ORIGINAL ARTICLE

Respiratory symptoms and bronchial responsiveness among cleaning and disinfecting workers in the food industry

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Objectives: To measure the levels of exposure to nitrogen trichloride (NCl₃) and aldehydes among cleaning and disinfecting workers in the atmosphere of food industry plants during cleaning and disinfecting operations, and to examine how they relate to irritant and chronic respiratory symptoms—which are indices of pulmonary function—and bronchial hyperresponsiveness (BHR) to methacholine.

Methods: 175 exposed workers (M = 149; F = 26) recruited from 17 enterprises of the food industry (8 cattle, pig, and ovine slaughterhouses, 8 fowl slaughterhouses, and 1 catering firm) and 70 non-exposed workers (M = 52; F = 18) were examined. Concentration levels of NCl₃ and aldehydes were measured by personal sampling. Symptoms were assessed by means of a questionnaire and the methacholine bronchial challenge (MBC) test using an abbreviated method. Subjects were labelled MBC+ if forced expiratory volume in one second (FEV1) fell by 20% or more. The linear dose-response slope (DRS) was calculated as the percentage fall in FEV1 at last dose divided by the total dose administered.

Results: 277 air samples were taken in the 17 food industry plants. For a given plant and in a given workshop, the actual concentrations of chloramines, aldehydes, and quaternary ammonium compounds were measured with personal samplers during the different steps of the procedures. For each cleaner, a total exposure index Σ was calculated. A statistically significant concentration-response relationship was found between eye, nasal, and throat symptoms of irritation—but not chronic respiratory symptoms—and exposure levels or exposure duration. No relation was found between BHR and exposure.

Conclusions: These data show that cleaning and disinfecting workers in the food industry are at risk of developing eye, nasal, and throat irritation symptoms. Although NCl₃ exposure does not seem to carry a risk of developing permanent BHR, the possibility of transient BHR cannot be ruled out entirely.

Consumer safety demands strict hygiene and cleaning requirements in the food industry processes. All equipment and work surfaces must be carefully cleaned on a daily basis. This imposes the use of detergents and disinfectants, which are usually chlorinated alkalis and aldehydes. These cleaning and disinfecting operations have been described in the vegetable processing industry¹ and in different food industries² where sensory irritation phenomena were notified. These acute eye and upper respiratory airway irritations were also reported by Sanderson³ in poultry processing plants. The irritant agents were chloramines, especially nitrogen trichloride (NCl₃), resulting from the reaction between hypochlorite and nitrogen compounds coming from the proteins released by vegetables or animals. The same applies in swimming pools, where the chlorine-containing agents used for disinfecting the water react with nitrogenous compounds introduced by swimmers.⁴

In the food industry, other disinfectants, including formaldehyde, glutaraldehyde, and quaternary ammonium compounds (quats) are commonly used. These compounds, like chloramines, are known for their irritant properties.⁵

The present study was carried out to determine the prevalence of ocular and respiratory symptoms among cleaning and disinfecting workers in the food industry and to examine the extent to which they are related to occupational exposure to nitrogen trichloride, aldehydes, and other detergents. Additionally, we also attempted to better understand how these variables relate to bronchial responsiveness to methacholine.

STUDY DESIGN AND SUBJECTS

The study was a cross sectional survey of the employees currently involved in cleaning and disinfecting operations

recruited in 17 food industry plants (8 cattle slaughterhouses, 8 poultry slaughterhouses, and 1 catering firm). 175 workers (86% of the workforce) accepted the invitation; 149 men and 26 women. The control population was a group of 70 subjects (52 men and 18 women) working in small manufacturing plants who were not clerical staff and who had never been at risk of occupational exposure to chlorinated alkalis, aldehydes or any other respiratory hazard. They represented 82% of the workforce at the following plants: food distribution (M = 6, F = 16), goods transportation (M = 9), and a salt packing factory (M = 37, F = 2). They worked the same shift as the exposed workers.

Written, informed consent was given by all the subjects. Information was obtained concerning age, number of hours worked per day, length of time in present job, and occupational history. Subjects who had experienced prior exposure to substances known to affect the respiratory system were excluded from the study. The same questionnaire was used to constitute exposed and non-exposed groups. The pre-study characteristics of the groups are shown in table 1.

The exposed and non-exposed men have significant differences in age, height, and weight (*t* test, *p* < 0.05), which is not the case for the women. There is no significant difference for tobacco for the exposed and non-exposed men (χ^2 0.73). The number of women is too low for this test.

Abbreviations: ACGIH, American Conference of Governmental Industrial Hygienists; BHR, bronchial hyperresponsiveness; DRS, dose-response slope; FEV1, forced expiratory volume in one second; MBC, methacholine bronchial challenge

Table 1 Anthropometric characteristics, smoking habits and duration of exposure of the food industry cleaners (n = 175) and controls (n = 70)

		Men		Women	
		Non-exposed	Exposed	Non-exposed	Exposed
Parameters		(n = 52)	(n = 149)	(n = 18)	(n = 26)
Age (years)	Mean (SD)	42 (10)	35 (9)*	33 (13)	38 (8)
Weight (kg)	Mean (SD)	80 (10)	72 (11)*	60 (10)	63 (14)
Height (cm)	Mean (SD)	175 (6)	172 (6)*	161 (6)	163 (5)
Smoking habits					
Smokers	% (n)	46 (24)	53 (79)	44 (8)	8 (2)
Ex-smokers	% (n)	23 (12)	20 (30)	17 (3)	27 (7)
Non-smokers	% (n)	31 (16)	27 (40)	39 (7)	65 (17)
Tobacco consumption					
Smokers (pack years)	Mean (SD)	22 (14)	14 (10)	8 (9)	14 (6)
Ex-smoker (pack-years)	Mean (SD)	14 (10)	16 (17)	11 (9)	12 (9)
Exposure (years)	Mean (SD)		6 (6)		8 (7)

*p<0.05.

Exposure monitoring

In the food industry, the cleaning and disinfecting of equipment and work surfaces are very important operations and must be thorough. A five-step procedure is generally followed in France:⁶

- Preliminary wash: elimination of large waste products by manual scraping and pressurised water cleaning. Following this phase, the surfaces and equipment should be visually clean (no apparent stains);
- Cleaning: a cleaning solution is applied to the surfaces and equipment in the form of foam in order to obtain a prolonged action;
- Intermediate rinsing is carried out after letting the cleaning solution act for about 30 minutes;
- Disinfecting ensured by the application of a chlorinated alkaline, aldehydes, quats or a mixture of the two latter;
- Final rinsing.

In numerous food industry plants, the cleaning schedules are limited to the first three phases, the disinfecting character of the chlorinated alkalines commonly used as cleaning agents being sufficient to satisfy bacteriological requirements.

The main cleaning and disinfecting agents used in the food industry are:

- Chlorinated alkalines: used as the cleaning agent in all the plants visited during the present study. In some establishments, they were also used for disinfecting;
- Acids and bases: used alternately with the chlorinated alkaline, generally once a week. Acids are primarily used to descale the installations and to renovate the stainless steel. No acid use was checked during this study;
- Aldehydes: used alone or in a mixture as disinfecting agents. Glutaraldehyde is used in most cases, even though formaldehyde is still used for certain applications;
- Quats: used as disinfecting agents either alone or mixed with aldehydes.

For a given plant and a given task, the current air concentrations of chloramines, aldehydes, and quats were measured with personal samplers at every step of the procedures, for periods of between 10 minutes and 2 hours, when real exposure occurred. Thus, exposure to chloramines was measured during the second and third steps and exposure to aldehydes and quats during the fourth step. The methods used are described in detail in Héry *et al.*²

Each cleaner was asked to describe the different tasks performed and their respective duration. Since all the compounds are irritants, we consider that the irritant effect is additive. This formula is based on the same principle as the formula proposed by the American Conference of Governmental Industrial Hygienists⁷ (ACGIH, 2004) for concomitant exposure to several solvents (mixtures).

A total exposure index Σ was calculated:

$$\Sigma = \frac{D_{\text{expo}} \text{NCl}_3 \times \text{expo NCl}_3}{\text{RD}_{50} \text{NCl}_3} + \frac{D_{\text{expo}} \text{aldehydes} \times \text{expo aldehyde}}{\text{RD}_{50} \text{aldehydes}} + \frac{\text{Idem for other substances}}{\text{RD}_{50} \text{other substances}}$$

In this formula, D_{expo} is the duration of exposure to a substance, expressed as a percentage of the total work shift (standardised at 7 hours); expo is the exposure concentration (mg/m^3); RD_{50} (respiratory decrease) is the concentration responsible for a 50% decrease in the respiratory rate.⁸ Determined in mice, it is a good indicator of the irritant properties of a compound: the lower the RD_{50} , the more irritant the substance. The RD_{50} value is 2.5 ppm for NCl_3 and 13.8 ppm for glutaraldehyde.⁹

The index Σ , without unit, is designed to increase with the irritant properties of the work atmosphere. When a respirator was worn during work, the corresponding exposure was divided by a factor of 5: this value corresponds to the actual workplace protection factor found in a field study.⁹ In each factory, the exposure corresponding to each task was measured by means of personal sampling for each worker included in the study (a mean exposure was calculated when several workers performed the same task). Alongside, the duration of each task was estimated for each worker from individual questionnaires and compared to the effective duration estimated by our team. From these data, individual exposure was calculated.

Respiratory health status

Medical history

Detailed histories concerning respiratory diseases and smoking habits were recorded using a two-part questionnaire. The first was a modified version of the European Coal and Steel Community questionnaire on respiratory symptoms.¹⁰ The second part of the questionnaire asked for specific symptoms, especially acute irritant symptoms. Both parts of the questionnaire are fully described in the paper on the respiratory symptoms of lifeguards.¹¹ To be considered as work related, a

Table 2 Exposure of workers to "chlorine" and nitrogen trichloride during foaming, foaming/rinsing, and rinsing operations

Factory	n*	Mean Cl ₂ + NCl ₃ (range)		
		Foaming	Foaming/rinsing	Rinsing
A	41	0.4 (0.11–0.78)	0.47 (0.14–0.74)	0.44 (0.04–1.19)
B	19	1.73 (0.26–5.46)	1.01 (0.35–2.63)	0.51 (0.29–0.85)
C	30	0.54 (0.17–0.98)	0.67 (0.27–1.42)	0.89 (0.16–1.86)
D	11	0.33 (0.19–0.54)		0.34 (0.15–0.59)
E	10	0.88 (0.44–1.66)		0.53 (0.26–0.98)
F	16	0.37 (0.14–0.87)		0.21 (0.11–0.28)
G	11	0.61 (0.24–0.96)		0.32 (0.06–0.49)
H	6	0.22 (0.12–0.29)		0.14 (0.12–0.16)
I	6	0.22 (0.21–0.23)		0.25 (0.18–0.39)
J	5	0.99	0.89 (0.52–1.57)	0.19
K	16	0.45 (0.18–0.77)		0.60 (0.06–2094)
L	7	0.53 (0.18–0.69)	0.16	0.11 (0.03–0.18)
M	27	0.21 (0.13–0.35)	0.17 (0.07–0.37)	0.12 (0.05–0.29)
N	39	0.17 (0.11–0.42)	0.27 (0.12–0.38)	0.15 (0.03–0.36)
O	24	0.11 (0.05–0.19)		0.06 (0.01–0.26)
P	6	0.31 (0.13–0.56)		0.45
Q	7	0.31 (0.20–0.36)	0.22 (0.18–0.23)	0.29 (0.20–0.37)
General means (range)		0.49 (0.05–5.46)	0.48 (0.07–2.63)	0.33 (0.01–2.94)

*Number of samples.

positive answer to the irritant symptoms and asthma questions had to be followed by another positive answer to the question: "Do these complaints disappear when you leave work (evenings, weekends, holidays)?"

Pulmonary function tests

Spirometry was carried out by only one experienced technician using an electronic spirometer (Spiro-Analyzer ST 300, Fukuda Sangyo Co, Tokyo, Japan). At the baseline, each subject performed at least three reproducible forced expiratory manoeuvres (within 5% for forced vital capacity (FVC) and forced expiratory volume in one second (FEV1)); thereafter, only two reproducible curves were required. The curve with the highest sum of FVC + FEV1 was used for the statistical analysis. The results were expressed as the difference between the observed and predicted values of the European Respiratory Society.¹²

Bronchial responsiveness

As the examinations were carried out during work shifts, an abbreviated version of the methacholine bronchial challenge (MBC) test was used.¹³ Three additive doses of methacholine (0.5 µmol, 2.5 µmol, and 7.5 µmol—that is, 100 µg, 500 µg, and 1500 µg respectively) were administered with a nebuliser (Mediprom FDC 88, Paris, France) delivering doses of 0.5 µmol of methacholine per breath. Spirometry was performed before and three minutes after the methacholine inhalations. The challenge test was discontinued either after the inhalation of the third dose of methacholine or if the FEV1 fell by 20% or more below the baseline value.

Subjects who experienced a fall in FEV1 of 20% or more were classified as having a positive MBC test (MBC+)—that is, bronchial hyperresponsiveness. A linear dose-response slope (DRS) was calculated by the method proposed by O'Connor *et al.*,¹⁴ namely the percentage fall in FEV1 at the last dose divided by the total dose of methacholine (µmol) administered.

Ethics

The study was approved by the local medical ethics committee.

Statistical analysis

In order to apply a multivariate analysis to the DRS, a transformation to normalise the data was applied. This transformation 1/(% fall in FEV1/µmol + 2.5) in the family of

shifted logarithmic and shifted inverse transformations was found to be optimal for a large unexposed population.¹⁵

The statistical analysis was carried out with the SAS statistical software.¹⁶ Multiple logistic regression analyses were used to assess the effect of the exposure on the symptoms, adjustment being made for smoking and age. Multiple linear regression was used to describe the effect of exposure on the baseline spirometric parameters adjusted for smoking, and on the transformed DRS adjusted for baseline FEV1 and age. We did not include smoking in this model as this variable was found to be unrelated to bronchial responsiveness. The stability of the variance and the approximate linearity of the linear models were checked on residual plots.

RESULTS

Exposure assessment

Total exposure index Σ

A total of 277 air samples were taken in the 17 plants: for chloramines, 125 samples were taken during foaming operations (step 2), 112 during intermediate rinsing operations (step 3) and 40 during both (steps 2 and 3) (table 2). Additional disinfectants (mainly glutaraldehyde) were not systematically used and only 22 samples were taken in five establishments, either alone or mixed with quats. As for quats, these were used alone in two establishments.

In terms of chloramine exposure, the results are expressed in the form of "chlorine" and nitrogen trichloride. This corresponds to the sampling method used:^{1,2} the first part of the sampling procedure allows the sampling of chlorine hypochlorite and mono- and di-chloramines, both being expressed under the name of "chlorine (Cl₂)" and the second part permits the sampling of nitrogen trichloride (NCl₃). All the compounds are irritant.

The disinfecting operations had an average duration of 22 minutes (5–90 minutes for 22 samples taken).

Account taken of their physical properties, quats exposure was logically very low (all of them being below the detection limit of the analytical method). As their vapour tension is very low, only the part emitted in aerosol form during application is likely to be found in the atmosphere.

For the exposed subjects, the exposure index Σ ranged from 0.18 to 56. Three subgroups were constituted according to the exposure index:

Table 3 Prevalence of chronic respiratory symptoms among the food industry cleaners (n = 175) and controls (n = 70) stratified by exposure index Σ and exposure duration

Exposure group	Chronic bronchitis % (n)	Chronic cough and/or, phlegm % (n)	Bouts of bronchitis % (n)	Dyspnoea % (n)	Asthma % (n)
Non-exposed group, n = 70	4.3 (3)	15.7 (11)	5.7 (4)	17.1 (12)	7.1 (5)
Group 1, n = 90	0	12.2 (11)	6.7 (6)	14.4 (13)	5.6 (5)
Group 2, n = 85	0	14.1 (12)	8.2 (7)	12.9 (11)	8.2 (7)
p value*	>0.5	>0.5	>0.5	>0.5	>0.5
Non-exposed group, n = 70	4.3 (3)	15.7 (11)	5.7 (4)	17.1 (12)	7.1 (5)
Duration 1, n = 89	0	11.2 (10)	7.9 (7)	9 (8)	4.5 (4)
Duration 2, n = 86	0	15.1 (13)	7 (6)	18.6 (16)	9.3 (8)
p value*	>0.5	>0.5	>0.5	0.3	>0.5

*Logistic regression analysis.

Group definition: non-exposed group: exposure index Σ = 0 and exposure duration in the food industry = 0; group 1 = exposure index Σ < 5.24; group 2 = exposure index Σ $\geq$ 5.24; duration 1 = exposure duration in the food industry $\leq$ 6 years; duration 2 = exposure duration in the food industry > 6 years.

- Non-exposed group: 70 non-exposed subjects (M = 52; F = 18);
- Group 1 (Σ < 5.24): 90 exposed subjects (M = 74; F = 16);
- Group 2 (Σ $\geq$ 5.24): 85 more exposed subjects (M = 75; F = 10).

The cleaners were divided as follows: in group 1, 32/90 (35.5%) of the subjects worked in a poultry slaughterhouse and 45/90 (50%) were subcontracted; in group 2, 55/85 (64.7%) worked in a poultry slaughterhouse and 20/85 (23.5%) were subcontracted.

Number of working years

The exposure duration was also taken into account and ranged from 1 month to 25 years. For this index, the exposure limits defining the three subgroups were as follows:

- Non-exposed group: 70 (M = 52; F = 18);
- Duration 1: 89 cleaners exposed between 1 month and 6 years (M = 81; F = 8);
- Duration 2: 86 cleaners exposed for more than 6 years (M = 68; F = 18).

Respiratory and irritant symptoms

The prevalence of chronic respiratory symptoms as a function of exposure (exposure index and exposure duration) is shown in table 3. Overall, their prevalence tended to be rather low, particularly for chronic bronchitis (0% for the exposed groups). A symptom-by-symptom analysis revealed no statistically

significant higher prevalence of chronic cough and/or phlegm, wheezing, dyspnoea, or asthma according to the exposure.

Conversely, the prevalence of irritant symptoms was relatively high whatever the exposure index. For the exposure index, the observed rate ranged from 14.6% for sore throat in group 1 to 48.2% for eye irritation in group 2 (table 4, upper panel). Similar results were observed for exposure duration (table 4, lower panel).

More importantly, the prevalence rates tended to increase with increasing exposure levels: for the exposure index and for exposure duration, a statistically significant exposure-response relationship was found for all symptoms (table 4).

Baseline level of pulmonary function

The pulmonary function variables for the various classes of exposure duration are shown separately for male and female subjects in table 5. For the male group, the baseline pulmonary function variables of the exposed subjects were similar to those of the unexposed controls. After adjustment for tobacco consumption, baseline FEV1 was not related to exposure.

In contrast, in the female group, the baseline pulmonary function variables measured were lower than the values predicted. However, when exposure was taken into account and after adjustment for tobacco consumption for baseline FEV1, no significant exposure-response relationship was found.

Bronchial responsiveness

The methacholine bronchial challenge (MBC) test was carried out on 233 subjects (table 6). For the statistical analysis, the men and women were grouped.

Table 4 Prevalence of irritation symptoms among the food industry cleaners (n = 175) and controls (n = 70) stratified by exposure index Σ and exposure duration

Exposure group	Eye, % (n)	Nose, % (n)	Sore throat, % (n)	Dry cough, % (n)	At least one sign, % (n)
Non-exposed group, n = 70	5.7 (4)	1.4 (1)	2.9 (2)	1.4 (1)	10 (7)
Group 1, n = 90	33.3 (30)	22.2 (20)	21.1 (19)	15.6 (14)	53.3 (48)
Group 2, n = 85	48.2 (41)	38.8 (33)	27.1 (23)	27.1 (23)	67 (57)
p value*	<0.0001	0.0002	0.003	0.002	<0.0001
Non-exposed group, n = 70	5.7 (4)	1.4 (1)	2.9 (2)	1.4 (1)	10 (7)
Duration 1, n = 89	30.3 (27)	20.2 (18)	14.6 (13)	15.7 (14)	46.1 (41)
Duration 2, n = 86	51.2 (44)	40.7 (35)	33.7 (29)	26.7 (23)	74.4 (64)
p value*	<0.0001	<0.0001	<0.0001	0.004	<0.0001

*Logistic regression analysis.

Group definition: non-exposed group: exposure index Σ = 0 and exposure duration in the food industry = 0; group 1 = exposure index Σ < 5.24; group 2 = exposure index Σ $\geq$ 5.24; duration 1 = exposure duration in the food industry $\leq$ 6 years; duration 2 = exposure duration in the food industry > 6 years.

Table 5 Pulmonary function parameters (observed values-predicted values (SD)) in males (n = 196) and females (n = 43) stratified by exposure duration

	Male				Female			
	n = 196	FCV (ml (SD))	FEV1 (ml (SD))	FEV1/FCV (% (SD))	n = 43	FCV (ml (SD))	FEV1 (ml (SD))	FEV1/FCV (% (SD))
Non-exposed group	n = 52	131 (846)	1 (1015)	0.173 (1.018)	n = 18	-958 (640)	-832 (503)	0.238 (0.927)
Duration 1	n = 78	-86 (979)	-218-1056	0.153 (0.884)	n = 7	-587 (937)	-617 (883)	0.504 (0.602)
Duration 2	n = 66	-23 (855)	-219 (883)	0.106 (0.803)	n = 18	-825 (587)	-874 (739)	0.470 (0.734)
p value*		>0.5	>0.5 †	>0.5 †		>0.5	>0.5 †	>0.5 †

*Linear regression.

†Adjusted for smoking.

FVC, forced vital capacity; FEV1, forced expiratory volume in one second.

Group definition: non-exposed group: exposure duration in the food industry = 0; duration 1 = exposure duration in the food industry ≤ 6 years; duration 2 = exposure duration in the food industry > 6 years.

The proportion of subjects with a positive MBC test (MBC+ = FEV1 fall >20%) was 3.4% in the unexposed group and between 6 and 7.7% in the different exposed groups. Once again, no significant exposure-response relation was found.

The mean dose response slope (DRS) was 0.285 in the unexposed group and a little steeper (from 0.253 and 0.271%) in the different exposed groups. There was no finding compatible with a dose-response relation.

No significant relation was found between a positive MBC test and tracheo-bronchial irritation.

DISCUSSION

This paper looks at the prevalence of different symptoms among cleaning and disinfecting workers of the food industry, mainly in slaughterhouses, exposed to nitrogen trichloride and aldehydes. A group of non-exposed workers was taken as control.

The exposure varies widely with the tasks performed and the different factories. Irritation symptoms generally appear for nitrogen trichloride concentrations of over 0.5 mg/m³.^{4,6} The presence of "chlorine" compounds (responding to the definition given earlier) obviously makes these irritation symptoms worse.

On the other hand, the glutaraldehyde concentrations measured were all below the French VLE (short term exposure limit value) (0.8 mg/m³), some concentrations observed being however much higher than the ACGIH ceiling value of 0.2 mg/m³ (exceeding this value by a factor of 3.3 in establishment K and 1.5 in establishment N). This situation was more worrying in enterprise K as one person alone ensured disinfecting of the workshop every day (operation lasting more than one hour), whereas in enterprise N each cleaner ensured the disinfecting

of his/her part (operation lasting on average 12 minutes); the exposure of each individual was therefore shorter.

In slaughterhouses and catering firms, nitrogen trichloride is a highly irritant chloramine derived from the reaction between chlorine (Cl₂), which is used to disinfect material and surfaces, and nitrogenated substances of animal origin (for example, meat, blood, etc).

It is now known that chloramines are found in certain sectors of activity: the presence of chloramines in swimming pool atmospheres is due to the reaction between the chlorine-containing agents used for disinfecting the water and nitrogenous compounds introduced by swimmers.⁴ Workers in factories processing green salads and vegetables are also exposed to chloramines:¹ the source of the nitrogen compounds necessary for chloramine formation is the sap proteins released when cutting the vegetables. An exposure assessment study was conducted² in eight food industry plants: three slaughterhouses (cattle and poultry), one fish curing plant, one pet food factory, one catering firm, and two delicatessens. Significant exposure to nitrogen trichloride beyond the "comfort" limit value of 0.5 mg/m³ was measured. Excessive exposure to formaldehyde and glutaraldehyde was also recorded. Special emphasis was placed on the need to carry out careful rinsing after the cleaning and disinfecting steps.

In our study, a high prevalence of irritant symptoms was found, and this increased significantly with increasing nitrogen trichloride concentration levels whatever the exposure index considered. Despite its cross sectional nature, this finding strongly supports the idea of a causal relation.

In addition to a toxicological study⁵ which evaluated the irritant power of nitrogen chloride, epidemiological studies have confirmed this irritant characteristic: acute eye and upper airway respiratory irritations were reported by Sanderson *et al*³

Table 6 Methacholine bronchial challenge (MBC) test among the food industry cleaners stratified by exposure index Σ and exposure duration

		MBC+ % (n)		Dose-response slope [1/(slope+2.5)] (mean (SD))	
Non-exposed group	n = 68	3.4 (8)		0.285 (0.08)	
Group 1	n = 89	7.7 (18)		0.266 (0.09)	
Group 2	n = 76	6 (14)		0.258 (0.10)	
p value		0.19		0.17	
Non-exposed group	n = 68	3.4 (8)		0.285 (0.08)	
Duration 1	n = 83	7.3 (17)		0.253 (0.09)	
Duration 2	n = 82	6.4 (15)		0.271 (0.10)	
p value		0.11		0.03	

MBC+, positive methacholine bronchial challenge test positive.

Group definition: non-exposed group: exposure index Σ = 0 and exposure duration in the food industry = 0; group 1 = exposure index Σ < 5.24; group 2 = exposure index Σ ≥ 5.24; duration 1 = exposure duration in the food industry ≤ 6 years; duration 2 = exposure duration in the food industry > 6 years.

in six poultry processing plants where machines and work areas were frequently sprayed with chlorinated water to remove waste products from the floors and machine surfaces. Chlorine levels were measured in the atmosphere and were high; in one plant, the levels were so high that employees could no longer work. The presence of chloramines, resulting from the reaction of hypochlorous acid and the decomposition products of organic nitrogenous matter, was suspected but not confirmed by measurement. An epidemiological study conducted on a population of swimming pool lifeguards exposed to the same pollutants¹¹ demonstrated the irritant characteristic of nitrogen trichloride; more importantly, for the acute exposure index measured, a significant concentration-response relation was found for all symptoms. A high prevalence of irritant symptoms was also reported among 22 swimmers.¹⁷ For aldehydes, it has long been known that they have an irritant power as regards the skin, eyes, and respiratory tract, particularly for aldehydes with a low molecular weight.

In contrast, no relationship was observed between chronic respiratory symptoms and nitrogen trichloride concentration levels, regardless of the exposure index. Similar results were found among our population of swimming pool lifeguards. However, the cleaning and disinfecting staff exposed to chloramines were young ($M = 35$ years; $F = 29$ years (mean)) and their exposure duration in the food industry was relatively short ($M = 6$ years; $F = 8$ years (mean)). Taken together, these two factors are perhaps not enough to result in chronic respiratory symptoms, particularly chronic bronchitis.

The possibility cannot be ruled out that our results merely reflect the fact that the exposure duration may not have been long enough.

The prevalence of asthma is quite low; and this result may be due to the fact that the study was a cross sectional survey. The subjects with asthma were probably unable to continue to be exposed and left this work; thus, a healthy worker effect could partly explain this fact. Chloramines have been implicated in occupational asthma: Thickett *et al* reported three cases of occupational asthma following exposure to airborne chloramines in indoor chloraminated swimming pools.¹⁸ The diagnosis was done using occupational peak flow readings and a specific bronchial challenge test for nitrogen trichloride or a workplace challenge. In France, this type of asthma is recognised as an occupational asthma.

Glutaraldehyde can cause dermal irritations and dermatitis.¹⁹ Respiratory symptoms of asthma have also been reported among nurses who sterilise endoscopes.²⁰

A positive MBC test ($MBC+ =$ fall in FEV1 of 20% or more) was observed in 32 (19.4%) of the 165 subjects exposed and tested. The proportion among exposed workers is twice that among controls; no significant relation was however found between MBC+ and exposure index or exposure duration. After adjustment for baseline FEV1 and age, this result is independent of smoking habits. Similar results were found in lifeguards, where the prevalence of MBC+ was quite high.

Among the controls, the mean value of the dose-response slope (DRS) was 0.285, which is very close to that found in other control populations or in populations with little exposure.^{15–21} Among the cleaning and disinfecting workers, the DRS was a slightly lower (0.271–0.253 depending on the exposure group), but the difference was not significant. In the study of Thickett *et al*, the specific bronchial challenge test for nitrogen trichloride showed that chloramines could cause occupational asthma.¹⁸ Thickett pointed out that, in these three cases, the mechanism of occupational asthma due to nitrogen trichloride was not, as is so often the case, completely clear. Specific reactivity to occupational sensitizers is commonly seen in workers with normal non-specific reactivity. As no cases of

occupational asthma were observed in our population, we are not in a position to confirm this statement.

In conclusion, this study has shown that cleaning and disinfecting staff in the food industry exposed to chloramines and aldehydes are at risk of developing acute irritant symptoms. A dose-response relation was found between eye, nasal, and throat symptoms and exposure levels, but not for chronic respiratory symptoms. There was no correlation between bronchial hyperresponsiveness and exposure to chloramines and aldehydes.

However, during cleaning and disinfecting operations, which are vitally important for the health and safety of consumers, cleaning and disinfecting products must be used with due care and attention—employing them in excessive quantities does not improve their effectiveness and may have secondary effects on the workers. Our study clearly shows the enormous difference between how cleaning operations are considered in the different factories, with the exposure index ranging from 0.18 to 56.

Main message

- Cleaning and disinfecting staff in the food industry exposed to chloramines and aldehydes are at risk of developing acute irritant symptoms. A dose-response relation was found between eye, nasal, and throat symptoms and exposure levels in this occupational activity, but not for chronic respiratory symptoms or bronchial hyperresponsiveness.

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