

Outdoor work exposure influences waste collection workers' exposure to airborne fungal and bacterial species in truck cabs



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The aim of this study was:

- to examine domestic waste collectors' exposure to airborne inhalable fungal and bacterial species and endotoxin during waste collection, and while seated in the truck cabs,
- and to acquire knowledge on transport of airborne fungi, bacteria and endotoxin from the outdoor work with waste collection and into the truck cab.

What is handled?

	Part of overall waste quantity, % wet	Part of overall waste quantity, % dry
Vegetable waste	31.08	7.15
Animal waste	9.88	4.23
Newsprints	3.73	3.25
Magazines	1.02	0.96
Advertisements	3.61	3.29
Books and phonebooks	0.16	0.14
Office paper	0.81	0.74
Clean paper	1.50	1.39
Paper and carton containers	1.80	1.40
Cardboard	0.42	0.35
Carton with plastic	2.32	1.93
Carton with Al foil	0.69	0.58
Dirty paper	2.40	1.81
Dirty cardboard	1.25	1.08
Kitchen tissues	3.47	1.84
Soft plastic	1.02	0.88
Plastic bottles	0.96	0.86
Other hard plastic	0.37	0.36
Non-recyclable plastic	6.82	6.33
Yard waste	3.31	1.72
Animals etc.	0.77	0.30
Diapers	6.59	3.59
Cotton sticks	0.15	0.07
Other cotton etc.	0.27	0.14
Wood	0.38	0.32

Textiles	1.95	1.83
Shoes, leather	0.45	0.42
Rubber	0.06	0.05
Office articles	0.36	0.34
Cigarette butts	0.21	0.14
Other combustibles	0.89	0.81
Vacuum cleaner bags	0.93	0.66
Clear glass	0.86	0.76
Green glass	0.86	0.83
Brown glass	0.86	0.82
Other glass	0.33	0.30
Aluminum containers	0.43	0.40
Aluminium foil	0.53	0.43
Metal like foil	0.94	0.84
Metal containers	0.19	0.16
Other of metal	1.17	1.07
Soil	0.36	0.20
Rocks, stones and gravel	0.82	0.82
Ash	0.31	0.31
Ceramics	0.58	0.57
Cat litter	1.43	1.20
Other non-combustibles	0.55	0.35
Batteries	0.17	0.16
Sum	100	58.2

Composite exposure: 31% vegetable waste, 10% animal waste, 6.6% diapers, 3.3% yard waste, and 0.93% vacuum cleaner bags (Riber, Petersen and Christensen, 2009).

Waste handling has been associated with:

- symptoms of the airways,
- diarrhea,
- ODTS

Casual agents have not been identified.
Suspected are endotoxin, fungi and bacteria



Knowledge is present	But not at
levels of endotoxin	
levels of bacteria	bacterial species
levels of fungi	fungus species
Presence of <i>Penicillium</i>	which species

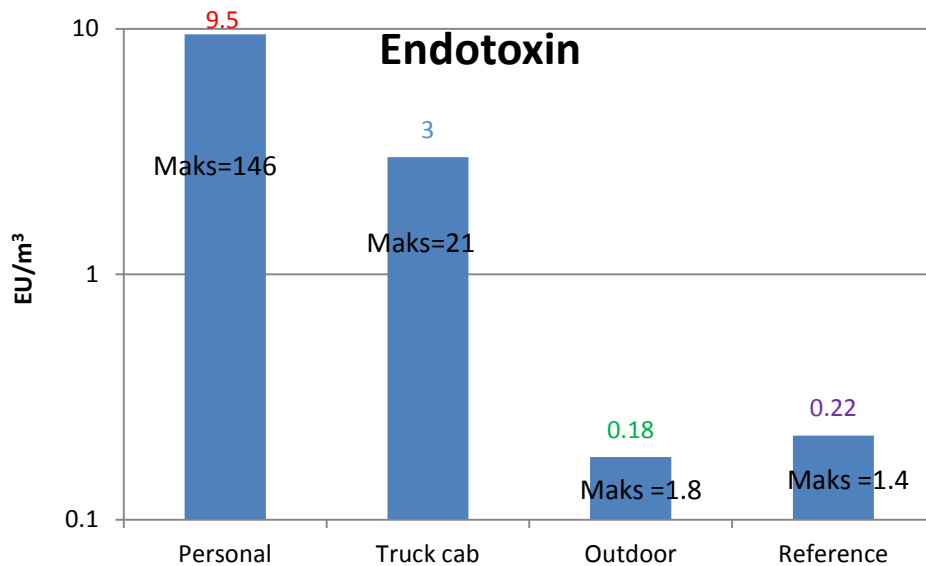
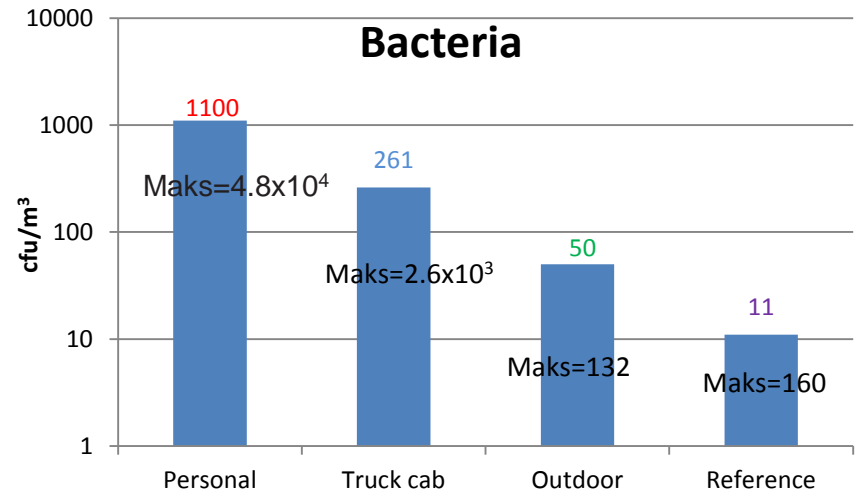
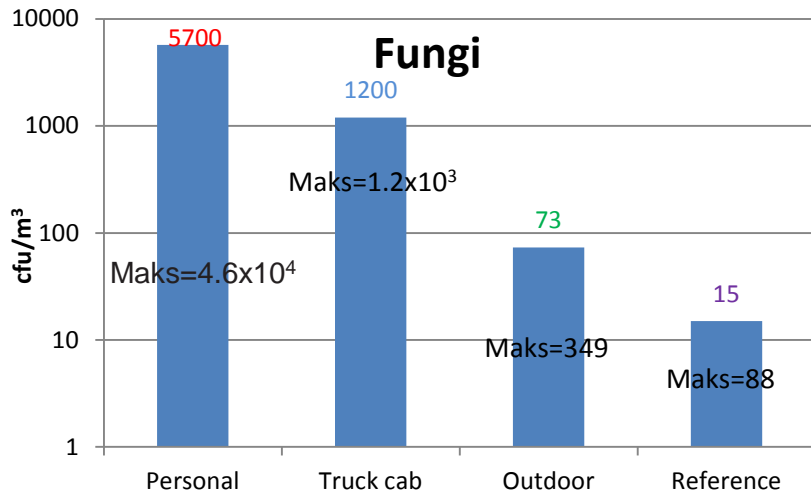
Exposure on workers and in truck cabs of waste collection trucks



Measurements on 1 or 2 drivers per truck
Spend **37%** of their working hours in the truck cab

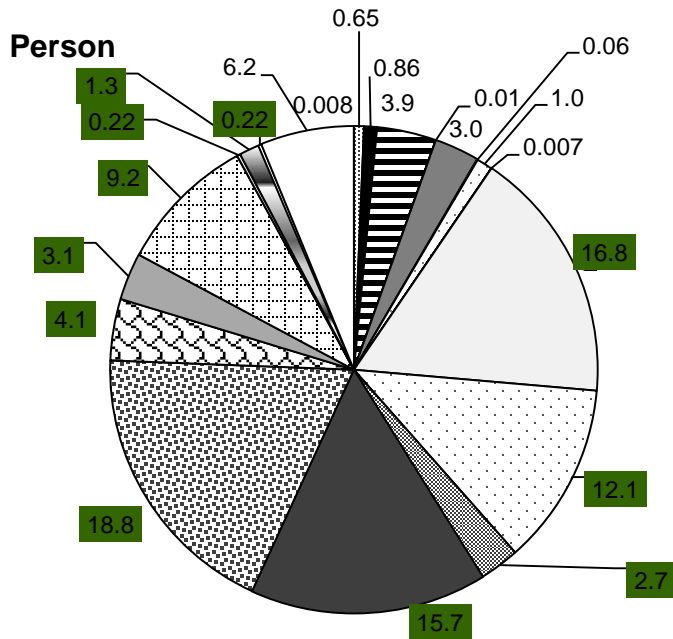
- GSP-inhalable samplers
- MALDI-TOF MS for identification at species level
- Temp. during sampling between 0 and 8 °C,
- RH between 79-100%

Exposure levels

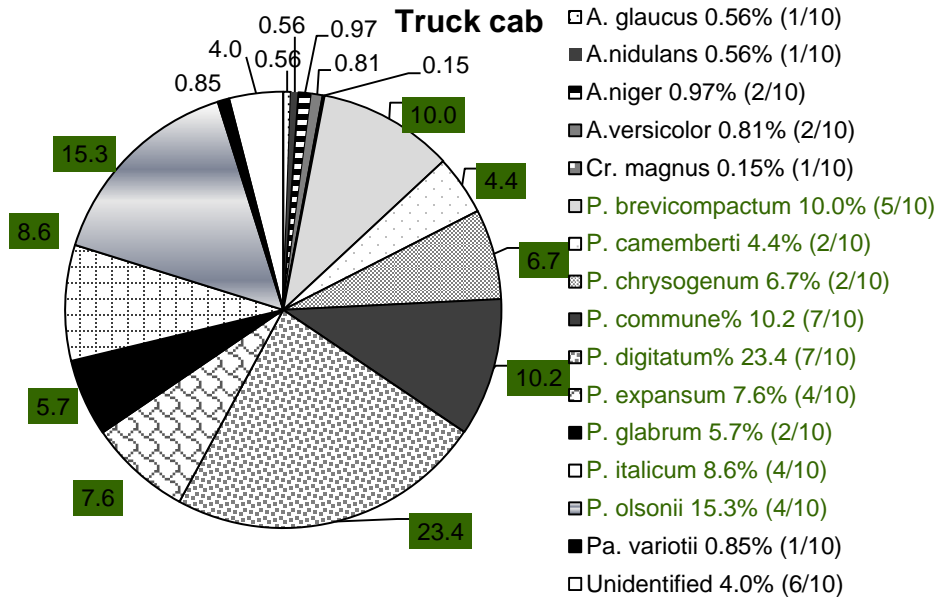


Samples	Fungi	Bacteria	Endotoxin
GM truck cab: outdoor ratio	17	4.1	24
GM truck cab: reference ratio	85	24	22

Fungal species



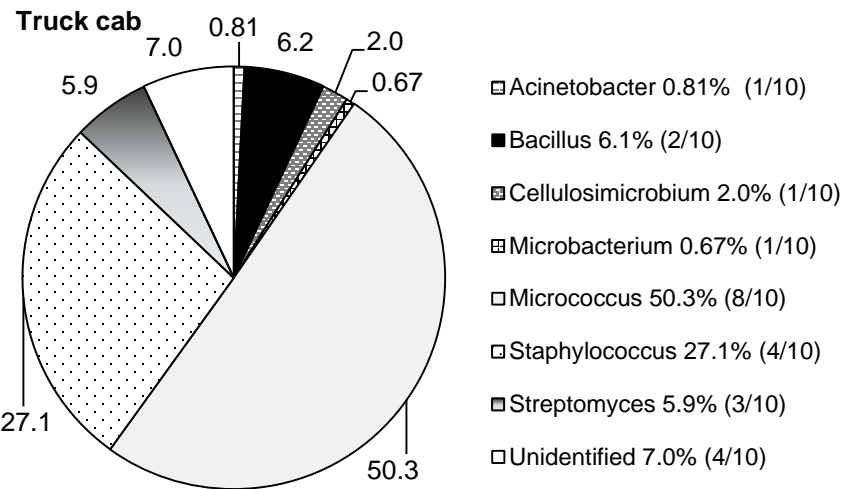
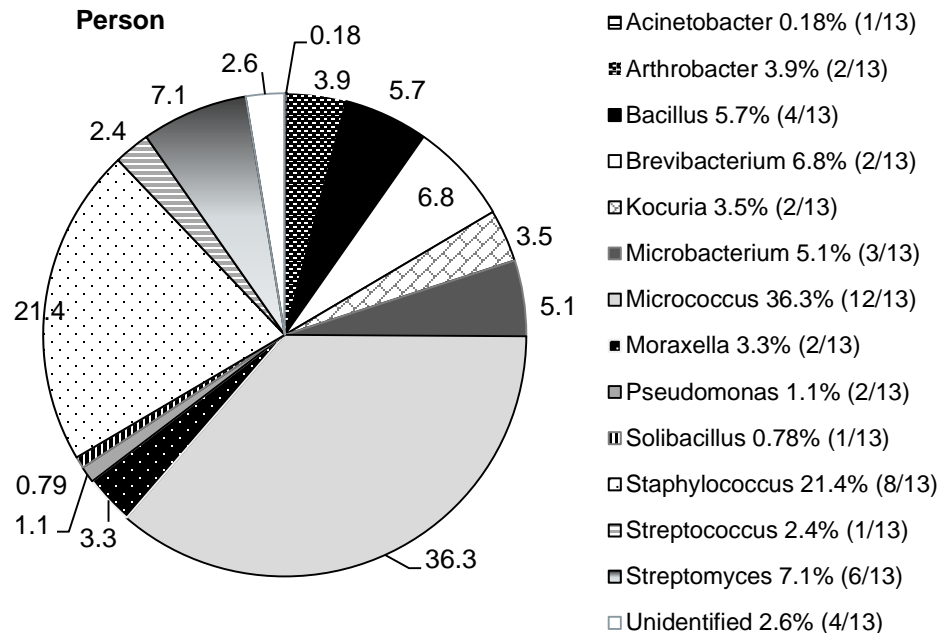
- A. flavus 0.008%(1/13)
- ▨ A. glaucus 0.65% (1/13)
- A. nidulans 0.86% (3/13)
- ▩ A. niger 3.9% (2/13)
- ▧ A. ochraceus 0.01% (1/13)
- ▦ A. versicolor 3.0% (2/13)
- Ch. funicola 0.06% (1/13)
- Cl. herbarum 1.0% (3/13)
- ▩ M. circinelloides 0.007% (1/13)
- P. brevicompactum 16.8% (8/13)
- P. camemberti 12.1% (5/13)
- ▨ P. chrysogenum 2.7% (2/13)
- P. commune 15.7% (10/13)
- ▨ P. digitatum 18.8% (9/13)
- ▩ P. expansum 4.1% (5/13)
- ▩ P. glabrum 3.1% (3/13)
- P. italicum 9.2% (7/13)
- P. lanosum 0.22% (1/13)
- ▩ P. olsonii 1.3% (1/13)
- ▩ P. roqueforti 0.22% (1/13)
- Unidentified 6.2% (6/13)



- A. glaucus 0.56% (1/10)
- A. nidulans 0.56% (1/10)
- ▩ A. niger 0.97% (2/10)
- ▩ A. versicolor 0.81% (2/10)
- Cr. magnus 0.15% (1/10)
- P. brevicompactum 10.0% (5/10)
- P. camemberti 4.4% (2/10)
- ▨ P. chrysogenum 6.7% (2/10)
- P. commune 10.2% (7/10)
- ▨ P. digitatum 23.4% (7/10)
- ▩ P. expansum 7.6% (4/10)
- P. glabrum 5.7% (2/10)
- P. italicum 8.6% (4/10)
- ▩ P. olsonii 15.3% (4/10)
- Pa. variotii 0.85% (1/10)
- Unidentified 4.0% (6/10)

- 23 different fungal species
- *Penicillium* constituted 84% and 92% of all fungi in personal and truck cab
- 11 *Penicillium* species were found
- 6 *Aspergillus* species

Date	Truck	Genus	Species	Personal samples CFU/m ³ air	Truck cab samples CFU/m ³ air	Ratio Personal:truck cab	Genus	Species	Concentrations CFU/m ³ air	n ¹⁾	
26/01/15	1a	<i>Penicillium</i>	<i>brevicompactum</i>	157	58	2.7	Aspergillus	<i>flavus</i>	12	1	
			<i>commune</i>	313	161	1.9		<i>glaucus</i>	759	11	
			<i>digitatum</i>	1.0 x10 ³	37	28		<i>nidulans</i>	48; 78	2	
	2a	<i>Penicillium</i>	<i>commune</i>	6.9x10 ³ 2)	68	102		<i>niger</i>	1517	1	
				6.0x10 ³		89		<i>ochraceus</i>	Bd ²⁾ ; 18	1	
			<i>digitatum</i>	2.1x10 ³ 2.3x10 ³	306	6.8 7.4		<i>versicolor</i>	20; 52	2	
	3a	<i>Penicillium</i>	<i>brevicompactum</i>	7.9x10 ³ Bd ³	205	38 -		Chaetomium	<i>funicola</i>	11	1
								Cladosporium	<i>herbarum</i>	24; 157	2
								Penicillium			
			<i>commune</i>	66 2.0x10 ³	46	1.4 31			<i>brevicompactum</i>	1.4 x10 ³ ; 1.5 x10 ³ , 2.9 x10 ³	2
			<i>digitatum</i>	1.3x10 ³ 667	58	23 12			<i>camemberti</i>	589; 7.7 x10 ³	2
			<i>italicum</i>	2.0x10 ³ 3.3x10 ³	615	3.2 5.4			<i>commune</i>	333	1
02/02/15	1b	<i>Penicillium</i>	<i>camemberti</i>	543	487	1.1		<i>digitatum</i>	238	1	
			<i>italicum</i>	4.9x10 ³	143	34		<i>expansum</i>	Bd; 78; 3.3x10 ³	2	
	2b	<i>Penicillium</i>	<i>brevicompactum</i>	8.8x10 ³	86	103		<i>glabrum</i>	Bd; 238	1	
			<i>commune</i>	442	43	10		<i>italicum</i>	Bd; 78; 7.6 x10 ³	2	
			<i>digitatum</i>	4.4x10 ³	43	103		<i>lanosum</i>	441	1	
	3b	<i>Penicillium</i>	<i>brevicompactum</i>	309	305	1.0		<i>roqueforti</i>	442	1	
							Mucor	<i>circinelloides</i>	Bd; 18	1	
				<i>commune</i>	254	103	2.5	Average (Geometric mean) of positive		1.1 x10 ³ (233)	-
	09/02/15	1c	<i>Penicillium</i>	<i>commune</i>	4.1 x10 ³	416	10	Genus	Species	Concentrations (CFU/m³ air)	Trucks¹⁾
				<i>digitatum</i>	3.7 x10 ⁴	3.3 x10 ³	11	Aspergillus	<i>glaucus</i>	51	3b
				<i>italicum</i>	1.1 x10 ³	416	2.6		<i>niger</i>	416	1c
	16/02/15	2c	<i>Penicillium</i>	<i>chrysogenum</i>	bd 2.3 x10 ³	154	- 15		<i>versicolor</i>	12, 416	2a; 1c
<i>olsonii</i>				bd 1.5 x10 ³	154	- 9.9	Cryptococcus	<i>magnus</i> ²	22	1d	
<i>commune</i>				3.2 x10 ³	61	53	Paecilomyces	<i>variotii</i>	43	2b	
16/02/15	1d	<i>Penicillium</i>	<i>digitatum</i>	3.9 x10 ³	1408	2.7	Penicillium	<i>brevicompactu m</i>	1248	1c	
			<i>Aspergillus</i>	<i>nidulans</i>	408	42		10	<i>camemberti</i>	153	2a
		<i>niger</i>	3.5 x10 ³	24	147	<i>chrysogenum</i>		86	2b		
	2d	<i>Penicillium</i>	<i>expansum</i>	1.2 x10 ³	59	20		<i>digitatum</i>	354	2d	
			<i>glabrum</i>	589	59	10		<i>expansum</i>	24; 305; 4.9x10 ³	1b; 3b; 1d	
			<i>italicum</i>	1.2 x10 ³	59	20		<i>glabrum</i>	689	2a	
Average of positive samples				3.5 x10³	320	27		<i>olsonii</i>	80; 215; 683	1a; 3a; 2b	
Geometric mean of positive samples				1.5 x10³	132	11					



Bacteria

- 38 different bacterial species
- *Micrococcus* followed by *Staphylococcus* constituted the largest portions
- Six different *Staphylococcus* species :

- ❖ *S. capitis*,
- ❖ *S. epidermis*,
- ❖ *S. equorum*,
- ❖ *S. hominis*,
- ❖ *S. saprophyticus*,
- ❖ *S. warneri*

- Several skin-related bacteria as:

- ❖ *Brevibacterium aurantiacum*,
- ❖ *M. luteus*,
- ❖ *S. capitis*,
- ❖ *S. epidermidis*,
- ❖ *S. hominis*,
- ❖ *S. warneri*



Only few Gram-negative bacteria, no major pathogens

Bacteria

Date	Truck	Genus	Species	Personal samples (CFU/m ³ air)	Truck cab (CFU/m ³ air)	Ratio Personal: Truck cab
26/01/15	1a	<i>Staphylococcus</i>	<i>epidermidis</i> ^h	64	32	2.0
	2a	<i>Micrococcus</i>	<i>luteus</i> ^h	21 76	2.6 x 10 ³	0.008 0.029
02/02/15	1b	<i>Micrococcus</i>	<i>luteus</i> ^h	190	110	1.72
	2b	<i>Micrococcus</i>	<i>luteus</i> ^h	5.5 x 10 ³	431	13
		<i>Staphylococcus</i>	<i>saprophyticus</i> ^h	44	431	0.10
3b	<i>Micrococcus</i>	<i>luteus</i> ^h	154	203	0.76	
09/02/15	1c	<i>Micrococcus</i>	<i>luteus</i> ^h	33	42	0.79
	2c	<i>Bacillus</i>	<i>altitudinis</i> ^o	Bd ²⁾	32	-
				110	3.4	
		<i>pumilus</i> ^o	Bd	-		
				303	25	
	<i>Micrococcus</i>	<i>luteus</i> ^h	2.3 x 10 ³	42	54	
			1.9 x 10 ³	45		
<i>Streptomyces</i>	<i>chartreusis</i> ^o	88	12	7.3		
		65	5.4			
		<i>violaceoruber</i> ^o	83	7.5		
		76	11	6.9		
16/02/15	1d	<i>Micrococcus</i>	<i>luteus</i> ^h	437	227	1.9
		<i>Staphylococcus</i>	<i>capitis</i> ^h	3.7 x 10 ⁴	29	1289
			<i>epidermidis</i> ^h	1.0 x 10 ⁴	48	215
	<i>Streptomyces</i>	<i>violaceoruber</i> ^o	402	32	12.6	
	2d	<i>Micrococcus</i>	<i>luteus</i> ^h	299	118	2.5
<i>Streptomyces</i>	<i>badius</i> ^o	169	28	6.0		
Average (Geometric mean) of all bacteria				2.7x10³ (274)	247 (68)	77(4.1)
Average (Geometric mean) of 'other' bacteria				162 (130)	21 (19)	9.3 (7.8)
Average (Geometric mean) of 'human' bacteria				4.2 x10³ (419)	360 (130)	116 (2.8)

h: human related bacteria

O: other bacteria

Genus	Species	Concentration (CFU/m ³ air)	n
<i>Acinetobacter</i>	<i>lwoffii</i> ^h	22	1
<i>Arthrobacter</i>	<i>creatinolyticus</i> ^o	543	1
	<i>oxydans</i> ^o	8	1
	<i>sulfonivorans</i> ^o	18	1
<i>Bacillus</i>	<i>cereus</i> ^o	Bd ²⁾ ; 62; 73	2
	<i>firmus</i> ^o	Bd; 8	1
	<i>megaterium</i> ^o	Bd; 59	1
	<i>mycooides</i> ^o	Bd; 16; 17	2
<i>Brevibacterium</i>	<i>aurantiacum</i> ^h	Bd; 21; 609	2
<i>Kocuria</i>	<i>rhizopila</i> ^o	607; 1157	1
<i>Microbacterium</i>	<i>sp.</i> ^o	76	1
	<i>aerolatum</i> ^o	42	1
	<i>phyllosphaerae</i> ^o	Bd; 76	1
<i>Micrococcus</i>	<i>flavus</i> ^h	515	1
	<i>luteus</i> ^h	17; 67	1
	<i>terreus</i> ^h	48	1
<i>Moraxella</i>	<i>osloensis</i> ^o	95; 263	2
<i>Pseudomonas</i>	<i>antarctica</i> ^o	379	1
	<i>monteilii</i> ^o	41	1
	<i>putida</i> ^o	24	1
<i>Solibacillus</i>	<i>silvestris</i> ^o	44	1
<i>Staphylococcus</i>	<i>epidermidis</i> ^h	Bd; 72	1
	<i>equorum</i> ^h	Bd; Bd; 172; 109	2
	<i>hominis</i> ^h	16; 173	2
	<i>saprophyticus</i> ^h	Bd; 76	1
	<i>Streptococcus</i>	<i>salivarius</i> ^h	290
<i>Streptomyces</i>	<i>badius</i> ^o	Bd, Bd; 21; 35	2
	<i>chartreusis</i> ^o	65; 88	1
	<i>galilaeus</i> ^o	Bd; 18	1
	<i>violaceoruber</i> ^o	Bd, Bd; 21; 28	2
Average (Geometric mean) of positive samples		115 (58)	-
Average (Geometric mean) of 'other bacteria'		88 (47)	-
Average (Geometric mean) of 'human bacteria'		168 (91)	-

Bacteria

Truck cab only

Genus	Species	Concentration (CFU/m ³ air)	Truck
<i>Acinetobacter</i>	<i>lwoffii</i> ^h	230	2a
<i>Bacillus</i>	<i>pumilus</i> ^o	37	1b
<i>Cellulosimicrobium</i>	<i>cellulans</i> ^o	51	3b
<i>Microbacterium</i>	sp. ^o	41	1d
<i>Microbacterium</i>	<i>liquefaciens</i> ^o	12	1d
<i>Staphylococcus</i>	<i>epidermidis</i> ^h	137	3a
	<i>warneri</i> ^h	68	3a
Average (geometric mean)		82 (57)	-

Outdoor reference samples:

- *Kocuria palustris* (65 CFU/m³),
- *Rhodococcus fascians* (103 CFU/m³),
- *Paenibacillus amylolyticus* (23 CFU/m³)

Person and the same persons truck cab

	Personal	Cab
Average (Geometric mean) of all bacteria	2.7x10³ (274)	247 (68)
Average (Geometric mean) of 'other' bacteria	162 (130)	21 (19)
Average (Geometric mean) of 'human' bacteria	4.2 x10³ (419)	360 (130)

Personal samples only

Average (Geometric mean) of positive samples	115 (58)
Average (Geometric mean) of 'other bacteria'	88 (47)
Average (Geometric mean) of 'human bacteria'	168 (91)

Conclusions and suggestions



- Waste collection workers were exposed to elevated levels of bacteria, fungi and endotoxin.
- fungal and bacterial species, found in high concentrations in personal samples, were also found in truck cabs, but in lower concentrations indicating that fungi and bacteria are transported by the workers into the truck cab and re-aerosolised
- *Penicillium* species dominated the fungal exposure
- workers were exposed to 11 different *Penicillium* species and 12 other fungal species.
- divergent results have been obtained concerning health effects on the airways of exposure *Penicillium*, this may be because the exposure covers many different species
- workers were exposed to 38 bacterial species including skin-related bacteria and bacteria expected to origin from the waste
- to reduce exposure inside the truck cab focus should be on interventions related to the unloading of waste and on good hygiene in the truck cab.

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