Int Arch Occup Environ Health (2016) 89:711–718
DOI 10.1007/s00420-015-1109-z

ORIGINAL ARTICLE

Biomarkers of inflammation in workers exposed to compost and sewage dust

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Received: 22 June 2015 / Accepted: 15 December 2015 / Published online: 23 December 2015

Abstract
Purpose The association between exposure during handling of sewage and compost and the serum concentration of inflammatory biomarkers was studied.
Methods A total of 44 workers exposed to sewage dust, 47 workers exposed to compost dust and 38 referents from the administrative staff participated. Microbial aerosols were collected by personal inhalable samplers. The concentrations of bacterial cells, spores from fungi and bacteria (actinomycetes) and endotoxins were determined by fluorescence and scanning electron microscopy and the Limulus assay. Fibrinogen, D-dimer, ICAM-1, VCAM-1 and IL-6 were determined by ELISA and C-reactive protein (CRP) by HS-MicroCRP assay in blood samples collected post-shift.
Results The exposure to dust ranged from 0.02 to 11 mg/m^3, endotoxins from 1 to 3160 EU/m^3 and bacteria from 0 to 209 $\times$ 10^6 cells/m^3. Fungal (0–41 $\times$ 10^6 spores/m^3) and actinomycetes spores (0–590 $\times$ 10^6 actinomycetes spores/m^3) were observed only at compost plants. The exposed workers had significantly higher fibrinogen (arithmetic mean 3.3 mg/ml) and CRP (geometric mean 1.5 mg/L) compared to the referents (2.8 and 1.0 mg/L, respectively). The serum concentration of CRP was negatively associated with forced expiratory volume in one second (FEV$_1$) in % of predicted. Exposure to inhalable dust and bacteria was positively associated with the serum concentration of ICAM-1.
Conclusions This study suggests that exposure to bacteria and dust when handling sewage and compost may initiate an inflammation shown by an increase in serum concentration of ICAM-1. The higher concentrations of fibrinogen and CRP in exposed workers compared to the referents may reflect a low-grade systemic inflammation.

Keywords Exposure · Bacteria · Endotoxins · Actinomycetes · ICAM · CRP

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Introduction

Waste water is normally processed chemically and mechanically in sewage treatment plants. Several plants in Norway have introduced a drying process to reduce the water content of the sludge by separate dryers to facilitate the use of sewage sludge as fertilizer. Waste is traditionally disposed or stored in landfills. However, in order to decrease the environmental burden and to reduce the total amount of waste, the domestic organic waste fraction is composted in waste composting plants, producing nutritious compost for agricultural use. Workers in these industries are at risk of being exposed to high levels of organic dust and toxic gases such as hydrogen sulfide (H_2S). Workers handling dried sewage dust may be exposed to Gram-negative bacteria and endotoxins, while compost workers are exposed to a more complex aerosol containing microorganisms, mostly dominated by actinomycetes from Gram-positive bacteria (Heldal et al. 2010, 2015).

It is well known that airborne exposure to endotoxins at sewage treatment plants may be high (Smit et al. 2005; Spaan et al. 2008). Endotoxin exposure may cause decreased lung function as well as increased respiratory symptoms (Friis et al. 1999; Douwes et al. 2001; Thorn and Kerekes 2001; Heldal et al. 2010). Less recognized, but well documented, are systemic effects in terms of fever reactions, headache and tiredness among sewage treatment workers (Melbostad et al. 1994; Douwes et al. 2001; Thorn et al. 2002). Allergic and non-allergic airway symptoms as well as fever reactions have been reported among compost workers (Schlosser et al. 2009). Also an increased number of neutrophilic cells and inflammatory markers in induced sputum and nasal lavage samples were observed, suggesting an unspecific airway inflammation (Douwes et al. 2000; Heldal et al. 2003; Wouters et al. 2006). However, the causative agents for these reactions in compost dust are not known.

We have previously shown that the workers included in this study reported exposure-related increase in subjective symptoms from the upper and lower airways with a concomitant decrease in lung function (Heldal et al. 2013, 2015). Among the workers exposed to sewage dust, a transient increase in serum pneumoprotein concentrations during short-term high exposure to bacteria was observed, suggesting a low-grade acute pulmonary inflammation (Heldal et al. 2013). This was not observed among the compost workers (Heldal et al. 2015).

The mechanisms for the non-specific inflammatory reactions to endotoxins are well known, and the lung macrophages, monocytes and epithelial cells seem to be the primary target cells for LPS (lipopolysaccharide) exposure (Ulmer 1997; Thorn 2001). A cascade reaction is initiated by the binding of a LPS complex, containing receptor proteins CD14, lipopolysaccharide-binding protein (LBP) and LPS, to different Toll-like receptors. Following activation, the macrophages will secrete a variety of soluble pre-inflammatory mediators amplifying the acute inflammatory response. The mediators include cytokines, such as interleukins 6 and 8 (IL-6 and IL-8), which upregulate the expression of adhesion molecules (ICAM and VCAM) for the attachment of neutrophils on the surface of endothelial cells, increase the capillary permeability and promote chemotaxis. IL-6 is well known to act on the liver by increasing the synthesis of a number of acute-phase reactants such as C-reactive protein (CRP) and fibrinogen (Roitt et al. 1996).

The purpose of this study was to investigate whether airborne exposure during handling of sewage and compost has an impact on the concentration of inflammatory biomarkers in serum. A further aim was to investigate dose–response associations between exposure to bacteria and endotoxins, and the measured inflammatory biomarkers.

Materials and methods

Study population

At the time of the study, there were four sludge treatment plants in Norway where sludge was dried in separate sludge driers. All workers ($N = 19$) from these plants were invited to participate in the study. Workers ($N = 25$) from four randomly chosen plants in Norway with chemical and mechanical treatment without sludge drying were also invited. Likewise, 47 workers from ten compost plants in Norway using different compost processes were invited to participate: 20 of these workers were recruited from five plants where the compost is processed outdoors in long windrows (windrow plants) and 27 workers from plants where the compost is processed in closed reactors indoors (reactor plants). All invited exposed workers agreed to participate in the study.

Altogether 38 referents, who were all from the administrative staff, were also invited to participate. Twenty-nine were invited from the compost plants and nine from the sewage treatment plants. All invited referents agreed to participate in the study. Background data of the participants are shown in Table 1.

The study was approved by the Regional Ethics Committee for Medical and Health Research. All participants were informed about the purpose of the study and gave their written consent to participate.

Clinical examination and blood sampling

All participants were examined before and after a day shift on the same day of the week (Tuesday) as earlier described (Heldal et al. 2013). A post-shift blood sample for the determination of biomarkers was collected (between 1 and 2 p.m.) from the cubital vein. Plasma samples anticoagulated with citrate for determination of fibrinogen and anticoagulated with ethylenediaminetetraacetic acid (EDTA) for determination of IL-6, ICAM-1, VCAM-1 and D-dimer (BD Diagnostics, Plymouth, UK) were kept on ice for up to 60 min before centrifugation at 3000 g for 15 min. Blood samples for the harvest of serum were collected in vacutainers without additives (BD Diagnostics, Plymouth, UK). The samples were kept at room temperature for coagulation for 60–120 min, before being centrifuged at 1500 g for 15 min. Plasma and serum samples were pipetted into NUNC® cryotubes (NUNC, Roskilde, Denmark) that were kept at −25 °C until analysis. The participants had been informed to abstain from smoking, drinking and eating for the last 2 h before blood sampling.

All participants completed post-shift a questionnaire on work-related symptoms experienced during the day (Melbostad and Eduard 2001). Background information of the participants was also obtained by a questionnaire. The subjects were classified as current or former smokers. Former smokers were defined as having stopped smoking more than a year ago.

Table 1 Characteristics of the participants

	Referents ($N = 38$)	All exposed workers ($N = 91$)	Sewage workers ($N = 44$)	Compost workers ($N = 47$)
Age (years)[A]	43 (10)	41 (10)	40 (11)	41 (10)
Male (%)[B]	74	97	96	98
Atopy (%)[B]	26	19	18	19
Current smokers (%)[B,a,b,c]	16	42	36	47
Tobacco consumption among smokers (pack-years)[A]	17 (8)	13 (9)	10 (9)	14 (9)

$p < 0.05$

[A] Arithmetic mean (standard deviation)

[B] Prevalence

[a] Between referents and all workers

[b] Between referents and sewage workers

[c] Between referents and compost workers

Spirometry

The pulmonary function was measured pre- and post-shift (Vitalograph 2160 Spirometer, Spirotrac®, UK). The participant wore a nose clip, and the measurements were carried out in a sitting position according to the American Thoracic Society guidelines (American Thoracic Society 1987). The same technician performed all tests. Predicted values were based on ERS reference population (European Respiratory Society 1993).

Determination of biomarkers

Atopy for respiratory allergens was tested in serum by a Phadiatop test (FEIA, UniCap system, Fürst Laboratory, Norway). High-sensitivity CRP was measured with an immunoturbidimetric assay with latex-bounded anti-CRP antibody at Fürst Medical Laboratories (Tina Quant-Roche, Roche Diagnostics Corporation, Germany). All other biomarkers were analyzed at the Sahlgren University Hospital, Gothenburg. The STA-R equipment and reagents from Diagnostica Stago (Asniéres, France) were used to determine fibrinogen in plasma based on the coagulation time at high thrombin concentration. D-dimers were measured using a sandwich enzyme-linked immunosorbent assay (ELISA) with reagents from Diagnostica Stago, Triolab AB (Molndal, Sweden). High-sensitivity interleukin 6 (IL-6), soluble intercellular adhesion molecule 1 (ICAM-1) and vascular adhesion molecule 1 (VCAM-1) were determined using commercial ELISA kits from R&D (Abingdon, UK). The imprecision, expressed as coefficient of variation (CV), as calculated from duplicate analyses was 4 % (IL-6), 8 % (ICAM-1) and 2 % (VCAM-1).

Air sampling

Air samples were collected by personal, parallel sampling with two inhalable PAS6 cassettes (Van der Wal 1983) connected to pumps (PS101, National Institute of Occupational Health, Norway) and operated at a flow rate of 2.0 l/min for approximately 4–5 h between the two health examinations. Polycarbonate filters with pore size 0.8 µm (Poretics, Osmonics, Livermore, USA) were used for dust particles, total bacteria and fungal and actinomycetes spores and glass fiber filters (Whatman GF/A, Maidstone, USA) for endotoxins. Three samples were lost because of disrupted pump flow.

Exposure measurements

Dust particles were determined in a climate-controlled weighing room using a Sartorius AG MC 210p balance (Sartorius AG, Göttingen, Germany). Endotoxins were extracted from the glass fiber filter and analyzed with a quantitative kinetic chromogenic Limulus amoebocyte lysate assay (Cambrex Bio Science Walkersville, Maryland, USA) as previously described (Douwes et al. 1995). Fungal and actinomycetes spores were analyzed by scanning electron microscopy (SEM) (Eduard et al. 1988) and total bacteria by epifluorescence microscopy (Heldal et al. 1996).

Statistical methods

The normality of the variables was tested with Kolmogorov–Smirnov statistic with a Lilliefors significance correction. Continuous variables that were not normally distributed were log-transformed to achieve normal distribution. Thus, the concentrations of D-dimer, CRP and all exposure variables were log-transformed. One-way analysis of variance (ANOVA) was used when more than two groups were compared, and the least significant difference test (LSD) was applied in order to separate groups that differed from each other. Univariate associations between variables

Table 2 Concentrations of airborne contaminants in the inhalable aerosol fraction measured after personal sampling

Exposure	Sewage workers			Compost workers		
	N	90 % Percentile	Median (min–max)	*N*	90 % Percentile	Median (min–max)
Dust (mg/m^3)	43	4.4	0.27 (0.02–9.3)	46	2.3	0.3 (0.1–11)
Endotoxins (EU/m^3)	43	806	30 (1–3160)*	44	53	3 (1–310)
Bacteria ($10^6/m^3$)	42	0.4	0.02 (0–4.9)	46	4.3	0.1 (0–209)*
Actinomycetes spores ($10^6/m^3$)	42[a]	–	–	46[b]	16	0.2 (0–590)
Fungal spores ($10^6/m^3$)	42[a]	–	–	46[c]	1	0.02 (0–41)

* $p < 0.05$

[a] Not counted spores in analyzed samples

[b] Not counted spores in 24 samples

[c] Not counted spores in 20 samples

were assessed using least square regression analysis, yielding Pearson's correlation coefficients (r_p) as the measure of association. Multiple regression analysis (backward procedure) was applied for the assessment of one dependent variable and several independent variables (age, smoking, gender, atopy), simultaneously. The significance level for the inclusion of a variable into the model was $p = 0.1$. General linear models were used to calculate adjusted group estimates. For FEV_1 and FVC in % of predicted, a quadratic term of $\log_{10}$CRP was added to study R^2 of nonlinear associations. The level of significance was set at 0.05 (two tailed). The statistics were calculated with SPSS (version 18.0) for Windows (IBM SPSS Inc., Chicago, IL, USA).

Results

Exposure

The concentrations of inhalable dust, endotoxins, total bacteria, fungal spores and actinomycetes spores measured after collection by personal sampling are shown in Table 2. The exposure to endotoxin was statistically significantly higher among sewage plant workers compared to compost plant workers. In contrast, exposure to bacteria was significantly higher among compost plant workers. The exposure to endotoxin was higher among sewage workers handling sewage dust compared to workers from chemical sewage plants, while exposure to dust and bacteria was comparable.

Fungal and bacterial spores were only detected in samples collected in the compost plants. The concentrations of endotoxin during handling of sewage dust and actinomycetes spores during composting ranged up to 3160 EU/m^3 and 6×10^8 spores/m^3, respectively. No actinomycetes or fungal spores were detected in air samples collected in the sewage treatment plants. There were weak positive correlations between the concentrations of endotoxin and bacteria ($r_p = 0.37$, $p < 0.05$) and between endotoxin and dust ($r_p = 0.47$, $p < 0.01$) when all samples were considered (not tabulated).

Biomarkers of inflammation

The concentrations of CRP and fibrinogen were significantly ($p < 0.05$) higher in all exposed workers as compared to the referents (Table 3). The differences remained after adjustment for age and smoke. When all exposed subjects were stratified into sewage or compost workers, both groups had significantly higher CRP concentrations compared to the referents, while the fibrinogen concentrations were significantly higher in the compost workers only ($p < 0.05$). After adjustment for age and smoke, the difference of CRP was no longer significant among compost workers ($p = 0.06$). The mean concentration of ICAM-1 was significantly higher among all exposed workers ($p = 0.05$) and among compost workers ($p = 0.01$) when compared to the referents. The association between ICAM-1 and age and current smoking, respectively, was poor ($p < 0.1$). Using Bonferroni as a post hoc test for group differences of the inflammatory markers (ICAM-1 and fibrinogen) maintained significance ($p < 0.05$) except for CRP where the p value increased from 0.04 and 0.02 to 0.1 and 0.07, respectively. No significant differences in inflammatory markers were found for the subgroups of sewage and compost workers. No significant differences between any of the groups were observed for IL-6, D-dimer or VCAM.

As previously reported, all exposed subjects had lower FVC (100.3 % of predicted value) than the referents (109.5 %) (Heldal et al. 2010, 2015). The serum CRP concentrations were associated with both pre- and post-shift FEV_1 (Fig. 1) and FVC in % of predicted in the exposed workers. The associations were significant ($p < 0.05$) when all workers and the sewage dust workers were considered, but not when only compost workers were assessed.

Table 3 Concentrations of biomarkers in sewage treatment plant and compost workers and referents

Biomarkers	Referents			All exposed workers			Sewage workers			Compost workers		
	N[A]	AM (range)		*N*	AM (range)		*N*	AM (range)		*N*	AM (range)	
CRP (μg/ml)[B,a,b,c]	38	1.0	(0.1–4.1)	91	1.5	(0.2–20.0)	44	1.5	(0.2–20.0)	47	1.4	(0.2–11.0)
Fibrinogen (mg/ml)[a,c]	38	2.8	(1.4–3.8)	83	3.3	(1.1–6.0)	36	3.1	(1.1–6.0)	47	3.4	(1.8–5.7)
ICAM-1 (ng/ml)[a,c]	38	201	(113–335)	86	230	(85–534)	39	215	(126–486)	47	242	(85–534)
IL-6 (pg/ml)	38	0.6	(0.04–1.9)	86	0.7	(0.01–2.8)	39	0.6	(0.01–2.0)	47	0.8	(0.1–2.8)
D-dimer (μg/ml)[B]	34	0.3	(0.1–3.1)	68	0.3	(0.2–1.1)	28	0.3	(0.2–1.1)	40	0.3	(0.2–0.8)
VCAM (ng/ml)	38	660	(486–1004)	86	677	(413–1198)	39	665	(444–931)	47	687	(413–1198)

$p < 0.05$

[A] Number of sample (missing values because of disrupting samples before analysis)

[B] Geometric mean

[a] Between referents and all workers

[b] Between referents and sewage workers

[c] Between referents and compost workers

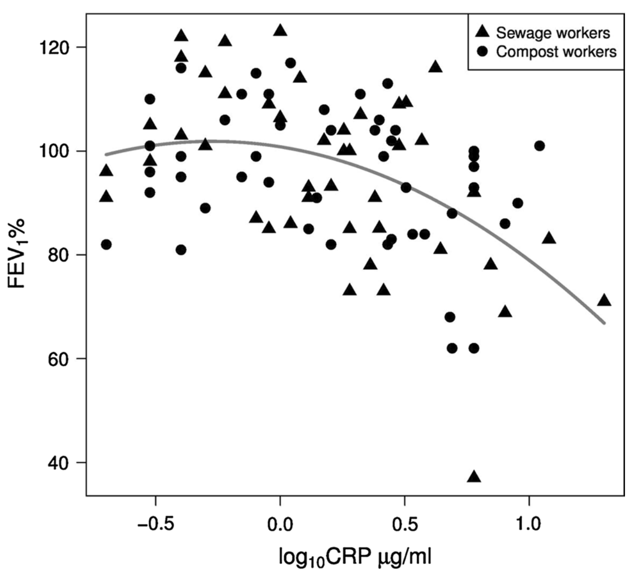

Fig. 1 Relationship between serum concentrations of CRP in 44 sewage workers and 47 compost workers and FEV_1 in % of predicted measured before work shift. The association was modeled using a polynomial (FEV_1 % = 100.8 − 7.2lgCRP − 14.2(lgCRP)^2, $R^2 = 0.22$, $p < 0.05$)

Nonlinear associations between serum CRP and FEV_1 % (Fig. 1) and FVC % were observed. A better model fit (R^2 from 0.13 to 0.2) was achieved when associations were modeled adding a quadratic term of $\log_{10}$CRP. The figure suggests that the decline in FEV_1 starts at a serum CRP concentration of approximately 2 mg/L (lgCRP = 0.3) for both FEV_1 and FVC (FEV_1 = 100.8 − 7.7 lgCRP − 14.2 (lgCRP)^2, $R^2 = 0.22$, $p < 0.05$, FVC = 105.1 − 11.4 lgCRP − 11.9 (lgCRP)^2, $R^2 = 0.26$, $p < 0.05$, respectively).

The serum concentrations of ICAM-1 were significantly associated with the CRP concentrations when all exposed workers were considered (ICAM-1 = 290 + 62.5 lgCRP, $R^2 = 0.10$, $p < 0.01$) and for the sewage and compost workers separately (not tabulated).

Associations between biomarkers of inflammation and exposure

The associations between biomarker concentrations and exposure variables were assessed using backward regression analysis (Table 4). The concentrations of ICAM-1 were positively associated with the exposure to dust ($\beta = 38.6$, $R^2 = 0.08$, $p < 0.05$) and bacteria ($\beta = 23.0$, $R^2 = 0.08$, $p < 0.05$) among all exposed workers. A significant association between the concentrations of sewage dust and ICAM-1 was also observed among sewage dust workers only (Table 4). No significant associations were observed among inflammatory markers in the subgroups of sewage and compost workers and exposure. There was no significant association between the other biomarkers and any of the exposure variables.

Discussion

This study shows that the fibrinogen and serum concentrations of CRP were higher in the exposed subjects compared to the referents. The higher concentrations of ICAM-1 were also positively associated with the concentrations of dust particles and bacteria among all exposed subjects. There were some differences in the inflammatory responses between sewage and compost workers. The association between poorer lung function and elevated serum

Table 4 Associations between ICAM-1 and exposure to (log)bacteria and (log)dust, respectively, in exposed sewage treatment plant workers, compost workers and all exposed workers

Workers	Bacteria				Dust		
	N	*β*	95 % CI	*p*	*β*	95 % CI	*p*
All exposed workers	91	22.9	4.9 to 40.8	0.01	36.1	6.0 to 66.3	0.02
Sewage treatment plant workers	44	18.8	−7.8 to 45.3	0.14	39.1	6.1 to 72.2	0.03
Compost plant workers	47	20.9	−10.5 to 50.5	0.15	32.3	−21.6 to 86.3	0.17

Regression coefficient (β), *p* value (*p*) and confidence intervals (CI) are given

concentrations of CRP and the positive association between dust concentrations and ICAM-1 were found among sewage dust exposed workers only. The nonsignificant associations of ICAM-1 among compost workers and exposure to dust and bacteria may be due to too low power of the study. In this study, we chose referents from the administrative staff at the compost and sewage plants. It cannot be excluded that they have been slightly exposed. A slight exposure among the referents would result in an underestimation of effects.

Obesity is associated with low-grade systemic inflammation (Thorand et al. 2006; Jung et al. 2010; Gläser et al. 2012). The concentrations of CRP, fibrinogen and IL-6 may therefore be confounded by obesity. Information about BMI was not available in the study, and it is imaginable that higher CRP concentrations among the exposed workers may be caused by higher BMI. However, it has been reported that obesity has a larger impact on inflammation in women compared to men (Thorand et al. 2006; Jung et al. 2010). According to the association between BMI and the concentration of CRP reported in the study of Jung et al. (2010), the difference in the CRP concentration between the exposed workers and referents in this study is much larger than could be explained by a difference in BMI.

The workers at the sewage treatment and the compost plants were exposed to airborne bacteria during work. The sewage treatment plant workers were more highly exposed to endotoxins, a cell wall component of Gram-negative bacteria, than the compost workers. In contrast, compost workers were more highly exposed to Gram-positive bacteria and actinomycetes spores. The cell wall component peptidoglycan with lipoteichoic acid (LTA) in the actinomycetes has been suggested to have inflammatory properties, but peptidoglycans are regarded to be much less potent than LPS in eliciting cytokine responses from pulmonary macrophages (Redl et al. 1989). LTA may activate pulmonary macrophage cytokine production through the same CD14 receptor pathway as LPS (Cleveland et al. 1996). While several investigators have studied the health effects in workers exposed to endotoxins at sewage treatment plants, little is known about inflammatory effects of inhaling actinomycetes from Gram-positive bacteria in a work environment. Among 38 healthy volunteers exposed to organic dust while weighing swine for 3 h, an increased concentration of IL-6 and fever reactions were observed after work. The concentration of peptidoglycans, but not LPS, correlated with an increase in blood granulocyte concentrations (Zhipping et al. 1996). Also $\beta(1 \rightarrow 3)$-glucans from the cell wall of fungal spores may affect the immune system and induce inflammatory markers (Douwes et al. 2000; Wouters et al. 2006).

We have previously reported that the exposed workers had lower FVC (in % of predicted) than the referents (Heldal et al. 2010). Furthermore, the workers at the sewage treatment plants had altered concentrations of the serum pneumoproteins CC-16 and SP-D which was not observed among the compost workers, indicating a pulmonary effect of exposure to sewage dust, but not to compost dust (Heldal et al. 2013, 2015). The present study shows a negative association between the concentration of CRP in serum and FEV_1 and FVC, respectively, when all exposed workers were considered, but particularly in the sewage workers. The nonlinear association observed between lung function (FEV_1, FVC) and CRP could indicate that the pulmonary function starts to decline at serum CRP concentrations of around 2 mg/L. The mean concentration of CRP among the referents was 1.0 mg/L. A negative association between FEV_1 and FVC and serum CRP has been reported previously in cross-sectional studies of inflammation in the general population, but to our knowledge not in working populations (Fogarty et al. 2007; Gläser et al. 2012).

The concentrations of CRP and fibrinogen were higher in the exposed subjects compared to the referents, while the concentrations of IL-6 which is known to induce the synthesis of fibrinogen and CRP in hepatocytes (Akira and Kishimoto 1992) were comparable in the referents and the exposed subjects. However, the half-life of IL-6 in serum is only 2–3 h (Gerhartz et al. 1994), making IL-6 less suitable for the detection of inflammation in population-based studies. Previous studies have shown that sewage workers have higher serum CRP concentrations and higher concentrations of fibrinogen degradation products (FDP) in urine compared to controls (Mattsby and Rylander 1978; Lundholm and Rylander 1983). The authors suggested that the causative agent was endotoxin or toxins from viable Gram-negative bacteria, although few exposure measurements were available. Higher concentrations of blood neutrophils among sewage workers compared to controls were also reported in a more recent study, but no increase in fibrinogen or IL-6 was reported (Thorn and Beijer 2004).

The concentrations of sewage dust, compost dust and bacteria were associated with higher concentrations of ICAM-1. Since the airways are the first target organ for the exposure, it is likely that ICAM-1 plays a pivotal role in acute and possibly in chronic pulmonary inflammation (Beck-Schimmer et al. 2002; Cormier and Israël-Assayag 2004). Animal studies have shown that ICAM-1 participates in the development of acute lung inflammation by adhesion of neutrophils to alveolar epithelial cells after instillation of bacterial LPS in rats (Beck-Schimmer et al. 1997, 2002). Also swine confinement workers exposed to bacteria and endotoxins had higher concentrations of VCAM, ICAM-1 and sL-selectin compared to referents (Cormier and Israël-Assayag 2004). The concentrations of ICAM-1 were also positively associated with the serum CRP concentrations. The results could suggest that the increased concentration of ICAM-1 may be a pulmonary endothelial response to the exposure for the recruitment of inflammatory cells into the pulmonary tissue.

In summary, the results from this study could suggest that the increase in ICAM-1 concentrations may be initiated by a local inflammatory response in the pulmonary tissue caused by exposure to bacteria and dust. The results also indicate that sewage dust may have higher inflammatory properties than compost dust. Furthermore, the higher concentrations of fibrinogen and CRP in the exposed workers compared to the referents may also indicate the occurrence of a low-grade systemic inflammation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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