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DIARRHOEA AMONG WASTE COLLECTORS ASSOCIATED WITH BIOAEROSOL EXPOSURE*

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Abstract: Gastrointestinal problems such as diarrhoea have previously been reported in small studies among waste collectors. The present nationwide study relates self-reported diarrhoea symptoms to self-reported working conditions and estimated levels of bioaerosols. A questionnaire based survey among Danish waste collectors (n = 2303) and a comparison group of male municipality workers (n = 1430) collected data on occupational exposures, present and past working environment, psychosocial work environment, and health status. Estimated exposure was related to self-reported working conditions. Prevalence Proportion Ratios (PPR) adjusted for relevant confounders were estimated by generalized linear models. The group with high exposure to fungal spores reported most diarrhoea symptoms (PPR = 5.60 (2.39;13.08)), medium exposure was associated with fewer diarrhoea symptoms (PPR = 3.45 (2.24;5.31)), and the low exposure was associated with the fewest diarrhoea symptoms (PPR = 3.02 (1.86;4.92)). Test for trend was significant. The group with high exposure to either total count of fungi or total count of microorganisms reported fewest symptoms compared to the low exposed. No positive trend was found. This study reported an association between level of exposure to fungal spores and self-reported diarrhoea among waste collectors.

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INTRODUCTION

Previous analysis has shown an association between gastrointestinal symptoms and the job as a waste collector and moreover that the symptoms predominantly occur in the summer [10]. Due to the planned recycling of increasing amounts of waste, it is expected that the number of employees in the waste industry will increase. Thus, knowledge about health and working conditions among waste collectors is needed in order to prevent new initiatives in the waste industry to result in health problems among the employees.

Source separation of the waste at the households is a likely element of the increased recycling. Thereby more fractions of waste are to be collected (for example fractions of biodegradable waste, combustible waste, paper and glass, and residual waste), which may decrease the collection frequency and thereby create more favourable conditions for growth of microorganisms.

To our knowledge no study exists on the association between gastrointestinal problems and level of bioaerosol exposure among waste collectors. The present study relates the self-reported diarrhoea symptoms to self-reported working conditions and estimated levels of bioaerosols (fungal spores, total count of fungi, total count of microorganisms).

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MATERIAL AND METHODS

Information on self-reported health status and working conditions was collected in a questionnaire based survey in 1994 among all waste collectors in Denmark [11]. A total of 2,412 waste collectors (employed at approximately 94% of all waste collection companies in Denmark) were identified, and a questionnaire was mailed to them. Two reminders were sent and a telephone interview was conducted additionally among those who had not replied to the mailed questionnaire. Data from the self-administrated questionnaire and from the telephone interview can be pooled without problem [24].

A total of 109 persons were excluded from the analysis as they were wrongly classified as waste collectors, because of retirement, illness or unemployment. The questionnaire was answered by 76% (n = 1747) of the remaining 2,303 persons. The 11 female waste collectors were excluded from the analysis due to the low number.

The questionnaire was also sent to a comparison group consisting of 1,460 municipal workers, mainly with outdoor work. Thirty of these persons stated that they had retired, were ill or unemployed. These persons were excluded while 82% (n = 1169) of the remaining 1,430 persons answered the questions. Of these 343 were road workers, 422 were park workers and the remaining 328 had other job functions. For 44 the job group was missing, and 32 were excluded because they were females.

It was expected that the park workers was the group with the lowest exposure to bioaerosols and traffic exhaust. Moreover it was found that the park worker group was different from the road worker group and the group with other outdoor job functions concerning age and amount of complaints. Thus, only the group of park workers was used as comparison group.

The questionnaire. The questionnaire had the following main groups of questions: Present and former working conditions, the psychosocial work environment, background information, smoking and drinking habits, and health status. Questions on working conditions dealt with, among others, length of employment, job function, type of waste collected, type of truck, and type of container.

The questions on type of truck most frequently used concerned compactor trucks with high or low scoop, and platform trucks.

The questions on type of waste concerned biodegradable waste (the wet, green part of household waste), mixed household waste (a non-separated fraction), the residual fraction (the dry, remaining fraction when the biodegradable part of the waste has been separated), paper (separated by the household), glass (separated by the household), and garden waste (a biodegradable fraction separated by the household).

Many waste collectors collected different waste fractions. Experience from field measurements [3] showed that the fractions of biodegradable waste, the residual fraction, and mixed household waste could be pooled into a 'mixed' fraction as no significant difference in exposure levels existed between these fractions. Paper was either a separate fraction or was pooled with glass. Garden waste was a separate fraction.

The questions on type of containers concerned sacks made of paper or plastic, bins without wheels, divided or non-divided containers with two wheels, and containers with four wheels. The field measurements showed no significant difference in exposure between collection of waste in two or four wheeled containers [3]. Therefore, these two types of bins were pooled.

The questions on job functions concerned driver, front runner (runs in front of the car and tugs out the waste containers to the road), and loader (takes the container at the roadside and tugs it up into the truck). Besides these job functions, the 'mixed' function was defined when the respondent reported shift in job function during the day, from day to day or from week to week.

The questions concerning the proportion of time spent with different fractions of waste, type of containers, and job functions were dichotomized so that if the time spent was half of the day or more, it was classified as 'exposure' whereas less than 1/4 of the day was classified as 'non-exposure'.

The psychosocial questions were from the Whitehall studies [19] which relates to the demand-control-support model [12, 13]. From these questions the three psychosocial exposure measures, demand, control and job-support were calculated [17].

The questions on gastrointestinal problems were dichotomized so that no problems and problems some times per year were grouped as 'No' and problems some times per month or more frequent were grouped as 'Yes' [24]. Missing values was grouped as 'No'.

The exposure matrix. Operating only with single exposure indications as either collected type of waste, type of bin used, or job function was too simple when the target group had a complex exposure structure as the group of waste collectors. Therefore the exposure was described by a combination of both waste type, job function, bin, and truck.

Distinctive working processes in the waste collector job were defined on the basis of information in the questionnaire. Each working process was described by type of (i) truck, (ii) bin, (iii) waste, and (iv) job function in order of priority. By this definition it was possible to divide most of the waste collectors into distinct working-processes.

Examples of working processes could be: (i) use of a compactor truck with low scoop, container with (2 or 4) wheels, biodegradable waste, mixed household waste or the residual fraction, and job function driver, or (ii) use of a compactor truck with low scoop, bins without wheels, biodegradable waste, mixed household waste or the residual fraction, and job function loader.

Table 1. Prevalence Rate of diarrhoea according to weekly dose (cfu or cells) of fungal spores, total fungi and total microorganisms in the study among Danish waste collectors, 1994.

Parameter	Group	Level	n	PR_1 (%)	PR_2 (%)
Fungal spores (cfu)	High	$> 1\times10^{10}$	10	40	2
	Medium	$> 1\times10^{9}$-1×10^{10}	711	20	68
	Low	1×10^{8}-1×10^{9}	229	18	20
	Comparison	$< 1\times10^{8}$	387	6	10
Total fungi (cells)	High	$> 2\times10^{10}$	68	18	6
	Medium	$> 2\times10^{9}$-2×10^{10}	813	20	77
	Low	2×10^{8}-2×10^{9}	69	22	7
	Comparison	$< 2\times10^{8}$	387	6	10
Total microorganisms (cells)	High	$> 6\times10^{10}$	18	17	1
	Medium	$> 6\times10^{9}$-6×10^{10}	847	20	80
	Low	6×10^{8}-6×10^{9}	85	20	8
	Comparison	$< 6\times10^{8}$	387	6	11

PR_1 indicates the percentage of diarrhoea reports according to the size of the group. PR_2 indicates the percentage of diarrhoea reports according to the total number of reports.

Each of the working processes was used as an entrance in a job exposure matrix [8, 21] with level of exposure as the second entrance [3]. The investigated exposure parameters were fungal spores, total count of fungi, and total count of microorganisms.

A weekly dose was estimated for each person by multiplying the level of exposure with the working process associated lung ventilation rate [3], and the self-reported number of working hours per week. The comparison group was regarded as having no exposure.

Statistical methods. To analyze the relationship between level of exposure and diarrhoea, logistic regression models were fitted (proc logistic in SAS). As explanatory variables were used level of exposure and variables which were almost statistically significant ($p<0.10$) in univariate analysis. All explanatory variables were included in the first model. Then the model was reduced depending on the Wald test, and the relevance of the biological variables. If removal of one variable lead to a 10% change in one or several parameter estimates for the other, relevant explanatory variables, the variable was maintained in the model no matter the p-value.

Weekly dose of fungal spores, total counts of fungi and total count of microorganisms were each grouped into four, (i) none, (ii) low, (iii) medium, and (iv) high. The groups were established to ensure the highest exposure contrast between the groups. The limits for the weekly dose were for fungal spores (ii) $> 1 \times 10^{8}$ cfu, $\leq 1 \times 10^{9}$ cfu, (iii) $> 1 \times 10^{9}$ cfu, $\leq 1 \times 10^{10}$ cfu, (iv) $> 1 \times 10^{10}$ cfu; for total counts of fungi (ii) $> 2 \times 10^{8}$ cells, $\leq 2 \times 10^{9}$ cells, (iii) $> 2 \times 10^{9}$ cells, $\leq 2 \times 10^{10}$ cells, (iv) $> 2 \times 10^{10}$ cells; and for total counts of microorganisms (ii) $> 6 \times 10^{8}$ cells, $\leq 6 \times 10^{9}$ cells, (iii) $> 6 \times 10^{9}$ cells, $\leq 6 \times 10^{10}$ cells, (iv) $> 6 \times 10^{10}$ cells (Tab. 2).

In the final model, the explanatory variables included average alcohol consumption per day calculated as the total amount of beer, wine, and spirits, smoking status, and the psychosocial exposure measures demand and support.

The fit of the final model was analyzed with the Hosmer-Lemeshow test [9] and with the area under the ROC-curve [14].

Finally, the risk estimates were fitted with a generalized linear model (proc genmod in SAS) with binomial error and a log link-function. This analysis yields as a result the prevalence proportion ratio (PPR) [27]. For each PPR are shown 95% confidence limits and p-value for level of significance (Wald test).

RESULTS

A total of 950 waste collectors were assigned a working process. Exposure was expressed as inhaled dose per week (cfu (Colony Forming Units), or cells). The mean level of weekly dose was for fungal spores 2.8×10^{9} cfu (Range: 1.2×10^{8}–1.8×10^{10}, SE = 7.9×10^{7}); for total counts of fungi 9.2×10^{9} cells (Range: 2.4×10^{8}–4.6×10^{10}, SE = 2.4×10^{8}), and for total counts of microorganisms 1.7×10^{10} cells (Range: 6.0×10^{8}–7.8×10^{10}, SE = 3.7×10^{8}). The number of self-reported hours per working week ranged from 7 to 74 (Mean = 33.8, SE = 0.2).

A total of 210 persons out of 1337 reported diarrhoea sometimes per month or more often. The prevalence of diarrhoea symptoms according to level of bioaerosol exposure is shown in Table 1.

Table 2. Final model for diarrhoea according to weekly dose (cfu or cells) of fungal spores, total fungi and total microorganisms in the study among Danish waste collectors, 1994. 1337 were included in the model, of these 210 with diarrhoea symptoms.

		Weekly dose				
Parameter	Group	Level	PPR (CI_{95})	p_{trend}[2]	p_{HL}[3]	$Area_{ROC}$[4]
Fungal spores (cfu)[1]	High	$> 1 \times 10^{10}$	5.60 (2.39; 13.08)			
	Medium	$> 1 \times 10^{9}–1 \times 10^{10}$	3.45 (2.24; 5.31)	0.001	0.50	0.70
	Low	$1 \times 10^{8}–1 \times 10^{9}$	3.02 (1.86; 4.92)			
	Comparison	$< 1 \times 10^{8}$	1 (-)			
Total fungi (cells)[1]	High	$> 2 \times 10^{10}$	2.91 (1.52; 5.55)			
	Medium	$> 2 \times 10^{9}–2 \times 10^{10}$	3.40 (2.22; 5.22)	0.94	0.14	0.70
	Low	$2 \times 10^{8}–2 \times 10^{9}$	3.53 (1.94; 6.41)			
	Comparison	$< 2 \times 10^{8}$	1 (-)			
Total microorganism (cells)[1]	High	$> 6 \times 10^{10}$	2.55 (0.86; 7.58)			
	Medium	$> 6 \times 10^{9}–6 \times 10^{10}$	3.39 (2.21; 5.19)	0.95	0.10	0.70
	Low	$6 \times 10^{8}–6 \times 10^{9}$	3.42 (1.91; 6.11)			
	Comparison	$< 6 \times 10^{8}$	1 (-)			

[1]corrected for mean alcohol consumption per day, smoking status and whether the psychosocial measures demand and support were above or equal to or below the mean value; [2]test for trend; [3]Hosmer-Lemeshow test for goodness of fit; [4]Area under the ROC curve.

In Table 2 the estimated PPR's for the relation of weekly dose of bioaerosols and diarrhoea are shown. The fit of the model are seen from Table 2.

High exposure to fungal spores was associated with most diarrhoea symptoms (PPR = 5.60 (2.39; 13.08)), medium exposure was associated with fewer diarrhoea symptoms (PPR = 3.45 (2.24; 5.31)), and the low exposure was associated with the fewest diarrhoea symptoms (PPR = 3.02 (1.86; 4.92)). Test for trend [1] was accepted (p = 0.001).

Using the parameters total counts of fungi or total counts of microorganisms as exposure variables did not show major differences between the exposure groups, although they appeared all significantly more prevalent than the comparison group. High exposure to total counts of fungi was associated with fewest diarrhoea symptoms (PPR = 2.91 (1.52; 5.55)), medium exposure was associated with more diarrhoea symptoms (PPR = 3.40 (2.22; 5.22)), and low exposure was associated with most diarrhoea symptoms (PPR = 3.53 (1.94; 6.41)). Almost the same pattern was seen concerning exposure to total counts of microorganisms. High exposure was associated with fewest symptoms (PPR = 2.55 (0.86; 7.58)), medium exposure was associated with more symptoms (PPR = 3.39 (2.21; 5.19)), and low exposure was associated with most symptoms (PPR = 3.42 (1.91; 6.11)) (Tab. 2).

DISCUSSION

The present cross-sectional study combined self-reported working conditions with estimated level of bioaerosol exposure (fungal spores, total counts of fungi, and total counts of microorganisms). A dose-response relationship between level of exposure to fungal spores and self-reported diarrhoea was indicated, meaning that the higher weekly dose, the more reports of diarrhoea. No positive trend was found for the other two bioaerosol parameters.

Several studies have related gastrointestinal problems to exposure to airborne Gram-negative bacteria. This is especially the case among sewage workers and employees at compost plants [15, 16, 28], and until now endotoxin from Gram-negative bacteria [5], has been suggested as a cause of gastrointestinal problems [16]. Gram-negative bacteria have also been found in waste [18].

This study indicates that the level of fungal spores was of importance concerning an association with diarrhoea. Fungal spores have been associated in other studies with pulmonary problems [7, 22]. To our knowledge this is the first study showing a dose-response relationship between diarrhoea and exposure to fungal spores. However, it is unknown whether the fungal spores cause the health problems or whether the measured fungal spores indicate the presence of other microorganisms. High microbial activity may also result in a high VOC (Volatile Organic Compounds) level in waste samples [26], and VOC's have been reported as a cause of gastrointestinal problems [6].

In this study the measured bioaerosol exposure concerned only an airborne exposure. It is unknown whether the measured level of airborne exposure was high enough to cause diarrhoea or whether other pathways were also of importance. Other relevant pathways for the exposure were ingestion (dirty hands when eating/ smoking) [4], which we have not been able to control for, or because of psychological factors (the smell of the waste, or an unhealthy psychosocial work environment), which was included in the model [13]. Measures of the psychosocial exposures were included in the final model which means, that the relationship that still exists, when psychosocial factors were included, must be explained by factors other than the psychosocial factors.

The assumption that the park workers had no bioaerosol exposure, may affect the dose-response relationship towards the null.

Using a job exposure matrix limits the results of dose-response relationship to group-level relationships. Detection of individual relationships needs other approaches. This should, however, be a minor problem in this study where establishment of homogeneous working processes was attempted.

The measurement of exposure may to some extent be misclassified. In the conversion from a self-reported work-process to estimated (continuous) level of bioaerosol exposure, and further to calculated weekly dose, grouped into three, some misclassification is inevitable. The magnitude of this misclassification could not be estimated as no true value exists neither on measured level of exposure nor on the conversion from self-reported exposure to measured exposure.

The working processes were defined by type of truck, bin, waste type and job function, but presumably also several other parameters as for example number of nearby colleagues, whether the working area is urban/rural, and season were of importance. These parameters were, however, not assessed during field measurement. Variation in exposure measurements was not calculated [3], neither the inter-individual variation nor the intra-individual variation. Moreover, part of the variation could not be measured. That is variation because of time spent in specific job-task, season, organisation (for example, number of nearby colleagues), and measurement errors. Also the calculated dose was not necessarily the same as the inhaled dose [20, 23]. In calculating the weekly dose it was also necessary to assume that the lung ventilation rate on the average was the same for each person in each working process which may add additional variation.

The exposure used in this study indicated present, weekly exposure on specific working-processes. Another approach would be to calculate cumulative exposure on the basis of information on seniority [2]. The cumulative exposure would also unavoidably be misclassified due to lack of information on previous working processes and historic exposure [25].

Higher estimates of the relationship to exposure were found compared to analysis with only single exposure variables, that is type of waste, or job function [10, 11]. Thus, despite misclassification of the exposure, the use of a job-exposure approach based on working processes seemed to be a useful approach in the explanation of the relationship between bioaerosol exposure and acute health problems such as diarrhoea.

In conclusion this study showed an association between diarrhoea and level of fungal exposure. This is, however, only the first step in the analysis on an association between bioaerosol exposure and gastrointestinal problems.

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