ORIGINAL ARTICLES AAEM

Ann Agric Environ Med 2001, 8, 39–45

WORK-RELATED SYMPTOMS IN SEWAGE TREATMENT WORKERS

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Douwes J, Mannetje A, Heederik D: Work-related symptoms in sewage treatment workers. *Ann Agric Environ Med* 2001, **8**, 39–45.

Abstract: The aim of this study was to investigate health symptoms in sewage treatment workers. A health questionnaire was distributed among 147 sewage treatment workers. Correlating symptoms were clustered using principal component analysis and the association with self-reported exposure was assessed by calculating prevalence odds ratios (OR). Endotoxin was measured in two treatment plants. Personal endotoxin exposure was low (<10 Endotoxin Units/m^3). Factor analysis of 29 symptoms resulted in four clusters of highly correlating symptoms: 'flu-like symptoms'; 'higher airway symptoms'; 'lower airway symptoms'; and 'neurological symptoms'. These clusters were positively associated with working with sewage, but only significant for 'flu-like symptoms' (OR=5.0; 95%CI=1.4-17.6; p<0.05) and 'neurological symptoms' (OR=4.2; 95%CI=1.5-11.7; p<0.01). Chemical exposure was associated with 'neurological symptoms' (OR=8.4; 95%CI=1.1-65.7; p<0.05). The use of daily washed working clothes was negatively associated with 'flu-like symptoms' (OR=0.3; 95%CI=0.1-0.6; p<0.01). In conclusion, sewage treatment workers develop a large variety of work-related symptoms that are not likely caused by endotoxin exposure only. Good hygienic practice at the workplace may prevent some of these symptoms.

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Key words: sewage, health, symptoms, factor analysis, endotoxin.

INTRODUCTION

Sewage workers are potentially exposed to a wide variety of pollutants ranging from specific chemical agents (e.g. H_2S, volatile organic components and specific industrial chemicals such as PCBs, heavy metals, etc.) to infectious and parasitic (e.g. hepatitis A virus, *Leptospira* and *Helicobacter* bacteria, *Ascaris* helminths, *Giardia* protozoans etc.) and non-infectious biological agents (e.g. endotoxins, mycotoxins). Health effects caused by chemical exposure have been reported when peak-exposures occurred [10, 16, 26], usually due to industrial accidents. For instance, Morse *et al.* [16] reported a high prevalence of airway irritation, headache, skin irritations and nausea in 145 workers after an industrial spill of hexachlorocyclopentadieen [HCCPD; a chemical intermediate in the production of pesticides] into a municipal sewage system. Several studies have assessed the risk of contracting infectious and parasitic diseases [1, 3, 13], and although some studies showed an increased risk for hepatitis A, disease risks were generally low. In addition, sewage treatment workers may develop work-related respiratory, gastrointestinal, and flu-like symptoms [14, 21, 22, 23] that may be associated with exposure to non-infectious microorganisms and specific microbial toxins. Many of the symptoms in the latter category are also common in other waste processing industries such as the compost industry [6, 19, 24].

Thus, workers in sewage treatment plants are at risk for developing a broad range of health effects which makes this occupational group difficult to study, and most studies have therefore only focussed on one particular exposure and the associated specific health outcome. However, in order to gain better insight in the occurrence

Received: 20 December 2000
Accepted: 12 March 2001

and causes of work-related adverse health effects in sewage treatment workers, a more extensive approach is needed and potentially a wide range of health effects and potential causal exposures have to be considered. We therefore conducted a questionnaire survey among sewage treatment workers which contained questions on flu-like, respiratory, throat, eye and nose, neurological and gastrointestinal symptoms. We subsequently identified specific clusters of highly correlating symptoms using factor analysis and studied the association between these clusters and self-reported occupational exposure. In addition, we measured bacterial endotoxin exposure, an agent that has been suggested to be involved in some symptoms, in two sewage treatment plants.

MATERIALS AND METHODS

Subjects. A total of 151 Dutch sewage treatment workers processing domestic wastewater were asked to participate in a health questionnaire study. Workers were approached through personnel departments or the site managers of all 51 sewage treatment plants situated in the east of The Netherlands. Of the 151 workers, 147 (97%) returned a completed questionnaire by mail, between January and September 1993. All subjects gave written informed consent.

Questionnaire. The questionnaire consisted of three parts, including: 1) personal and work characteristics; 2) health symptoms; and 3) smoking and drinking habits. Health symptoms (n = 29) consisted of 'flu-like symptoms', 'respiratory symptoms', 'throat, eye, nose and skin irritation', 'neurological symptoms' and 'gastrointestinal symptoms'. Subjects were asked whether symptoms occurred frequently, occasionally or never during the past 12 months. A positive response was defined as frequently or occasionally occurring symptoms during the past 12 months (*versus* no symptoms). In addition, two questions on the occurrence and frequency of vomiting during work and diarrhoea were asked. Exposure was also assessed by questionnaire and two types of exposure were defined: 1) frequent *versus* occasional or no contact with sewage and/or sewage sludge, and 2) frequent *versus* occasional or no contact with work-related chemicals used for sewage treatment. In addition, we asked for information concerning general hygiene practices at work including the use of daily washed company clothes *versus* use of own clothes during work.

Endotoxin measurements. Since some authors have argued that endotoxin exposure might be involved in some of the symptoms expressed by sewage workers [22] we measured (8-hr measurements) personal inhalable dust and endotoxin (n = 79) in 11 workers from two sewage plants. In addition, ambient inhalable dust and endotoxin (n = 66) was sampled in the same sewage treatment plants. The two plants were considered representative for all sewage plants included in the study. In one plant sampling was conducted during four time periods (winter, spring, summer and autumn) for 2-4 days per season whereas in the other plant sampling was performed for two days only in winter. Since in The Netherlands most processes of sewage treatment takes place outdoors (with the exception of sludge dewatering) most of the sampling was performed outdoors. Dust was sampled on 25 mm glass fibre filters (Whatmann GF/A) mounted in a PAS-6 sampling head at a flow rate of 2 l/min using portable pumps (Gilian Gil-Air). Gravimetric measurements, and endotoxin extractions were performed, as described earlier [5]. Endotoxin concentration was determined by using a kinetic chromogenic *Limulus* amoebocyte lysate (LAL) method (BioWhittaker; LAL lot no. 1L2360) [5]. The endotoxin potency of the standard (BioWhittaker; lot no. 1L2180) was 13 endotoxin units (EU)/ng.

Table 1. Personal and ambient geometric mean (GM) endotoxin exposures in sewage treatment plants, expressed in Endotoxin Units (EU) per m^3 with geometric standard deviation (GSD).

	N	GM (EU/m^3)	GSD	Min-Max
Personal exposure	79	9.5	3.0	0.3-143.2
Ambient Exposure				
All areas except sludge dewatering area[†]	56	3.4	3.4	0.2-99.8
Sludge dewatering area[¶]	10	85.6	1.6	44.3-172.7

[†] Areas near sewage/influent intake, sedimentation tank, aeration tanks, sludge collection belts, sludge basins, workshop, pump areas, laboratory and offices; [¶] Sludge dewatering was performed by using a belt press.

Statistical analysis. Data were analysed using SAS statistical software (SAS 6.12; SAS institute, Cary, NC). The interrelationship between the reported health symptoms was analysed using principal component analysis with orthogonal varimax rotation [9]. This procedure enabled the creation of clusters of symptoms that were reported regularly in combination of each other. Instead of evaluating the individual symptoms, that are usually not very specific (e.g. headache, shivering, nausea, eye and nose irritation, etc), we have evaluated the occurrence of more specific and meaningful clusters of symptoms obtained by the factor analysis.

Symptom clusters (or factors) were identified based on 'eigenvalues' (>1) and factor loadings (>0.3) of the individual symptoms, resulting in four clusters of highly correlating symptoms. These four clusters consisted of 21 symptoms, and eight symptoms were not included in the newly defined symptom clusters. A subject was considered to have a positive response for a symptom cluster when the subject expressed a minimum number of individual positive symptoms within that particular symptom cluster. The cut-off for this minimum number was chosen so that the prevalence of each symptom cluster was approximately 20% (see results, Table 4). For instance, a 20% prevalence of the symptom cluster 'flu-like symptoms'

Table 2. Symptom prevalence during past 12 months in 147 sewage treatment workers.

Symptoms	Frequently (%)	Occasionally (%)	Never (%)
Flu-like symptoms:			
Fatigue	6.1	33.3	60.6
Fever	0.7	23.1	76.2
Shivering (not due to low temperature)	2.1	24.6	73.3
Perspiration (not due to physical activity)	3.4	17.8	78.8
Joint and muscle aches (not due to sports)	10.2	27.9	61.9
Trembling limbs	2.0	7.5	90.5
Respiratory symptoms:			
Cough	4.8	59.1	36.1
Cough with phlegm	4.1	27.4	68.5
Wheezing in the chest	0.7	8.8	90.5
Dyspnea	0.7	19.0	80.3
Shortness of breath	2.8	5.4	91.8
Chest tightness	0.7	13.0	86.3
Irritation symptoms:			
Stuffed/runny nose	8.2	64.4	27.4
Nose irritation	7.5	55.5	37.0
Throat irritation	6.1	47.6	46.3
Eye irritation	3.4	22.8	73.8
Skin irritation	2.7	21.3	76.0
Skin rash	2.1	11.1	86.8
Neurological symptoms:			
Headache	9.5	49.7	40.8
Oppressive sensation in the head	6.9	26.2	66.9
Difficulty at concentrating	1.4	23.3	75.3
Forgetful	3.4	39.0	57.6
Dizziness	0.0	15.6	84.4
Gastrointestinal symptoms:			
Nausea	2.1	19.8	78.1
Acid indigestion	10.3	22.4	67.3
Lack of appetite	0.7	14.4	84.9
Vomiting during work (yes/no)		(yes) 7.5	(no) 92.5
Diarrhoea (yes/no)		(yes) 39.5	(no) 60.5
Other symptoms:			
Palpitations	2.0	12.2	85.8

was obtained when three or more positive individual symptoms (within the flu-like symptom cluster) were used as cut-off. The cut-off values for the symptom clusters 'higher airway symptoms', 'lower airway symptoms', and 'neurological symptoms' were >4, ≥2 and ≥3, respectively.

Prevalence odds ratios to describe the association between self-reported exposure and the presence of symptom clusters were calculated by means of a logistic regression analysis. The symptoms that were not part of a symptom cluster were individually evaluated. Associations were adjusted for smoking and age. Although some authors [12, 25] have argued for the use of prevalence ratios, the standard effect measure in prevalence studies is the prevalence odds ratio [2, 20] since, in a stable population, this provides an estimate of the ratio of the products of disease incidence and average disease duration in the two populations being compared. Thus, if an exposure does not affect disease duration, then the prevalence odds ratio directly estimates the incidence rate ratio [18].

RESULTS

Endotoxin exposure. No differences in endotoxin exposure were observed between the different seasons and no significant differences in exposure existed between both sewage treatment plants (data not shown). Therefore data from both plants and all four seasons were pooled. Personal endotoxin exposure was relatively low

Table 3. Four groups of highly correlated symptoms as determined by factor analysis (factor loadings after orthogonal rotation between brackets).

Symptom cluster 1 "flu-like symptoms"		Symptom cluster 2 "higher airway symptoms"		Symptom cluster 3 "lower airway symptoms"		Symptom cluster 4 "neurological symptoms"	
Lack of appetite	(0.80)	Stuffed/runny nose	(0.79)	Chest tightness	(0.71)	Oppressive sensation in the head	(0.61)
Shivering	(0.74)	Cough	(0.62)	Shortness of breath	(0.68)	Headache	(0.63)
Nausea	(0.66)	Throat irritation	(0.62)	Wheeze	(0.68)	Acid indigestion	(0.49)
Fever	(0.61)	Nose irritation	(0.60)	Dyspnoea	(0.51)	Difficulty at concentrating	(0.47)
Perspiration	(0.59)	Cough with phlegm	(0.46)			Dizziness	(0.42)
Vomiting	(0.37)						
Trembling limbs	(0.36)						

Table 4. Symptom cluster prevalence, by number of individual symptoms included in the symptom cluster.

Symptom clusters	Number of symptoms						
	≥1	≥2	≥3	≥4	≥5	≥6	≥7
Flu-like symptoms	48.3%	33.1%	20.0%	11.0%	7.6%	2.1%	1.4%
Higher airway symptoms	84.7%	74.3%	62.5%	43.1%	20.1%	-	-
Lower airway symptoms	26.7%	13.7%	7.5%	3.4%	-	-	-
Neurological symptoms	71.1%	49.7%	25.5%	12.4%	4.1%	-	-

with a geometric mean of 9.5 EU/m^3 (n=79; Table 1) with only incidental exposures above 50 EU/m^3, a health based occupational exposure limit recently suggested in The Netherlands [4]. At only one location, i.e. the sludge dewatering area, significantly elevated endotoxin levels were measured (GM=85.6 EU/m^3, n=10), while geometric mean levels in all other areas of the plants were low (Tab. 1). Inhalable dust levels were also low with the majority of levels below the limit of detection (0.3 mg/m^3; data not shown). Since personal endotoxin and inhalable dust exposures were low and no exposure grouping based on job titles or tasks could be conducted because of the large diversity of tasks in the majority of subjects, we used self-reported exposure to sewage or chemicals in all further analyses.

Population characteristics and symptom prevalence. All workers (n=147) were males. Their mean age was 40.7±9.9 (SD) and they all worked eight-hour shifts, five days a week for 9.8±7.4 years. Twenty four percent were current smokers. Prevalence rates for all symptoms are listed in Table 2. Diarrhoea occurred in 39.5% of the subjects. After correction for travelling in the tropics and diarrhoea in the family, a prevalence of 33% remained. Diarrhoea episodes lasted on average 2-3 days and episodes returned on average 3-4 times a year.

Factor analysis. Twenty-one out of 29 symptoms loaded on four symptom clusters: ‘flu-like symptoms’, ‘higher airway symptoms’, ‘lower airway symptoms’ and ‘neurological symptoms’ (Tab. 3). The percentage of variance explained by these four clusters was 94%. All symptoms loaded high on only one cluster, except ‘cough with phlegm’, which also loaded high (0.43) for the cluster of ‘lower airway symptoms’. Symptoms that were not associated with any of the symptom clusters included fatigue, joint and muscle aches, eye and skin irritation, forgetfulness, palpitations and diarrhoea. ‘Higher airway symptoms’ appeared to be common in sewage workers with 20.1% of the population reporting all five individual symptoms. At least three symptoms of the ‘flu-like’ and ‘neurological’ cluster were reported by 20.0% and 25.5% of the sewage workers, respectively, and at least two lower respiratory symptoms were reported by 13.7% of the study population (Tab. 4).

Symptom clusters and exposure. Exposed workers (66% for sewage and 85% for chemical exposure) did not differ from non-exposed workers with respect to age, years of employment, smoking or drinking habits (data not shown). Exposure to sewage was not correlated with exposure to chemicals (Pearson correlation coefficient = 0.15, p = 0.08). Table 5 describes the relationships between self-reported exposure and the symptom clusters. ‘Flu-like symptoms’ and ‘neurological symptoms’ were significantly associated with exposure to sewage (OR = 5.0 and OR = 4.2, respectively; Tab. 5). Elevated ORs were also observed for chemical exposure, but only the association with neurological symptoms was statistically significant (OR = 8.4). No significant associations were found between exposure and ‘higher airway symptoms’ and ‘lower airway symptoms’ (ORs were elevated, however). As expected, ‘lower airway symptoms' were more common in smokers (OR = 3.1,

Table 5. The associations between various exposure variables and clusters of symptoms expressed as odds ratios (OR) with 95% confidence intervals (95% CI). Associations were adjusted for age and smoking.

	Flu-like symptoms		Higher airway symptoms		Lower airway symptoms		Neurological symptoms	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Contact with sewage	5.0*	1.4-17.6	2.7	1.0-7.7	2.9	0.8-10.8	4.2**	1.5-11.7
Working with chemicals	6.4	0.8-50.5	2.8	0.6-13.1	4.6	0.5-38.4	8.4*	1.1-65.7
Working clothes washed daily by plant	0.3**	0.1-0.6	1.3	0.5-3.6	3.3	0.7-15.2	0.9	0.4-2.2
Smoking†	1.5	0.6-3.7	1.6	0.8-3.3	3.1*	1.1-8.7	0.7	0.3-1.6
Stopped smoking in previous year†	1.4	0.3-7.6	0.8	0.2-3.6	8.3**	1.8-37.2	0.5	0.1-3.3

* p<0.05; ** p<0.01; † adjusted only for age

Table 6. Prevalence of symptom clusters, smoking and exposure by the period of employment in the sewage treatment industry.

Years of employment	N	Mean age	Smoking	Smoking previous year	Contact waste water	Flu-like symptoms	Higher airway symptoms	Lower airway symptoms	Neurological symptoms
0-5	51	36.2	29.4	5.9	62.7	13.7	10.0	0.0	18.0
5-10	33	35.4	25.0	3.1	66.7	18.2	34.3**	24.2**	27.3
10-15	23	42.4**	34.8	4.3	76.2	39.1*	26.1	18.2**	43.5*
>15	38	50.5**	29.0	7.9	63.2	16.7	16.2	15.8**	21.6

* p<0.05, ** p<0.01; compared to group with 0-5 years of employment.

Tab. 5) and ex-smokers (when the subject had stopped in the previous year) (OR = 8.3). Sewage workers who had their clothes washed daily at the plant (73%) reported significantly fewer flu-like symptoms (OR = 0.3; Table 5). No associations were found between symptoms and other hygienic practices at the work place (e.g. use of gloves, masks, and shower after work). Using multiple regression models including both types of exposure (sewage and chemicals) and the variable 'clothes washed daily at the plant' did not significantly alter the results described above (data not shown).

The majority of the participants (93.2%) did not report a difference in symptom frequency or severity over the days of the week or seasons of the year. About one half (51.4%) of the sewage workers used some sort of medication in the last year; medicine-use was significantly associated with all symptom clusters (ORs ranged from 2.0-10.2, p<0.05, with the highest odds ratio for neurological symptoms), but no associations existed with exposure to sewage.

Individual symptoms and exposure. Significant associations with exposure to sewage (but not with chemical exposure) were found for joint and muscle ache (not related to sports) (OR=2.8; 95%CI=1.3-6.2; p<0.05), skin rash (OR=11.0; 95%CI=1.4-85.5; p<0.05) and palpitations (OR=12.1; 95%CI=1.6-93.9; p<0.05). Fatigue and forgetfulness were more common in the group with exposure to chemicals with ORs of 4.0 (95%CI=1.3-13.0; p<0.05) and 4.1 (95%CI=1.3-13.3; p<0.05), whereas no association with sewage exposure was found for these symptoms. Diarrhoea was not associated with any of the exposure variables. Also no associations existed between exposure and self reported symptoms of allergy, including rhinitis, conjunctivitis and eczema.

Symptom prevalence and work duration. For all symptom clusters, lowest prevalence rates were found in subjects who had worked five years or less at the plant (Tab. 6). Prevalence rates were notably higher in subjects working 5-10 years, whereas mean age, smoking habits and current exposure to waste water did not differ. Symptom cluster prevalence rates decreased again after 15 years of employment.

DISCUSSION

In this study we found a significant positive association between self-reported exposure and clusters of flu-like and neurological symptoms. We also found a very strong association between exposure and skin rash, palpitations, fatigue and forgetfulness. Interestingly, the use of company clothes that were washed daily was negatively associated with flu-like symptoms suggesting that good hygienic practice at the workplace may prevent some of these symptoms. Endotoxin exposures were generally low.

Our study is potentially subject to both differential and non-differential information bias because we relied entirely on questionnaire data for both symptoms and exposure. Differential information bias may have occurred due to over-reporting of symptoms by exposed subjects or over-reporting of exposure by subjects with

symptoms, both of which may have resulted in an overestimation of the effect. However, we consider that this kind of bias is unlikely to have seriously affected the results, because it seems unlikely that subjects would over-report symptoms in such a systematic way that they would be in accordance with the four symptom clusters identified in the factor analysis. In addition, the effects of smoking on lower respiratory symptoms were consistent with previous studies, whereas when over-reporting of symptoms by exposed workers would have occurred, these effects are likely to have been obscured. A possible bias due to over-reporting of exposure by symptomatic subjects cannot be excluded. However, non-differential information bias due to non-differential misclassification of exposure seems more likely to have occurred because exposure was very broadly defined in our study, while it is expected that symptoms are caused by very specific exposures (e.g. specific chemicals, microorganisms, toxins etc.). In our study 'exposed' subjects may thus have had frequent contact with sewage and/or chemicals but may not necessarily have been frequently exposed to the causal agent. The latter form of bias may have potentially resulted in an underestimation of the effects. Unfortunately, more informative exposure grouping based on job titles or tasks could not be conducted because of the large diversity of tasks in the majority of subjects. Potentially, the healthy worker effect may also have biased our findings; once again this would most likely result in an underestimation of the effects reported in this study. The fact that symptoms in workers increased over the first 10 years of employment for all studied symptom clusters, but dropped after more than 15 years (Tab. 6) suggests a healthy worker effect in our study.

Our findings are consistent with various other studies [8, 10, 14, 15, 17, 21, 22, 27] in that they clearly demonstrate that sewage treatment workers experience a wide variety of symptoms. By employing factor analysis we were able to identify distinct patterns in the symptoms that may further extend our understanding of the etiology. In the present study we focussed on five groups of symptoms including flu-like, respiratory, mucous membrane and skin irritation, neurological, and gastrointestinal symptoms. The four symptom clusters identified by factor analysis confirmed this classification to a certain extent. However, surprisingly, flu-like symptoms were correlated with symptoms such as nausea, vomiting, lack of appetite (but not diarrhoea), and respiratory symptoms were divided into two separate clusters (higher and lower airway symptoms). Neurological symptoms consisted of the expected symptoms (headache, difficulty at concentrating and dizziness) but also acid indigestion, whereas fatigue and forgetfulness were not included.

The large variety of symptoms expressed by sewage workers suggests that causal exposures are likely to be diverse and several agents have been considered in the literature. Bacterial endotoxin has been suggested as playing a role in the flu-like and respiratory symptoms [14, 22] and some studies have shown elevated levels of airborne endotoxin in the sewage treatment environment [11, 22]. However, in the present study ambient endotoxin concentrations measured in two sewage treatment plants were elevated only in some confined areas of the sewage treatment plants (i.e. the indoor sludge dewatering area), and personal endotoxin exposures were low with a geometric mean of approximately 10 EU/m^3 (Tab. 1). In addition, in our study the classical flu-like symptoms (typical for high endotoxin exposures) as in various other studies among waste workers [6, 15, 24] were, accompanied with nausea and vomiting which are not normally associated with endotoxin exposure. Melbostad *et al.* [15] measured the exposure to endotoxin and bacteria in 15 municipal sewage treatment plants, and workers reporting airway symptoms (as well as headache, tiredness and nausea) had higher exposure levels to rod-shaped bacteria and total bacteria compared to workers not reporting these symptoms, whereas no such association was found for endotoxin exposure. Thus, other currently unknown agents of biological (e.g. bacterial products other than endotoxins) or chemical nature may be more likely to be causally related with respiratory and flu-like symptoms. It should be noted, however, that most endotoxin exposure measurements, including the ones conducted in our study, have been performed using sampling equipment not designed for outdoor sampling. Therefore, exposures may have been underestimated [7]. However, in our study even the indoor concentrations were low (with the exception of the sludge dewatering area). The finding that flu-like symptoms occurred significantly less in workers whose company clothes were washed daily at the plant, suggests that the etiological factor can be accumulated in the workers clothes. However, it cannot be excluded that this protective effect is a result of other associated hygiene measures, although no associations were found with other hygienic practices (e.g. use of gloves, masks, shower after work) for any of the symptom clusters.

In the present study, neurological symptoms were associated with both exposure to sewage and chemicals (used in the process). Also, fatigue and forgetfulness were more common in subjects working with chemicals. Generally, these neurological symptoms seem suggestive for chemical exposures (either used in the process or produced during the process e.g. volatile organic components); however, from this study it is not clear which chemicals may be involved. A role for biological agents cannot be excluded; in fact Melbostad *et al.* [15] showed an association between bacterial exposure and headache and tiredness in sewage treatment workers.

It is not clear what factors could be responsible for joint and muscle aches, palpitations and skin rash, all of which are individually significantly associated with sewage exposure. Skin rash in waste workers has been reported previously by others [24] and may be caused by frequent skin contact with sewage. The prevalence of diarrhoea (39.5%) was rather high but was not correlated with any of the other symptoms, nor with any of the exposure

variables, suggesting that the causal agent is different from most of the other reported symptoms. Gastrointestinal infections may possibly explain the high prevalence of diarrhoea. Lundholm and Rylander [14] hypothesised that the etiological agent may be enterotoxins from Gram-negative bacteria present in the sewage environment; however, no data were presented to support this hypothesis. In a later publication Rylander [22] suggested endotoxin as the causal agent but no direct relationship was demonstrated.

CONCLUSIONS

Sewage treatment workers may develop a large variety of work-related symptoms. Distinctly different symptom clusters of highly correlating symptoms can be identified (including flu-like symptoms, respiratory symptoms and neurological symptoms), indicating that the causal exposures are probably diverse. In our study, endotoxin exposure is not likely to explain most (if any) of the symptoms. Some of the symptoms (e.g. flu-like symptoms) may be preventable by introducing relatively simple hygienic measures.

Acknowledgements

The authors are indebted to the management and workers of the water treatment plants for their participation. The authors also thank Susan Peelen and Lutzen Portengen for their assistance in the data entry and Neil Pearce for his comments on the draft manuscript. Jeroen Douwes is supported by a research fellowship from the Netherlands Organization for Scientific Research (NWO).

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