

## BIOMONITORING AND WORK RELATED SYMPTOMS AMONG GARBAGE HANDLING WORKERS\*

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**Abstract:** This cross sectional study of recycling workers was planned to identify adverse health effects of modern waste handling including recycling of materials from household waste. The study-group comprised 40 garbage handling, 8 composting, 20 paper sorting workers from all over Denmark and 119 drinking water supply workers from Copenhagen served as controls. Earlier we have described the respiratory tract, mucosal, and eye symptoms. This paper describes the skin and gastrointestinal symptoms as well as the concentrations of trace elements in the blood from recycling workers. Among garbage handling workers 13.6% experienced irritation of the skin more than once a month, compared to none among the controls,  $p < 0.05$ . The odds ratio OR (95% CI) for itching of the skin more than once a year was raised to 3.78 (1.46–9.8) in the garbage handling workers. The OR for ever having experienced vomiting or diarrhoea in relation to work was 7.51 (1.17–48.1) and 7.30 (2.50–21.3) among the composting and the garbage handling workers, respectively. The concentrations of trace element in this study were all within normal ranges. We found a higher cadmium blood concentration of 3.09 (1.80)  $\mu\text{g/l}$  (mean (SD)) among the garbage handling workers vs. 1.29 (3.36)  $\mu\text{g/l}$  among the controls,  $p < 0.05$ . This increase in Cd levels among garbage handling workers might stem from exposure to batteries in the waste. In all groups the Cd concentration was higher among smokers compared to non-smokers. Probably as a consequence of routine machine repair work, the controls had significantly higher lead concentrations of 56.2 (28.8)  $\mu\text{g/l}$  vs. 40.8 (36.1)  $\mu\text{g/l}$  and 37.2 (23.3)  $\mu\text{g/l}$  among the composting and the garbage handling workers, respectively. This study emphasises the need to address the working environment in recycling facilities handling organic material.

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### INTRODUCTION

Garbage recycling was first described as an occupational problem during the second world war. The women engaged in sorting of dug-up rubber from the Copenhagen landfill suffered from diarrhoea and vomiting, fever and chest tightness [1].

During the last 15 years, several studies have shown increased prevalence rates of gastrointestinal symptoms among workers in the sewage treatment-plants and among sewer workers. Symptoms have been characterised as acute episodes of self-limited diarrhoea [5-7, 10]. Resource recovery and composting plants have also been shown to induce gastrointestinal as well as skin symptoms

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**Table 1.** Hygienic survey of the Danish garbage handling facilities; mean (SD).

Plant type	Control	Paper sorting	Compost	Garbage handling
Total dust mg/m <sup>3</sup>	0.42 (0.25)	0.83 (0.57)	0.62 (0.57)	0.74 (0.77)
Total viables cfu/m <sup>3</sup> × 10 <sup>3</sup>	0.08 (0.04)	4.7 (5.9)*	54.4 (77.1)* †	46.1 (125.5)*
Endotoxins ng/m <sup>3</sup>	2.5 (3.9)	1.3 (1.5)	0.8 (1.1)	2.5 (4.4) †
Numbers of samples	6	18	13	50

\* t-test group vs control,  $p < 0.05$ ; † t-test group vs paper sorting,  $p < 0.05$ .

among employees [11, 15]. The studies have mostly been focused on the adverse effects of bioaerosols on respiratory organs. However, one report has shown that a newly built resource recovery plant exposed the workers to heavy metals [11].

This study was performed to investigate the working environment and to see if the presently employed workers suffered any work-related symptoms. We have described earlier the respiratory and allergic symptoms [23], and this paper will deal only with gastrointestinal and skin disorders. Furthermore, we studied the blood content of trace elements and heavy metals among the workers under study.

## MATERIALS AND METHODS

**Plant types.** The survey includes all Danish resource recovery systems in 1991. As controls, blue collar workers from the drinking water supply industry of Copenhagen were chosen. The participants were divided into four categories: controls; paper sorting where only paper was processed; compost plants (chopping and composting garden waste only); and garbage handling plants where pre-separated fractions of mixed household waste were treated by various methods, mechanical or hand sorting for subsequent reuse. The residue was either composted or used as fuel in an incineration plant.

One garbage handling worker did not wish to participate. Ninety nine percent of the recycling workers and 81% of the controls participated. Thus, the study comprises 40 garbage handling, 8 composting, 20 paper sorting workers from all over the country, and 119 drinking water supply workers from Copenhagen who served as controls.

**Hygienic survey.** Area sampling of total dust was carried out by methods specified by the National Labour Inspectorate, Denmark [25] over a work-shift with a sampling time of approximately 7 hours. Dust samples were collected on 37 mm, 8 µm poresize membrane filters enclosed in two-piece filter holders and weighed to an accuracy of 10<sup>-5</sup>g. Samples were taken from representative workers at every job type.

Endotoxin content was determined in the dust from the filters using the *Limulus* lysate method [12]. A lysate with a sensitivity of 0.06 EU (Cape Cod) was used.

Airborne bacteria and fungi were collected with impingers over 3 hours at a flow rate of 0.9 l/min. Tryptone soy agar was used for total count, Drigalsky agar for Gram-negative bacteria and modified Rose Bengal agar for fungi.

**Interview and diagnosis.** The questionnaire has been reported earlier [23] and will only be described briefly in this paper.

The questionnaire was designed to identify respiratory, gastrointestinal and skin symptoms. Questions of cough and earlier diseases were taken from the British Medical Research Council questionnaire of respiratory symptoms [3]. This was supplemented by questions about asthma and allergy.

Questions about gastrointestinal symptoms concerned lack of appetite, nausea, changes in stool quality, and vomiting or diarrhoea in relation to work.

A complete occupational history was obtained. This was especially detailed for periods of employment in the recycling industry allowing us to link these periods to the hygienic measurements.

**Skin prick testing.** Skin prick test was performed to evaluate immediate allergic reactions towards a panel of 10 common inhalant allergens, extended with storage mites (*Tyrophagus putrescentiae*, *Lepidoglyphus destructor*) and moulds (*Rhizopus nigricans* and *Aspergillus niger*). The test was quantified by the diameter of the reaction and graded in relation to a histamine reaction (1 mg/ml histamine chloride). Weak reactions were reactions  $\geq 2$  mm in relation to a negative result on a saline extract. Strong reactions were  $\geq$  histamine reference.

**Analysis of trace elements.** Sera and blood from the participants were analysed for trace elements and heavy metals. Mercury, lead and cadmium were analysed on whole blood samples by atomic absorption-spectrophotometry (Perkin Elmer 1100B). For Pb and Cd a graphite furnace (HGA300) was used and for mercury a mercury/hydride system (MH520). Analytical quality control was performed on an internal daily blood standard and a certified reference blood sample, Seronorm Trace Elements, whole blood I and II, Nycomed AS Oslo.

**Table 2.** Skin symptoms and skin prick tests of Danish recycling workers at the different plants; N (%).

Symptoms	Plant type			
	Control	Paper sorting	Compost	Garbage handling
Itching of the skin more than once a year	12 (10.1)	2 (10.0)	0 -	10 (22.7)
Itching of the skin more than once a month	0 -	1 (5.0)	0 -	6 (13.6)*
One or more attacks of blister in the skin in the past 12 months	3 (0.25)	0 -	0 -	3 (6.8)
Skin prick > 2 mm towards <i>Lepidoglyphus destructor</i>	1 (0.8)	0 -	0 -	3 (6.8)
One or more skin prick > histamine reference	9 (7.6)	0 -	1 (12.5)	0 -
N	119	20	8	44

\*  $\chi^2$  test,  $p < 0.05$  group vs controls.

The other trace elements were measured by PIXE (particle induced X-ray emission) analysis [14]. Yttrium was used as internal standard.

**Statistics.** Tabulation, graphical analysis and analysis of the data in group means were carried out using SPSS statistical package for continuous measurements [17]. To compensate for multiple comparison Duncan's test with a confidence limit of 0.05 was used in the oneway analyses. For dichotomised data a  $\chi^2_{MH}$  test was used. If not stated otherwise the level of significance used is 0.05. For categorised data logistic regression analysis was performed using one dependent and one or more independent variables. Confidence intervals were calculated according to standard procedures [2].

## RESULTS

The personal characteristics of the participants have been reported earlier [23], and will only be briefly described here. Mean (SD) age was 37.7 (11.9) years among garbage handling workers which was significantly lower than 44.5 (11.3) years among the controls. Mean employment time in current job was significantly higher among the controls compared to paper sorting, composting and garbage handling workers, 12.2 (10.1), 5.2 (8.0), 0.8 (1.1) and 2.8 (5.0) years in the four groups respectively. No differences were found for smoking neither as pack-years nor as cigarette equivalents smoked per day. The mean pack years in the controls, the paper sorting, the composting and garbage handling workers were: mean(SD) 15.6 (17.5), 9.2 (20.6), 22.8 (29.2) and 12.8 (12.7), respectively.

Table 1 summarises the hygienic survey. Dust was found in all plants with the lowest concentration in the water-supply plant. The mean concentration of  $0.74 \text{ mg/m}^3$  in the garbage handling plants was significantly higher than the  $0.42 \text{ mg/m}^3$  found in the water supply-plants. Sampling of microorganisms revealed great variations in the total count. Far greater counts of total microorganisms and moulds were found in the resource-recovery plants compared to the very few found in the water supply plants. Significantly higher amounts of total bacteria were

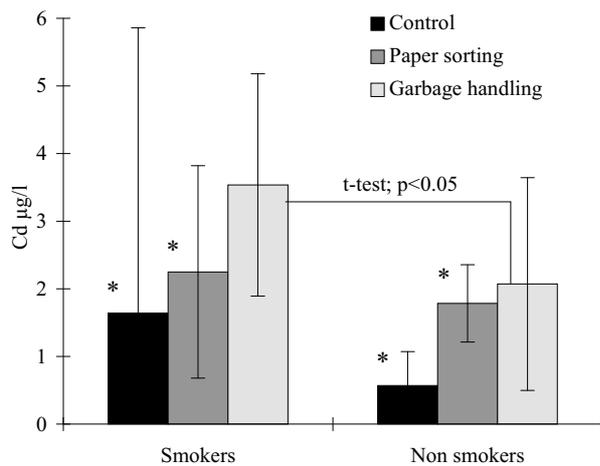
found in compost plants as well as garbage handling plants, compared to paper sorting plants. Significantly higher counts of Gram-negative bacteria were found in the composting and garbage handling industries compared to the water supply industry. The concentrations of endotoxins were low in all plants but the concentrations in the garbage handling plants were significantly higher than in the paper sorting plants. In the garbage sorting plants we found the highest concentrations of microorganisms in the reception hall where the garbage is dumped from trucks ( $0.2 - 27.6 \times 10^4 \text{ cfu/m}^3$ ) and during hand sorting ( $0.2 - 14.8 \times 10^4 \text{ cfu/m}^3$ ). In the composting plants the concentrations of microorganisms were highest in association with aeration of piles ( $1.0 - 83.6 \times 10^4 \text{ cfu/m}^3$ ). The highest concentration measured in this survey was in a plant during indoor aeration of a compost pile.

Skin symptoms were significantly increased in the garbage handling industry (Tab. 2). Itching of the skin more than once a month was reported by 6 (13.6%) of the garbage handling workers compared to none of the controls. However, no difference was found in the prevalence of attacks of blisters in the skin during the past 12 months. Storage mites induced weak skin prick reactions on 3 of the garbage handling workers but no person was found in this branch with a positive skin prick test greater than the histamine control, in contrast to a prevalence of 7.6% among the controls. The logistic regression analysis showed that itching of the skin more

**Table 3.** Logistic regression of symptoms among Danish recycling workers on plant type controlled for confounding by smoking, age and familial allergy. Odds ratio (95% confidence intervals).

Work	Ever experienced vomiting or diarrhoea in relation to work	Itching of the skin more than once a year
Water supply	1.00	1.00
Paper sorting	NC	1.39 (0.28-7.1)
Garden compost	7.51 (1.17-48.1)	NC
Garbage handling	7.30 (2.50-21.3)	3.78 (1.46-9.8)

NC: not calculated due to unilarity.



**Figure 1.** Cd blood levels among smokers and non-smokers in the study; mean, SD. \*  $p < 0.05$ , t-test vs garbage handling workers.

than once a year was significantly increased among garbage handling workers, when the analysis was controlled for smoking, age and familial allergy. OR (95% CI) was 3.78 (1.46–9.8) (Tab. 3).

Gastrointestinal symptoms, ever having experienced vomiting or diarrhoea in relation to work, were significantly more common in the garbage handling and composting industry than in the controls. OR (95% CI) were 7.30 (2.50–21.3) and 7.51 (1.17–48.1) in the two groups respectively (Tab. 3).

Table 4 shows the results of the trace element analysis. It is seen that all the concentrations of metals and trace elements are within the normal range. The paper sorting and garbage handling workers had significantly lower Pb-levels (40.8, 37.2  $\mu\text{g/l}$  respectively) compared to control workers (56.2  $\mu\text{g/l}$ ). Mercury was higher among the paper sorting workers (2.65 (2.23)  $\mu\text{g/l}$ ) compared to controls and garbage handling workers (2.16 (1.94) and 1.93

(2.60)  $\mu\text{g/l}$ ). For cadmium we found significantly higher concentrations among garbage handling workers. Furthermore, we found a higher level associated to smoking in all groups. However, this difference was only significant for the garbage handling workers compared to the controls. There was a significant increase in the Cd level in smoking as well as non-smoking garbage handling workers of 3.6 (1.7) and 2.1 (1.6)  $\mu\text{g/l}$  compared to 1.7 (4.3) and 0.6 (0.5)  $\mu\text{g/l}$  among controls and 2.3 (1.6) and 1.8 (0.6)  $\mu\text{g/l}$  among paper sorting workers, as seen in Figure 1.

Selenium showed lower concentrations among the garbage handling workers compared to controls. For the rest of the trace metals only minor differences were found. Interestingly, we have been able to measure strontium in the serum of all groups. This strontium concentration was only seen in smokers and at levels of (mean (SD)): 10 (0), 10 (30), 20 (10) and 10 (10)  $\text{mg/l}$  in the smoking controls, paper sorting, composting and garbage handling workers, respectively.

## DISCUSSION

The mean age and length of employment was higher in the paper sorting industry than in the garbage handling industry. This might be explained by the newness of the branch. Another possibility is a high turnover among the newly employed garbage workers. The latter explanation are currently being investigated.

The total dust measurements were lower than the results from a resource recovery plant in USA [11], and also lower compared to compost plants in USA and Sweden [4, 9]. The total numbers of microorganisms however, were comparable to concentrations in the above mentioned plants. The endotoxin levels were low compared to other industries with exposure to organic dust [8, 19–21], but comparable to other compost plants [9]. However, they

**Table 4.** Element content in whole blood and serum among recycling workers according to plant type.

Concentration	Control		Paper sorting		Compost		Garbage handling	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pb ( $\mu\text{g/l}$ )	56.2	28.8	40.8 <sup>1</sup>	36.10	-	-	37.2 <sup>1</sup>	23.2
Hg ( $\mu\text{g/l}$ )	2.16	1.94	2.65	2.23	-	-	1.93	2.60
Cd ( $\mu\text{g/l}$ )	1.29	3.36	2.00	1.13	-	-	3.09 <sup>1</sup>	1.80
Fe (mg/l)	1.57	0.76	1.53	0.36	1.20	0.23	1.53	0.49
Cu (mg/l)	0.85	0.16	0.74	0.10	0.88 <sup>2</sup>	0.11	0.85	0.14
Zn (mg/l)	0.79	0.16	0.80	0.17	0.74	0.12	0.76	0.13
Se (mg/l)	0.12	0.02	0.11	0.02	0.10 <sup>1</sup>	0.01	0.11 <sup>1</sup>	0.02
Br (mg/l)	4.36	1.21	3.85	0.89	2.91 <sup>1,2,3</sup>	0.93	3.89 <sup>1</sup>	1.08
Rb (mg/l)	0.44	0.23	0.35 <sup>1</sup>	0.09	0.29 <sup>1</sup>	0.06	0.33 <sup>1</sup>	0.09
Sr (mg/l)	3.3	15.6	5.9	19.8	0.0	0.0	4.8	17.5
N*	112		20		8		40	

<sup>1</sup>  $p < 0.05$  oneway group vs control; <sup>2</sup>  $p > 0.05$  oneway group vs garbage handling; <sup>3</sup>  $p > 0.05$  oneway group vs paper sorting; \* For Pb, Hg and Cd only 102, 19, 0 and 29 samples were available.

were substantially lower than what was found at a resource recovery plant with a high prevalence of respiratory symptoms [22]. We have not measured the heavy metal content in the air of the plants. From another study [11] it is known that there might be exposure to heavy metals in the sorting facilities. In the former study no Cd was found in the samples, but the authors state that this must be due to shortcomings in their measuring technique.

The prevalence of skin symptoms in this study are comparable to what was found by Clark *et al.* during composting of wastewater treatment sludge [6]. Our finding of more skin symptoms among the garbage handling workers compared to the controls, and at the same time more people with positive skin reactions among the controls indicates, like what we found for asthma, that there seems to be a healthy worker selection into these types of jobs. Had this not occurred, the OR of 3.78 for itching of the skin among the garbage handling workers, might have been even greater.

The OR of 7.51 and 7.30 for ever having experienced vomiting or diarrhoea in relation to work is according to the composting and garbage handling workers related to "bad quality" of the household waste or to "burned down piles" in the composting plants. Both situations are characterised by high concentrations of microorganisms which might be aerosolised during manipulation of the material. Situations like that have not been found in this survey. Hence, it is not possible to calculate any dose response relationship between exposures and symptoms.

The content of trace elements in the blood of all the workers investigated in this survey shows values within the normal range [13, 16, 18, 24]. However, there was an effect of smoking as well as job on the concentration of Cd with the garbage handling workers having the highest blood concentrations of Cd. This might reflect an occupational exposure, although much has been done in Denmark to get rid of batteries containing heavy metals from the waste. There has been an ongoing campaign with a maximal impact possibly after this survey. The Cd-concentrations were, however, small and will not cause any health effects on the workers. Still emphasis must be laid on the reduction of the exposure to Cd in the garbage handling industry. The lead concentrations were highest among the control workers. For this we have no obvious reason, although some of the workers were tending the diesel engines used to pump water into Copenhagen. A few of the control workers were skilled auto-mechanics with some ongoing hobby garage work. A third possibility would be lead water-piping which has not been used in the Copenhagen area for the last 40 years. An interesting finding in our material is the detectable level of Sr. Although at low concentrations, we consistently found mean serum concentrations of Sr from 10 to 20 mg/l among smokers with a peak of 97 mg/l. This means, that cigarette smoke may contain some amounts of strontium, since there is no other source of this trace element known to us.

## CONCLUSION

We found higher risk of skin as well as gastrointestinal symptoms among the garbage handling workers and compost workers. This study shows that garbage handling workers are prone to higher concentrations of Cd in their serum compared to controls. Together with the former study, this survey emphasises the need to address the working environment, when recycling facilities are being planned.

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