

Exposure and Airway Effects of Seafood Industry Workers in Northern Norway

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Objective: In this study, we explored airway symptoms and exposure to bioaerosols and exhaust gases in seafood industry plants. **Methods:** The study details the results from personal and environmental exposure measurements (17 plants), a questionnaire (n = 984), and clinical examinations (n = 225). **Results:** The workers were exposed to allergens, endotoxins, molds, and exhaust. The 1-year prevalence of work-related airway symptoms was 42.8% for production workers and 25.9% for administrative workers. Mean levels of forced expiratory volume in 1 second and forced vital capacity were less than the predicted values in all exposed nonsmoker groups. A total of 20.5% had increased levels of total IgE (≥ 100 kU/L). Specific IgE-mediated reactions seemed to be relevant only in the shrimp industry. **Conclusions:** Seafood industry workers showed a high prevalence of work-related airway symptoms. Further research on the relationship between exposure and effects is necessary. (J Occup Environ Med. 2005;47:482–492)

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Airway symptoms and asthma have been reported in the seafood industry.^{1–13} These symptoms may be caused by both irritative and immunological reactions to occupational exposures. However, exposure measurement data from seafood industry are sparse, and the importance of different exposures in connection to airway symptoms is yet to be elucidated.

It is evident that employees in the seafood industry are exposed to a wide variety of factors that may cause airway symptoms. Many processes in the seafood industry involve the extensive use of water, and the production areas often are characterized by a moist environment and high relative humidity. Wet aerosols generated from production machines or washing procedures are spread in varying degree to the breathing zones of the workers. The aerosols may contain biological materials from the raw material itself or from microbiological organisms in the environment. The moist environment may facilitate the growth of mold and other microorganisms in areas not subjected to regular disinfection procedures. Dry particles also may be generated from some processes. Air jets used for shell removal in the shrimp industry, salt particles from salt spreading machines, and exhaust particles from forklift engines may be sources of dry aerosols. Other exposures than aerosols may furthermore contribute to airway symptoms. In this study, we show that, in some factories, the indoor use of forklifts with diesel or propane engines results in high lev-

els of exhaust gases, including NO_x, known to cause respiratory symptoms at low concentrations. The objective of this study was to describe the exposure to agents of relevance to respiratory effects in the occupational environment in different kinds of seafood industry and to investigate airway symptoms and IgE levels in different worker groups.

Materials and Methods

Exposure Measurements

Exposure measurements were performed on a selection of 17 plants. The selection was based on type of seafood processed, that is, salmon, white fish, shrimp, or herring. In addition, geographical availability was considered. The plants participating in exposure measurements also participated in the questionnaire study. The selection of workers participating in personal exposure measurements was based on work-tasks. Only work tasks in the seafood production area were measured. Each work task was measured for 2 following days, preferentially with the same person performing the task. The conditions were normal, not worst case.

Full-shift personal aerosol samples for determination of allergens, endotoxins, and microorganisms were collected on filters from the breathing zone of the workers by means of portable sampling pumps. The airflow through the filter was 2 L/min. A limited number of stationary samples of allergens were performed with the same equipment, located close to worker positions in machine rooms in the shrimp industry.

Samples for allergen analysis were collected, using air monitoring cassettes (Gelman Sciences, Ann Arbor, MI) containing a PTFE filter (1.0 µm, Millipore, Billerica, MA). Allergens were extracted from the filter in 2 mL of phosphate buffer saline with 0.5% Tween (PBS-T 0.5%). The eluates were then assayed with an inhibition enzyme-linked immunosorbent assay (ELISA). The serum

pool from patients with known IgE reactivity to the relevant allergen was diluted 1:4 with PBS and incubated overnight at 4°C with an equal volume of eluates from the filters. The serum pool was made with sera from three patients with clinical histories of fish allergy, positive skin-prick test, and CAP/FEIA (Pharmacia AB, Uppsala, Sweden) class 4. One of the patients had food allergy, the two others worked with cooking and catering, respectively, and may thus have been sensitized via work environment in addition to food. Allergen (10 µg/mL) was coated to 96-well microtiter plates (Falcon 35-3911, Becton Dickinson Labware, Franklin Lakes, NJ) overnight at 4°C. The plates were washed with PBS-T 0.05%. Thereafter 100 µL of either standard allergen or samples (eluates mixed with serum pool) was added to the wells in triplicate and incubated overnight at 4°C. After repeating the washing procedure, 1:1000 anti-human IgE alkaline phosphatase conjugate (Sigma Chemical Co., St. Louis, MO) was added and incubated for 2 hours at room temperature. Finally, after another wash, substrate Sigma-FAST *p*-nitrophenyl phosphate was added and absorbance was read at 405 nm in an ELISA reader.

Samples for determination of endotoxins were collected on 37-mm diameter Whatman GFA 3.7-cm glass fiber filters with closed face polystyrene standard aerosol cassettes (SKC Inc., Eighty Four, PA). The samples were stored at 4°C and analyzed by the Limulus Amoebocyte Lysate assay¹⁴ at the University of Uppsala, Department of Clinical Microbiology.

Samples for determination of microorganisms were collected on 25-mm diameter polycarbonate filters with pore size 0.8 µm in closed faced graphite filled polystyrene filter cassettes and analyzed by fluorescence microscopy¹⁵ at the Norwegian National Institute of Occupational Health.

Environmental samples of culturable molds were collected with a MAS 100 microbiological air sampler (Merck). The sampling volume was 500 L at a flow rate of 100 L/min. In shrimp, salmon and herring industry, V8 medium was used for sampling and incubation. Exposed agar plates were incubated at 22 to 25°C for 5 to 7 days. After incubation, the colonies were identified to genus level as described.¹⁶ In white fish industry, parallel samples with malt agar and DG18 agar were taken. The latter medium has a lower water activity (*a_w*), and thus favors growth of less hydrophilic fungi. The agar plates from white fish industry were stored at 4°C before transport and analysis by a commercial laboratory (Mycoteam, Norway). All samples were taken from September to April with outdoor temperatures ranging from +9.7 to −10.4°C. The results are given as colony-forming units (CFU) per m³ air.

The levels of the exhaust gasses nitrogen dioxide, carbon monoxide, and carbon dioxide were measured in seven plants with the multi gas analyzer Multiwarn II (Dräger). Personal exposures were measured in the forklift cabin close to the driver's breathing zone. Exhaust gasses were also measured in the storage rooms and at worker positions nearby forklift transport areas. The measurement periods varied from 10 minutes to 6.5 hours. The measurements were taken randomly and not at "worst-case" episodes.

Questionnaire Study

A questionnaire was sent to 3551 employees in 118 fish processing plants in the northern part of Norway. A total of 1767 answers were received, resulting in a response rate of 49.8%. A further selection of a group of 984 persons with special interest to this study was performed based on industry type and exposed or nonexposed work tasks. Included in the 984 were workers in the shrimp, white fish (haddock, cod and

pollack), salmon, and herring industries.

Excluded from the study group were workers in other types of industries, that is, processing of other crustaceans, fresh water species and mixed species; fishers; canteen workers; laboratory workers; and workers with insufficient data on work tasks or type of industry.

The seafood-exposed worker groups included, in the shrimp industry, thawers, peelers, packers, and technicians; in white fish industry, fillet cutters, receivers, salt fish workers, and machine operators; in the salmon industry, slaughterers and packers; and in the herring industry, all production workers. In addition, forklift drivers in the four types of industry were included as representatives of exhaust exposed workers. Administrative workers in the same industries represented a nonexposed control group.

The questions on respiratory symptoms, not coupled to the work situation, were derived from the MRC questionnaire. The questions on work-related airway symptoms were derived from questionnaires previously used in Scandinavian studies on organic dust-related airway effects^{12,17} All questions on work-related symptoms were limited to the last year. The questions on asthma, chronic obstructive lung disease, or allergy diagnoses were asked in the form: "Have you ever received one of the following diagnoses from a medical doctor?" The questions on smoking habits were asked in the form: "Do you smoke?" The alternative answers were: "yes, daily," "sometimes," "used to smoke previously," "no, never smoked." Current smokers were defined as persons with positive designation of the alternative "yes, daily." All other designations were defined as non-smokers.

Clinical Study

A clinical study was conducted on 225 production workers from 13 different plants. The selection of partic-

ipants was based on type of industry and work tasks with exposure to seafood. The plants selected were three shrimp plants, six white fish plants, and four salmon plants. Work tasks with exposure to seafood were selected based on daily contact with fish or shrimp, judged by a site contact person. The participants in the clinical study also participated in the questionnaire study. The questionnaire results from the clinical study group were comparable with the results from the total exposed group with respect to the prevalence of airway symptoms, allergies, and diagnoses from medical doctors. Exposure measurements were performed in 9 of the 13 plants in this part of the study. The results of the exposure measurements in these plants did not differ significantly from the other plants in the study.

Lung function tests were performed according to ATS guidelines of 1987^{18,19} with a Vitalograph Compact 2 spirometer. The ventilatory tests were conducted with the subject seated. Nose clips were not used. The subjects were given standardized instructions. The tests were terminated after three technically satisfactory blows if the highest forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV₁) value did not exceed the next highest one by more than 5% or 0.1 L, whichever was greater. If the difference was larger, up to eight forced vital capacity maneuvers were performed to reach FVC and FEV₁ values within the given limits. Reference values for predicted normal values were based on a Norwegian normal population.²⁰

Blood samples were analyzed for total and specific IgE by ELISA (UniCAP, Pharmacia Diagnostics, Uppsala Sweden). Levels ≥ 100 kU/L total IgE and ≥ 0.35 kU/L specific IgE were defined as "increased levels." The specific IgEs analyzed were cod, salmon, shrimp, herring, and latex.

Statistical Analysis

Differences in exposure levels between different worker groups were tested with a Mann-Whitney *U* test. Differences in symptom prevalence were tested with a Pearson χ^2 test. Odds ratio calculations for nose and other airway symptoms were performed with a binary logistic regression analysis. Smoking habits, production work, forklift driving, gender and age were included in both the logistic regression analyses. Administrative workers were regarded as the baseline. The computer program SPSS 11.0 (SPSS inc., Chicago, IL) was used for statistical calculations.

Results

Study Population

Table 1 shows the demographic data of the study population. The mean age of the different worker groups were 34.1 to 41.4 years with median employment from 9.5 to 12 years. The majority (98%) of forklift drivers were men. Also, the administrative worker group had a slight overweighting of men (59%), whereas the genders were almost equally represented in the production worker group. More women (65%) than men participated in the clinical study. Fewer administrative workers (36.7%) than production workers (49.3%) were current smokers. Among the forklift drivers, 57.4% were current smokers.

Bioaerosol Exposure

Personal exposure measurements showed that workers in all kinds of seafood industry investigated, were exposed to airborne allergens from the processed species (Table 2). All samples from the shrimp, whitefish, and herring industries were positive for allergens. In the salmon industry only 5 of 18 samples were positive. The actual levels in positive samples varied from 0.035 $\mu\text{g}/\text{m}^3$ (salmon) to 6.26 $\mu\text{g}/\text{m}^3$ (shrimp). In the shrimp industry, one stationary sample near the air jets used for shell removal,

TABLE 1
Demographic Data of the Groups of Seafood Industry Workers

	Number N	Age yr $\pm$ SD	Gender, Male/Female %	Employment Yr Median	Current Smokers %
Questionnaire study					
Production workers	791	38.8 $\pm$ 12.2	47/53	10.0	49.3
Forklift drivers	54	34.1 $\pm$ 10.2	98/2	9.5	57.4
Administrative workers	139	41.4 $\pm$ 10.5	59/40	12.0	36.7
Clinical study					
Seafood production workers	225	39.4 $\pm$ 11.4	35/65	11.0	54.7

SD indicates standard deviation.

TABLE 2
Exposure Levels of Allergens, Total Microorganisms, Endotoxins in Different Industries, and Job Groups

	Shrimp				White fish				Salmon		Herring
	TH	PE	PA	TE	FC	RE	SF	MO	SL	PA	PW
Allergens ($\mu\text{g}/\text{m}^3$)											
Allergen	Shrimp	Shrimp	Shrimp	Shrimp	Cod	Cod	Cod	Cod	Salmon	Salmon	Herring
n	15	9	12	5	8	ND	2	12	18	ND	3
Min	2.0	2.3	1.5	2.9	4.0	ND	4.5	3.8	0.0	ND	0.3
Max	4.6	3.4	6.3	3.8	4.9	ND	5.1	4.8	1.6	ND	1.9
Median	2.3	2.9	2.1	3.2	4.4	ND	4.8	4.4	0.0	ND	1.2
Mean	2.8	2.8	2.4	3.2	4.4	ND	4.8	4.4	1.2	ND	0.9
SD	0.9	0.4	1.3	0.4	0.3	ND	ND	0.4	0.4	ND	0.8
Micro-organisms (number/ m^3)											
n	5	6	4	ND	16	3	ND	9	22	6	8
Number of positives	3	3	3	ND	16	3	ND	9	13	4	6
Min	0	0	0	ND	4000	5000	ND	1000	0	0	0
Max	20,000	50,000	10,000	ND	203,000	10,000	ND	512,000	85,000	30,000	55,000
Median	4000	1500	5000	ND	8000	7000	ND	5000	4000	3500	11,000
Mean	6200	10,000	7250	ND	23,000	7333	ND	69,111	10,863	7333	16,625
SD	8258	19,788	8256	ND	48,712	2517	ND	166,835	19,332	11,413	19,175
Endotoxin (EU/ m^3)											
n	7	6	4	ND	14	3	ND	9	23	4	14
Min	0.2	0.0	1.0	ND	1.4	7.5	ND	3.2	0.9	3.3	0.5
Max	100.0	50.0	11.0	ND	22.7	9.1	ND	59.0	36.0	15.0	1350.0
Median	15.0	1.5	5.5	ND	8.0	7.5	ND	18.0	3.3	4.4	4.0
Mean	29.9	10.0	5.8	ND	8.6	8.0	ND	23.9	7.9	6.8	103.7
SD	33.2	19.8	5.0	ND	6.3	0.9	ND	18.7	10.5	5.6	359.2

Full shifts (8-h) samples taken from the person's breathing zone.

ND indicates not determined; SD, standard deviation. Job groups: TH, thawers; PE, peelers; PA, packers; TE, technicians; FC, fillet cutters; RE, receivers; SF, salt fish workers; MO, machine operators; SL, slaughterers; PW, production workers.

was 30.8 $\mu\text{g}/\text{m}^3$ (mean level during the 1.5-hour sampling). Three of 85 endotoxin samples were at or above the suggested OEL of 50 EU/ m^3 .²¹ The maximum level found was 1350 EU/ m^3 measured during herring fillet production. In white fish industry, the machine operators were exposed to significantly higher endotoxin levels than the fillet workers ($P = 0.011$, Mann-Whitney U test). For the other exposure agents, there were no statistical differences between ex-

posure levels of different worker groups, different plants, or different types of industry.

Personal exposure measurements of total levels of microorganisms (Table 2) showed that 80 of 82 samples were less than 100 000/ m^3 . The remaining two samples were 203 000/ m^3 and 512 000/ m^3 , measured in the white fish industry at manual worker positions and machine operator positions, respectively. In 16 of 17 investigated

plants, one or more indications of indoor mold sources were found. The indications were 1) visible colonies, 2) indoor CFU levels >5 times outdoor levels, or 3) dominating species different in indoor and outdoor samples. Table 3 shows that a dominating genus in all samples with V8 and malt agar medium was *Penicillium*. In addition yeast, *Stachybotrys chartarum*, *Phoma sp*, *Trichoderma viridae*, and *Cladosporium spp* were found to be dominating in separate

TABLE 3
Exposure Levels of Molds in Different Industries and Job Groups

	TH	PE	PA	TE	FC	RE	SF	MO	SL	PA	PW
Indoor (CFU/m ³)											
n	6	4	6	ND	6	1	ND	6	12	7	9
Min	16	8	38	ND	107	366	ND	131	16	7	12
Max	537	60	221	ND	>2600	366	ND	>2600	494	>2600	>2600
Median	65	28	77	ND	275	366	ND	268	218	46	461
Dominating genus	Pen. spp yeast	Pen. spp Stac. sp*	Pen. spp yeast m.m.	ND	Pen. spp Phoma sp Thri. spt	Pen. sp	ND	Pen. spp Thri. spt	Pen. sp m.m. yeast	Pen. spp	Pen. spp yeast
Outdoor (CFU/m ³)											
n		2				5			6		2
Min		6				18			16		67
Max		18				207			104		74
Median		12				33			42		71
Dominating genus		Pen. sp				Pen. sp; Clad spp			Pen. sp; mm; yeast		Pen. sp

Environmental samples taken close to worker positions. The samples were grown on V8 medium (shrimp, salmon and herring industry) or malt agar (MEA, white fish industry). *n* = number of samples. ND, not determined.
 Job groups: TH, thawers; PE, peelers; PA, packers; TE, technicians; FC, fillet cutters; RE, receivers; SF, salt fish workers; MO, machine operators; SL, slaughterers; PW, production workers.
 Molds: Pen., *Penicillium*; Stac., *Stachybotrys*; Thri., *Thrichoderma*; Clad., *Cladosporium*; mm, miscellaneous molds; sp, one species; spp, more than one species
 **Stachybotrys chartarum*.
 †*Thrichoderma viride*.

samples. Parallel samples from white fish industry with DG18- medium also showed *Penicillium* as the dominating genus in most samples. Other dominating molds found with this medium included *Aspergillus versicolor*, *Aspergillus sp*, *Phoma sp* and *Cladosporium sp* (not shown).

Exposure to Forklift Exhaust Gases

Levels of the exhaust gases carbon monoxide and nitrogen dioxide exceeded the Norwegian OELs (short-term OEL 100 ppm and ceiling OEL 2 ppm, respectively) in five of seven plants (Table 4). The maximum levels measured in storerooms were 364 ppm for carbon monoxide and greater than 20 ppm (instrumentation limit) for nitrogen dioxide. Inside forklift cabins, the maximum levels were 152 ppm for carbon monoxide and 7 ppm for nitrogen dioxide. The maximal levels for carbon dioxide (not shown) were 7,700 and 12,600 ppm, measured in store room and forklift cabin, respectively (8-hour OEL 5000 ppm).

Airway Symptoms and Diagnoses

Production workers, daily exposed to fish or shrimp during their work, had increased prevalence of work-related airway symptoms compared with office workers in the administrative departments (Tables 5 to 7). In addition, the forklift drivers had significantly more airway symptoms than the administrative workers. There were, however, no statistical significant difference in the frequency of doctor diagnosed asthma, chronic obstructive lung disease and allergy between production workers, forklift drivers and administrative workers (Table 5).

Symptoms from the nose were frequent in a majority of the exposed worker groups (Table 7). In addition, all worker groups in the shrimp industry, salmon packers, and machine operators in the white fish industry reported cough. Shrimp packers also

TABLE 4

Mean and Peak Levels of Carbon Monoxide and Nitrogen Dioxide in Different Sampling Positions During Forklift Driving and Lifting Activity

Plant	Forklift Cabin						Storeroom						Adjacent Worker Positions					
	Sampling Time Hours	Carbon monoxide ppm		Nitrogen dioxide ppm		Sampling time hr	Carbon monoxide ppm		Nitrogen dioxide ppm		Sampling time hr	Carbon monoxide ppm		Nitrogen dioxide ppm				
		Mean	Peak	Mean	Peak		Mean	Peak	Mean	Peak		Mean	Peak					
A	6.0	3	41	0.0	0.0	0.7	25	28	0.0	0.0	2.0	51	78	0.4	1.6			
B	6.0	0	0	0.0	0.0	*	0	0	0.0	0.0	*	0	0	0.0	0.0			
C	2.0	15	23	4.0	7.0	1.0	7	8	3.0	3.0	ND	ND	ND	ND	ND			
D	1.5	32	134	0.0	0.0	1.0	100	170	0.0	0.0	ND	ND	ND	ND	ND			
E	5.5	10	27	0.2	5.0	ND	ND	ND	ND	ND	6.5	10	129	0.01	≥20.0			
F	1.0	62	152	0.0	0.0	0.2	267	364	≥20.0	≥20.0	3.0	44	78	0.0	0.0			
G	6.0	1	11	0.1	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND			

A to G are various seafood industry plants. Instrumentation limit for NO₂ was 20 ppm. Adjacent worker positions refers to positions near transport areas.

*Instant measurements.

reported dyspnea and chest tightness. Nonsmoking forklift drivers had significantly increased prevalence compared to controls, of all work related airway symptoms investigated, except cough (Tables 5 and 7).

Table 6 shows that the risk of airway symptoms is coupled to type of work performed. Forklift drivers had the highest risk of airway symptoms both from the nose and lower parts of the airways. Production workers had significantly increased risk of symptoms from the lower parts of the respiratory system.

Clinical Findings

Table 8 shows the levels of FVC and FEV₁ presented as percentage of predicted values. None of the non-smoking worker groups reached a mean level of 100% of predicted values of FVC and FEV₁. Prevalence of FEV₁ ≤ 80% of predicted values was 16.4% and prevalence of FVC ≤ 80% was 10.7% in the total examined group. In the nonsmoker group, 13.7% and 11.8% had less than 80% of predicted values of FEV₁ and FVC, respectively.

As much as 20.3% of the examined shrimp workers had increased specific IgE toward shrimps, as compared with 8.2% and 6.9% in the whitefish and salmon industries, respectively (Table 8). Prevalence of specific IgE toward cod and herring were low, but the two individuals with cod IgEs were both working in the white fish industry. None of the examined workers had specific IgE toward salmon antigen.

Discussion

In the present study we showed that seafood industry workers are exposed to several biological active agents. We also showed that workers in different types of the seafood industry have work-related airway symptoms. Exposure to aerosols containing biological components from the seafood itself or microorganisms, may explain the high frequency of symptoms. Exhaust from indoor use of forklifts with propane and diesel

TABLE 5
Prevalence of Self-Reported Diagnoses and Symptoms of Different Worker Categories

	Shrimp Workers		White Fish Workers		Salmon Workers		Forklift Drivers		Administrative Workers (Controls)	
	Smokers	Non-smokers	Smokers	Non-smokers	Smokers	Non-smokers	Smokers	Non-smokers	Smokers	Non-smokers
N	79	83	192	195	106	105	31	23	51	87
Diagnosis by medical doctor (ever)										
Asthma	12.7	6.0	9.9	4.1	9.4	5.7	12.9	13.0	9.8	9.2
COLD	8.9	2.4	7.8	4.1	4.7	1.9	—	4.3	2.0	1.1
Allergy***	19.9		15.3		18.5			17.2		15.8
Symptoms										
Wheezing, within last year	32.9	14.5	22.9	10.3	27.4	13.3	25.8	30.4	37.3	9.2
Wheezing with dyspnea, within last year	22.8	13.3	18.8	7.2	17.9	8.6	22.6	30.4	25.5	6.9
Morning cough	50.6	24.1*	33.9	13.3	43.4	15.2†	58.1	21.7	45.1	5.7
Morning cough with phlegm	34.2	15.7	19.8	7.2	27.4	7.6	41.9	17.4	31.4	3.5
Cough, 3 months a year	27.8	13.3†	16.1	6.2	18.9	4.8	22.6	13.0	13.7	3.4
Work-related airway symptom, last year										
Dyspnea	24.1	20.5†	14.1	9.2	13.2	4.8	16.1	26.1*	17.6	6.9
Chest tightness	19.0†	12.0†	6.3	4.1	8.5	1.0	19.4	17.4†	5.9	3.4
Wheezing	17.7	9.6	9.9	3.6	13.2	3.8	16.1	21.7*	17.6	3.4
Frequent sneezing	19.0	20.5†	16.7	13.3	16.0	9.5	16.1	21.7†	17.6	6.9
Irritable, running nose	34.2†	28.9*	24.0	20.5*	25.5	24.8*	32.3†	34.8*	13.7	5.7
Cough	24.1†	25.3*	19.3	10.8	18.9	12.4	35.5*	13.0	7.8	4.6

Shrimp workers, white fish workers, and salmon workers are production workers with work tasks as specified in Table 7 (job groups). n = number of workers in category. Smokers = current smokers.

* Difference from controls $P < 0.01$ Pearson chi-square test.

† Difference from controls $P < 0.05$ Pearson chi-Square test. ***Smokers and nonsmokers.

COLD indicates chronic obstructive lung disease.

engines is also likely to contribute to airway symptoms in this industry.

In the shrimp industry, the process of shell removal is the most important aerosol generating process. After the initial mechanical shell removal, air or water jets are used to remove shell remains. All the five shrimp-processing plants in this study used air jet techniques for removal of shell remains. The air jets were placed in separate rooms with no permanent worker positions. However, technical maintenance personnel entered these rooms several times each day and sometimes stayed there several hours to solve technical problems. One stationary sample in a “machine room” showed a mean allergen concentration during 1.5 hours of 30.8 $\mu\text{g}/\text{m}^3$. Other studies have shown that substitution of air jets with water jets reduce the aerosol exposure considerably.¹ In the salmon industry, the allergen levels found were lower than in the other types of seafood industry. Only 5 of 18 samples were positive. The maximum level found was 1.6 $\mu\text{g}/\text{m}^3$, measured during removal of residual entrails after automated gutting of salmon. A Swedish study in one salmon factory reported allergen levels between 15 and 156 ng/m^3 .²² Allergen levels ranging from 0.001 to 5.051 $\mu\text{g}/\text{m}^3$ have been reported previously in various kinds of seafood industry.²³ To our knowledge, allergen levels in white fish or herring industry have not been published previously. In this work, we present data from allergen measurements performed with an IgE-based methodology using ELISA inhibition and sera from individuals with IgE-mediated allergy to fish and shrimp, respectively.

The personal exposure to total levels of microorganisms was predominantly low compared with no effect levels in other types of industry, where symptoms may arise from mainly non-infectious microorganisms.^{24–26} This may be the result of extensive disinfection procedures in the process areas. The levels of total microorganisms were 16 to 76 times

TABLE 6

Association Between Airway Symptoms and Relevant Risk Factors in Seafood Processing Industry

Risk Factor	Nose Symptoms			Other Airway Symptoms		
	OR	95% CI	P Value	OR	95% CI	P Value
Smoking	1.52	0.97–2.38	0.065	2.03	1.49–2.75	<0.001
Production work	1.97	0.83–4.65	0.123	1.70	1.02–2.84	0.043
Forklift driving	3.75	1.15–12.28	0.029	2.97	1.39–6.32	0.005

Nose symptoms include frequent sneezing and irritable, running nose. Other airway symptoms include dyspnea, chest tightness, wheezing, and cough. Production work refers to work tasks in production areas, with contact to seafood, that is, all worker groups in Table 7 except forklift drivers and administrative workers.

TABLE 7

One-Year Prevalence (%) of Airway Symptoms While Working in Different Job Groups

Type of Plant	Job Group	n	Dyspnea	Chest Tightness	Wheezing	Frequent Sneezing	Irritable, Running Nose	Cough
Shrimp	Thawers	15	20.0	13.3	6.7	6.7	20.0	20.0†
	Peelers	33	15.2	9.1	9.1	18.2†	18.2	24.2*
	Packers	25	28.0*	16.0†	8.0	32.0†	52.0*	28.0*
	Technicians	10	20.0	10.0	20.0	20.0	20.0	30.0*
White Fish	Fillet cutters	94	6.4	4.3	2.1	17.0†	19.1*	11.7
	Receivers	30	10.0	3.3	6.7	0.0	6.7	0.0
	Salt fish workers	42	14.3	4.8	7.1	14.3	28.6*	11.9
	Machine operators	29	10.3	3.4	0.0	13.8	27.6*	17.2†
Salmon	Slaughterers	87	5.7	1.1	4.6	9.2	21.8*	10.3
	Packers	18	0.0	0.0	0.0	11.1	38.9*	22.2†
Herring	Production workers	11	6.1	0.0	0.0	9.1	18.2	0.0
All	Forklift drivers	23	26.1*	17.4†	21.7*	21.7†	34.8*	13.0
	Administrative workers (controls)	87	6.9	3.4	3.4	6.9	5.7	4.6

Job groups are based on self-reported main work task. Results for the nonsmokers are shown.

*Difference from controls, $P < 0.01$, Pearson chi-square test.

†Difference from controls, $P < 0.05$, Pearson chi-square test.

the levels of culturable molds. Even if the number of CFU/m³ air were modest, the results from the mold survey showed that indoor mold growth may contribute to the environmental load in the workplace atmosphere. In most cases the mold species in the indoor samples were also found in outdoor samples, demonstrating the outdoor primary source of the molds. However, difference in dominating species of indoor compared to outdoor samples, as well as increased number of colony forming units in indoor samples, suggest that indoor environments have allowed growth of indoor molds. Seasonal as well as diurnal variations in spore numbers complicate the interpretation of the results from air samples. In addition to the

air samples, visible mold colonies confirmed the air analysis in some plants (results not shown). The visible colonies most often were found in the upper parts of the rooms (ceilings and adjacent walls). In some cases, the mold also could be traced to the use of wooden pallets. The most abundant genus was *Penicillium*. Many of the mold types found are capable of producing allergic reactions or other health effects. *Stachybotrys chartarum*, dominating one sample from the shrimp industry and *Aspergillus versicolor*, found in significant numbers in one white fish industry plant, are capable of producing potent mycotoxins. Some mold experts recommend that finding these species in significant numbers always should be regarded as reason

for further investigation/action.²⁷

The finding of these species as well as the elevated CFU-levels in general, indicate that indoor mold growth may contribute to airway effects in the seafood industry.

The results show that both forklift drivers and workers in positions near transport areas, were exposed to high concentrations of NO₂, CO, and CO₂. The use of forklifts with gas and diesel engines produced toxic exhaust gases in concentrations high enough to give health effects. In five of the seven plants measured, the recommended occupational exposure limits (Norwegian Labor inspection) for exhaust gases were exceeded. The random selection of measurement intervals, makes the results even more con-

TABLE 8
Spirometric and IgE Data of Exposed Production Workers From Seafood Industry

	Shrimp Workers				White Fish Workers				Salmon Workers				All Production Workers			
	S	NS	T		S	NS	T		S	NS	T		S	NS	T	
Spirometric data																
<i>n</i>	33	27	60		64	51	115		26	24	50		123	102	225	
Mean FEV ₁ , %	89.1*(13.4)	94.9†(14.1)	91.7*(13.9)		92.6*(13.8)	93.1*(14.1)	92.7*(13.9)		87.5*(11.0)	92.9(14.1)	90.1*(12.8)		90.6*(13.3)	93.6*(14.0)	91.9*(13.6)	
predicted (SD)																
Mean FVC %	91.2*(13.9)	97.9(12.0)	94.2*(13.4)		101.3(12.6)	96.5(14.4)	99.0(13.6)		93.4*(11.9)	94.6†(12.4)	94.0*(12.1)		96.9*(13.6)	96.5†(14.0)	96.6*(13.4)	
predicted (SD)																
Prevalence (%) of FEV ₁ ≤ 80%	21.2	11.1	16.7		14.1	13.7	13.9		23.1	16.7	20.0		17.9	13.7	16.4	
predicted																
Prevalence (%) of FVC ≤ 80%	18.2	7.4	15.0		3.1	11.8	7.0		15.4	12.5	14.0		9.8	11.8	10.7	
predicted																
Prevalence (%) of FEV ₁ /FVC < 0.75	12.1	29.6	20.0		21.9	7.8	15.7		19.2	33.3	26.0		18.7	19.6	19.1	
Total IgE (kU/L)																
<i>n</i>	32	27	59		63	52	115		23	23	46		118	102	220	
Min	2.3	3.7	2.0		2.0	2.0	2.0		2.0	2.0	2.0		2.0	2.0	2.0	
Max	667	677	677		3373	1782	3373		706	388	706		3373	1782	3373	
Median	30.8	21.8	26.2		42.9	26.2	31.6		25.6	19.1	24.5		33.0	24.6	27.9	
Prevalence of IgE ≥ 100 kU/L (%)	12.5	14.8	13.6		23.8	25.0	24.8		26.1	13.0	19.0		21.2	19.6	20.5	
Specific IgE																
<i>n</i>	32	27	59		43	30	73		23	23	46		98	80	178	
Prevalence of IgE ≥ 0.35 kU/L (%)																
IgE shrimp	34.4	3.7	20.3		7.0	10.0	8.2		4.3	8.7	6.5		15.3	7.5	11.8	
IgE cod	0	0	0		4.7	0	2.7		0	0	0		2.0	0	1.1	
IgE herring	0	0	0		2.3	0	1.4		0	0	0		1.0	0	0.6	
IgE latex	0	0	0		2.3	3.3	2.7		0	0	0		1.0	1.3	1.1	

Spirometric results are given as percentages of predicted values.

n indicates the number of workers tested. SD, standard deviation; S, current smokers; NS, nonsmokers; T, total group.

* Difference from 100, $P < 0.01$, one-sample *t* test.

† Difference from 100 $P < 0.05$, one-sample *t* test.

cerning, as they were not “worst case conditions.” In addition to the measured agents, low ambient temperatures in parts of the production and storage areas may contribute to airway symptoms.²⁸

Work-related airway symptoms in shrimp and salmon industry were confirmed in this study. For the first time, we also show increased prevalence of airway symptoms in the Norwegian white fish industry, where cod, pollack, and haddock are the main species processed. A prevalence of occupational asthma between 7% and 36% have been reported from various kinds of seafood industry.²³ In contrast to some previous studies,^{2,3,9} the increased prevalence of symptoms in our study did not correspond to an increased prevalence of asthma or allergy diagnosis in any of the types of industry investigated. This may be attributable to the selection of “problem plants” in other studies, or it may be a consequence of a “healthy worker survival effect,” demonstrating the phenomenon that workers with severe airway symptoms have to leave the exposed work environment. Workers with less severe symptoms may be able to continue their work, as reflected in the increased symptom prevalence.

Asking for symptoms *while working* gave marked differences between administrative workers and seafood production workers. Nose symptoms were most common. The forklift drivers and the production workers in the shrimp industry reported symptoms from both upper and lower respiratory tracts. The differences between production workers and administrative workers were most pronounced in the nonsmoker groups.

In this study, we were not able to show a clear relationship between any of the exposure agents measured and the frequency of symptoms, mainly because there were no significant differences in exposure levels between the different worker groups. For microorganisms and endotoxins

the variability within the different worker groups were high, causing insignificant differences between worker groups. For allergens, the variability was lower, but differences between different worker groups were still not significant.

The response rate of the questionnaire part of the study was relatively low (49.8%), mainly because of production shut-down at some factories. Periods of production shut down are normal events in this industry, and are often related to sparse raw materials or low marked prices. Another contributing factor to the low response rate was the high percentage of foreign workers at some factories. The questionnaire was not translated to other languages because earlier attempts to do so had shown that answers were difficult to interpret equally because of differences in cultural aspects.

The results from the questionnaire study were supported by results from clinical examinations. Spirometric data were compared with a Norwegian normal population,²⁰ corrected for variations in age, gender, and height and presented separately for smokers and nonsmokers. The results showed that not only the smokers but also many of the nonsmokers had mean levels of FEV₁ and FVC (% of predicted values) below 100%, suggesting a reduction in lung function.

Increase in airway symptoms and lowering of lung function parameters among seafood workers, may be caused by immunological or irritative effects of pollutants in the work environment. In the shrimp industry others have shown that airway symptoms and asthma may be caused by IgE-mediated allergic reactions.^{2,3} In one study from a salmon processing plant, Douglas et al. showed occupational asthma with IgE response to aerosolised salmon proteins.⁹

Shrimp allergy is relatively common in the general Norwegian population, as reflected in the results from specific IgE measurements. However, in the shrimp industry, a

higher frequency of elevated specific IgEs against shrimp, were found among the workers than in the other industries, suggesting sensitization through work exposure. Thus, the importance of IgE-mediated reactions was confirmed in the shrimp industry, where 20% of the examined production workers showed increased levels of specific IgE against shrimp antigen. IgE-mediated mechanisms may not be of equal importance explaining airway effects in the other types of seafood industries. In the white fish industry, only 2.7% of the examined workers showed increased levels of IgE against cod, and in the salmon industry none of the examined workers showed increased levels of IgE against salmon. This result conflicts the result of Douglas et al.,⁹ who found that 8.6% of all employees in a salmon processing plant had positive IgE against salmon. However, the plant investigated by Douglas et al was selected on basis of increased frequency of airway symptoms, whereas our study group was selected only on basis of exposure to salmon in the working environment.

Increased total IgE levels (≥ 100 kU/L) were found in 20.5% of the examined workers ($n = 220$). A study of a Swiss adult normal population ($n = 8344$) showed that 20.5% of nonsmokers and 27.5% of smokers had IgE levels ≥ 100 kU/L.²⁹ The median level of total IgE in the seafood worker group examined was 27.9 kU/L. Omenaas et al.³⁰ found geometric mean levels of total IgE in a Norwegian adult normal population ($n = 1512$) of 17.8 kU/L (men) and 13.8 kU/L (women). The IgE levels of the examined seafood worker population were thus higher than the Norwegian normal population, but the percentage of persons with IgE levels ≥ 100 kU/L were comparable with the Swiss normal population. Omenaas et al.³⁰ also showed that subjects with occupational dust or gas exposure had higher total IgE levels than nonexposed. The higher levels of total IgE

among the seafood workers compared to the Norwegian normal population may thus be a combined effect of allergen aerosol and non-allergenic dust and gas exposure.

Conclusion

Workers in the seafood industry are exposed to bioaerosols containing allergens, endotoxins, and molds, as well as forklift exhaust gases. The workers in this industry showed a high prevalence of work-related airway symptoms. The data suggest specific IgE-mediated reactions are relevant mechanisms only in the shrimp industry. Further studies on mechanisms of airway symptoms among seafood industry workers as well as further investigations of exposure-response associations are needed.

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