand	bio	low	closed container	3.6 (2.9 - 6.2) (4)	44	7.5 (2.1-16.2) (4)	0.9 (0.1-1.0) (4)	a
	bio	moderate high	closed container	0.8 (0.1- 2.2) (15)	25	1.7 (0.0-3.2) (9)	0.1 (0.0-0.2) (9)	a
	unsorted	low	closed container	2.4 (0.8-18.0) (12)	25	6.0 (0.6-13.0) (3)	1.5 (0.1-1.8) (3)	
	residual	low	closed container	0.4 (0.2-1.4) (5)	25	-	-	
Innherred	bio	low	compostainer	1.2 (0.4-2.2) (6)	67	3.6 (1.2-39.4) (8)	0.4 (0.1-1.5) (8)	b
	unsorted	low	plastic sack	0.3 (0.1-11.6) (16)	0	3.2 (0.8-6.7) (11)	0.2 (0.2-1.3) (11)	b
	residual	low	closed container	1.3 (0.3-2.0) (5)	39	19.0 (1)	1.3 (1)	
Senja	bio-residual	two chamb./ moderate high	source sorting cabinet	1.0 (0.4-1.8) (4)	70	1.8 (0.4-7.6) (5)	0.2 (0.1-0.3) (5)	
	unsorted	low	plastic sack	0.4 (0.1-1.1) (5)	0	1.4 (0.3-6.6) (5)	0.2 (0.1-0.2) (5)	

* The results are given as median (range) (number of measurements). Wilcoxon, Mann-Whitney test a: $p < 0.01$, b: $p < 0.05$.

Exposure measurements. Each worker carried two field monitors for collection of bioaerosols situated at each side of the workers chest. One monitor was used for determination of the concentration of «total dust» and endotoxins, the other monitor was used for determination of microorganisms. Both samples were collected on polycarbonate filter (25 mm, 0.4 µm) using a closed face Nuclepore field monitor made of graphite filled propylene (Nuclepore, Pleasanton, California) and operated at an airflow of 1.5 l/min.

Microorganisms. Microorganisms were quantified by a modification of the CAMNEA-method [7] which includes determination of airborne microorganisms by epifluorescence microscopy (total counts). The numbers of microorganisms observed in not countable aggregates were estimated using a linear regression method [7]. The microorganisms were classified as cocci or rod shaped bacteria and fungal spores.

Dust and endotoxins. Collected mass of total dust was determined by gravimetry in an air-conditioned room. Endotoxin analysis was assayed in duplicate samples using a quantitative kinetic method, *Limulus* Amoebocyte Lysate test (Kinetic-QCL kit, Bio Whittaker). A standard curve obtained from *Escherichia coli* reference endotoxin was used to determine concentration of endotoxin units in the air (EU/m^3). If desired, the concentration can be converted to nanograms/m^3 using 1 ng = 15 EU.

Data analysis. Non-parametric statistics (Mann-Whitney test) were used as measurement data were not normally distributed. The median and range of the measurements are given in the text and tables.

RESULTS

Exposure during collection of waste. The exposure level of total microorganisms and the proportion of fungal spores, endotoxins and total dust during collection of waste are presented in Table 2 (summer measurements) and Table 3 (winter measurements). As samples from each fraction in the three different systems were collected on the same day, comparisons can be made between the systems within the same regions. The results indicate that there is no significant difference between the exposure level during collection of biowaste and unsorted waste, except for collection of biowaste using the compostainer and collection of unsorted waste using the traditional plastic sack system in the summer at Innherred. No significant differences between exposure levels during collection of biowaste and unsorted waste within the systems were seen in the winter measurements.

There was a significantly ($p < 0.01$) higher exposure level using trucks with loading point at approximately 1 meter (total counts 3.6×10^6 cells/m^3), compared to a higher loading point at approximately 2 meter (0.8×10^6 cells/m^3). The residual fraction collected in closed container in the system of Innherred, collected with a frequency of four weeks (Tab. 1), showed a slightly higher exposure level than biowaste (1.2×10^6 cells/m^3), but the difference was not significant.

The results show a significant decrease in the exposure levels from summer to wintertime using the closed container ($p < 0.05$). A very low temperature of -10°C was recorded in Kristiansand in the wintertime, and the exposure level decreased from $0.8–3.6 \times 10^6$ cells/m^3 to 0.4×10^6 cells/m^3 for all fractions. The same seasonal variation were not found using the compostainer at Innherred and source sorting cabinet at Senja. The proportion of fungal

Table 3. Exposure levels of microorganisms, endotoxin and dust during collection of waste in three different regions, using different waste collection equipment (winter time).

Region	Type of waste	Truck/ loading point	Collection equipment	Exposure level during working day in winter*				
				Total counts 10^6 cells/m^3	Fungal spores %	Endotoxin EU/m^3	Total dust mg/m^3	Signi-ficance
Kristiansand	bio	low	closed container	0.4 (0.2-1.3) (7)	25	0.2 (0.2-0.2) (2)	0.2 (0.2-0.3) (2)	a
	bio	moderate high	closed container	0.4 (0.2-0.6) (10)	50	0.0 (2)	0.1 (0.1-0.2) (2)	a
	unsorted	low	closed container	0.4 (0.1-0.8) (3)	0	4.4 (0.8-8.0) (2)	0.5 (0.2-0.5) (2)	
Innherred	bio	low	compostainer	2.0 (0.3-5.7) (6)	43	4.0 (2.4-5.6) (2)	0.1 (0.1-0.4) (2)	
	unsorted	low	plastic sack	0.5 (0.2-1.1) (8)	0	2.9 (2.8-2.9) (2)	0.3 (0.1-0.3) (2)	
	residual	low	closed container	1.0 (0.8-2.4) (4)	0	2.0 (1.1-6.0) (4)	0.2 (0.1-0.5) (4)	
Senja	bio-residual	two chamb./ moderate high	source sorting cabinet	0.8 (0.1-2.5) (4)	50	0.5 (0.2-1.1) (3)	0.2 (0.2-0.3) (3)	
	unsorted	low	plastic sack	0.4 (0.2-0.4) (5)	0	0.3 (0.1-0.5) (3)	0.1 (0.1-0.2) (3)	

***** The results are given as median (range) (number of measurements). Wilcoxon, Mann-Whitney test a: $p = 0.01$.

spores in the samples was higher in the summer time and ranged from 0 to 70% of the total microorganisms.

Collection of biowaste using closed container indicated a higher exposure than the compostainer. We must take into consideration a warm and sunny period (20°C) during the storage time of the waste, that may have caused an increased microbiological growth in the container. The highest proportion of fungal spores were found in the biowaste fraction using the compostainer (67%) and source sorting cabinet (70%).

The endotoxin levels during collection of sorted and unsorted waste were low. Median levels were from 1 to 19 EU/m^3 during the summertime and from 0 to 4 EU/m^3 during wintertime. Individual measurements were not higher than 40 EU/m^3. There were significantly higher exposure levels to endotoxin during the summertime ($p < 0.01$).

The total dust concentration was also low, with median levels from 0.1 to 1.5 mg/m^3 during the summer and 0.1 to 0.5 mg/m^3 in the wintertime. The highest individual measurement was 1.8 mg/m^3. There was no significant difference between summer and winter measurements.

Exposure at composting plants. Workers at the composting plants using no protection against the exposure during work operations were exposed to high levels of microorganisms (> 10×10^6 cells/m^3) (Table 4 and Table 5). Exposure during turning of piles using trucks with closed cabin was below 5×10^6 cells/m^3 and during compacting waste at the landfill was even lower (< 0.1×10^6 cells/m^3). The proportion of fungal spores was high at composting plants for biowaste collected with compostainer (ca. 10%) and source sorting cabinet (ca. 40%).

The endotoxin levels were higher than during collection of waste with median levels from 0 to 67 EU/m^3, and one individual measurement reached 174 EU/m^3. A proportion of rod shaped bacteria were found in the samples with high level of endotoxins, and also actinomycetes (Table 4

Table 4. Exposure levels of microorganisms, endotoxin and dust during different work operations at composting plants (summer time).

Composting plant	Work operation	Closed cabin/ ventilation	Exposure level during work operations in summer*			
			Total counts 10^6cells/m^3	Endotoxin EU/m^3	Total dust mg/m^3	n
Kristiansand/Holskogen	turning piles	yes	1.2 (0.6-5.3)	2.8 (0.0-10.7)	0.1 (0.1-0.3)	9
	control measurements of piles	no	13.2 (5.7-20.7)	12.1 (8.4-15.7)	0.5 (0.3-0.7)	2
	sieving	yes	0.4	2.0	0.1	1
	clearing between piles	no	23.4^A	174.0	1.1	1
	compaction of waste	yes	< 0.1	0.0	0.2 (0.2-0.3)	2
Innherred/Mule	turning piles	yes	0.7 (0.5-2.6)	6.4 (4.6-38.5)	0.3 (0.2-0.4)	6
Senja	turning piles	no	10.6 (5.0-13.3)^A	68.6 (18.2-109.2)	0.2 (0.1-0.4)	5
	control measurements of piles	no	0.6 (0.4-2.6)	6.9 (4.5-17.1)	0.1 (0.1-1.1)	5

* The results are given as median and range. ^{A} Registration of rod shaped bacteria

Table 5. Exposure levels of microorganisms, endotoxin and dust during different work operations at composting plants (winter time).

Composting plant	Work operation	Closed cabin/ ventilation	Exposure level during work operations in winter*			
			Total counts 10^6cells/m^3	Endotoxin EU/m^3	Total dust mg/m^3	n
Kristiansand/Holskogen	turning piles	yes	0.7 (0.4-1.0)	1.4 (0.4-1.7)	0.1 (0.0-0.1)	4
	control measurements of piles	no	1.1 (0.8-1.4)	2.4 (1.6-3.2)	0.1 (0.1-0.1)	2
Innherred/Mule	turning piles	yes	0.7 (0.1-1.3)	3.0 (0.6-11.4)	0.2 (0.1-0.3)	6
Senja	turning piles / control measurements of piles	no	1.4 (0-5.6)^A	2.2 (1.0-4.6)	0.1 (0.1-0.2)	8

***** The results are given as median and range. ^{A} Registration of rod shaped bacteria

and Table 5). The endotoxin levels decreased significantly during wintertime ($p < 0.001$).

The concentrations of dust at the composting plants were low. The personal measurements ranged from 0.0 to 1.1 mg/m^3, and there was a significant decrease between summer and winter measurements ($p < 0.01$).

DISCUSSION

The level and composition of the aerosols generated during handling of waste depends on several factors including the type and composition of the waste, the type of microorganisms in the waste, the weather condition, number of households in the district, type of collection equipments, trucks and the collection procedure. Comparisons between systems are therefore difficult.

In this comparative study where exposure measurements during collection of biowaste and unsorted waste are performed at the same days, we can do comparisons within the regions, assuming that the composition of the waste, the storage time and number of households are approximately the same.

General exposure level. The results show that the exposure level of microorganisms during collection of waste is relatively high during the summer. 50% of the measurements were higher than 1×10^6 cells/m^3. Studies of other populations indicate that health effects may occur at this level [6]. The levels decreased by a factor of two during the winter.

The endotoxin level during collection of waste was low and no individual measurement exceeded the level where health effects can be expected (120 EU/m^3 to 150 EU/m^3). The exposure to dust was also low.

The concentrations of microorganisms, endotoxin and dust during collection of waste are similar to levels reported earlier [1, 2, 11], but somewhat higher than results reported during collection of unsorted waste in the summer time (0.5×10^6 cells/m^3) [10]. The exposure levels of fungal spores were somewhat higher in the Danish reports using viable methods.

Type of waste. The exposure level during collection of biowaste was higher compared to collection of unsorted waste. The differences were not significant except for collection of biowaste using the compostainer compared to collection of unsorted waste using the traditional plastic sack system in the summer at Innherred.

The collection of the residual fraction collected with container at Innherred every fourth week, showed similar exposure levels as collection of biowaste (1.2×10^6 cells/m^3), probably due to contamination and storage for a long time.

Type of truck. The data obtained indicated that low loading was associated with high exposure compared to high loading during the summer. This was also found in a Danish study which reported a reduction of the exposure from 3 to 14 times using trucks with high loading, curtain and exhaust system [2, 16]. This difference was not seen in the exposure levels at our study during the winter.

Temperature and season. The influence of the temperature on the microbial growth in the waste and consequently also on the exposure level may be expected to be substantial [11]. This may explain the decrease in the exposure level from summer to winter in Kristiansand. On warm sunny days in the summer with temperatures > 20°C, 52% of the measurements were above 10^6 cells/m^3 while during cold winterdays (-10°C) only 6% of the measurements were above 10^6 cells/m^3. The humidity and fall of rain or snow were approximately the same, so the differences may be related to the temperature and possible variations in the composition of the waste.

Corresponding seasonal variations in the exposure level were not registered using the compostainer and the source sorting cabinet. The lower outdoor temperature from +12°C in the summer to -5°C in the winter may not have influenced the microbial growth in the waste, probably due to the heat produced in the waste by the composting process. A study of the influence of temperature on compostable household waste, kept in open air at an ambient temperature varying from 0°C to 20°C reported that the temperature in the waste in paper sacks reached 45–50°C after ten days, while waste kept in plastic sacks had a temperature close to the ambient [8]. The decrease in the temperature from +10°C to -5°C at Senja did not cause any reduction in the exposure level. This may be due to removal of the plastic curtain along the roof above the scoop of the collection truck in winter. This may have increased the exposure levels. Controlled experiments carried out in the laboratory showed that the existence of a curtain and exhaust equipment may reduce waste collectors' bioaerosol exposure [2].

Comparison of systems. It is difficult to compare the source sorting systems because of the many factors that may influence the exposure level between the different regions. However, adjusting for the different number of households, the temperature during sampling (ca. 12°C) and type of truck used (loading point at 1 meter), there was a higher exposure level during collection of biowaste in closed bin (3.6×10^6 cells/m^3) compared to the compostainer (1.2×10^6 cells/m^3). We must however take into consideration a warm period in Kristiansand during the storage time of the waste (ca. 22°C), while it was relatively cold at Innherred (ca. 12°C). At Senja it was raining heavily during both the storage time and the week of the sampling. They used in addition a two chambered collection truck with curtain for simultaneous collection of biowaste and residual waste, and the comparisons with the other systems are therefore difficult.

Also other studies have found that the exposure level to microorganisms appears to be related to the type of equipment used. The level of viable mould spores and endotoxin was higher when waste was collected in closed bins using a compactor truck compared to sacks collected by platform truck [11, 12].

A higher but not significant exposure to mould spores was found using the compostainer and source sorting cabinet compared to closed container. In the compostainer, which is based on an aerated decomposition of the waste, an increased temperature will lead to evaporation of water from the content. In the source sorting cabinet there is also to some extent access to air. The lower humidity will favour the growth of moulds. Loss of moisture may also increase the dustiness of the biowaste and therefore its potential to emit bioaerosols during handling operations [3]. This is not in accordance with results from this study which indicates that the exposure levels to microorganisms using compostainer and source sorting cabinet are lower compared to the container with more moisture content.

Composting plants. At the composting plant more than 60% of the measurements were higher than 10^6 cells/m^3 during the summer but exposure levels decreased with a factor of ten during the winter. The endotoxin levels were higher than during collection of waste, but still not near the level where health effects may occur [4], except for two measurements. During this work operation, the workers did not use any personal respiratory protection.

CONCLUSIONS

In this study we have estimated the personal exposure to airborne microorganisms and endotoxins during collection of source sorted and unsorted waste using different types of collection equipment. Exposure to microorganisms during collection of biowaste did not differ significantly from collection of unsorted waste except for the compostainer compared to the sack system during the summer time. A seasonal difference in the exposure level was registered using the closed container. Exposure levels to microorganisms during collection of all waste fractions during the summer are fairly high compared to levels associated with health effects, while personal exposure to dust and endotoxins were low. Exposure levels during the winter time were lower by a factor of two compared to levels in the summer. Waste collectors were significantly lower exposed when they used a truck with a loading at 2 meter, a curtain and exhaust ventilation, compared to a truck loaded at a level of 1 meter in the summer.

Workers at composting plants without personal protection can be exposed to high levels of microorganisms and moderate levels of endotoxin. Some individual samples reached the proposed «no effect level» of 120-150 EU/m^3 for endotoxins.

REFERENCES

1. Breum NO, Ebbehøj N, Hansen AAM, Ivens U, van Lelieveld D, Nielsen BH, Nielsen EM, Poulsen OM, Schibye B, Stenbaek EI, Wilkins KC, Juul-Kristensen B: Interventionundersøgelse System 2000. Eksponeringer og helbredseffekter ved skift fra indsamling of usortert affald til 4-strømsindsamling of kildesorteret husholdningsaffald. National Insitute of Occupational Health, Copenhagen (Internal report) 1994.
2. Breum NO, Nielsen BH, Nielsen EM, Poulsen OM: Eksponering for luftforurening ved indsamling af husholdningsaffald ved anvendelse af komprimatorvogne med og uden udsug. Report Nr. 2, National Insitute of Occupational Health, Copenhagen 1995.
3. Breum NO, Nielsen BH, Nielsen EM, Midtgaard U, Poulsen OM: Dustiness of compostable waste: A methodological approach to quantify the potential of waste to generate airborne microorganisms and endotoxin. *Waste Management & Research* (in press).
4. Castellan RM, Olenchock SA, Kinsley KB, Hankinson JL: Inhaled endotoxin and decreased spirometric values. *N Engl J Med* 1987, **317**, 605-610.
5. Ducel G, Pitteloud JJ, Rufèner-Press C, Bahy M, Rey P: Importance de l'exposition bactérienne chez les employés de la voirie chargés de la levée des ordures. *Médecine Sociale et Préventive* 1976, **21**, 207-222.
6. Eduard W, Sandven P, Levi F: Exposure and serum IgG antibodies to mould spores in wood trimmers: Exposure-response relationship with respiratory symptoms. *Appl Occup Environ Hyg* 1994, **9**, 44-48.
7. Heldal K, Skogstad A, Eduard W: Improvements in the quantification of airborne microorganisms in the farm environment by epifluorescence microscopy. *Ann Occup Hyg* 1996, **40**, 437-447.
8. Mortensen B, Domela H: Bates Combi System - a new Danish waste collection system. *Proc Biowaste'95, 2nd Int. Conf. and Exhibition Forum on Biological Waste Treatment*, 21-24 May 1995, Aalborg (in press).
9. Nielsen BH, Würtz H, Holst E: Endotoxin and microorganisms in percolate derived from compostable domestic garbage. *Am J Ind Med* 1994, **25**, 121-122.

10. Nielsen EM, Nielsen BH, Breum NO: Occupational bioaerosol exposure during collection of household waste. *Ann Agric Environ Med* 1995, **2**, 53-59.

11. Nielsen EM, Breum NO, Ebbehøj N, Ivens UI, Nielsen BH, Poulsen OM, Stenbæk EI, Wilkins CK, Midtgård U: *Eksponeringsvurdering samt helbredsstatus for skraldemænd der indsamler komposterbart husholdningsaffald. Report Nr. 7*. National Insitute of Occupational Health, Copenhagen 1996.

12. Poulsen OM, Breum NO, Ebbehøj N, Hansen ÅM, Ivens UI, van Lelieveld D, Malmros P, Matthiasen L, Nielsen BH, Nielsen EM, Schibye B, Skov T, Stenbaeck EI, Wilkins CK: Collection of domestic waste. Review of occupational health problems and their possible causes. *Sci Tot Environ,* 1995, **170,** 1-19.

13. Poulsen OM, Breum NO, Ebbehøj N, Hansen ÅM, Ivens UI, van Lelieveld D, Malmros P, Matthiasen L, Nielsen BH, Nielsen EM, Schibye B, Skov T, Stenbaeck EI, Wilkins CK: Sorting and recycling of domestic waste. Review of occupational health problems and their possible causes. *Sci Tot Environ,* 1995, **168,** 33-56.

14. Sørensen C, Bjørnstrup H: Indsamling af madaffald fra husstande i København. Miljøprosjekt nr. 220, Miljøstyrelsen, Copenhagen 1993.

15. Wilkins CK: Volatile organic compounds (VOC's) from household waste. *Chemosphere* 1994, **29**, 47-53.

16. Würtz H, Breum NO, Midtgård U, Poulsen OM, Nielsen M, Nielsen BH: Exposure to bioaerosols during waste collection. *Abstracts of the International Meeting on Waste Collection and Recycling*, 13–14 September 1996, Køge, Denmark.