Occupational asthma in maritime environments

an update

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REVIEW PAPER

Occupational asthma in maritime environments: an update

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ABSTRACT

In 2006 we published our first review based on the available literature on occupational asthma in maritime environments in the "International Maritime Health" journal. Since then, we have obtained a great deal of new knowledge on asthma in seafood workers and fishermen and on the impact of exposures from sulphites preservatives, container fumigants etc. in maritime workers. This review aims to provide an update of the current knowledge base about occupational asthma in a maritime context and to provide recommendations regarding medical surveillance of workers at risk.

(Int Marit Health 2016; 67, 3: 144–152)

Key words: occupational asthma, maritime environments, review

INTRODUCTION

In 2006, we published a specific article on occupational asthma (OA) in maritime environments [1]. Since then, additional knowledge has emerged and a number of articles on risk factors, pathophysiological mechanisms and preventive options have been published on the subject. In recent reviews on occupational respiratory diseases in the field of maritime environment published in the literature, a big part of the articles deal with the onset of allergy [2–4]. We thought that an update specifically for maritime physicians could be relevant to publish. Asthma affects 5–10% of the general population in the developed countries and 9–25% of asthma in adults is regarded as due to occupational factors [5, 6].

The maritime environment is characterised by the variety of products to which workers in the different trades in the whole maritime industry (merchant navy, fishing and fish processing industry, and other harbour industries) are exposed.

In 2010, the Food and Agriculture Organisation estimated that more than 45 million people worldwide were directly involved in fishery and aquaculture production and that 142 million tons of seafood were produced per year [3]. Occupational asthma is the most frequently related respiratory disease reported in the seafood industry [4].

From the International Chamber of Shipping, the worldwide population of seafarers serving on internationally trading merchant ships is estimated to be in the order of 466,000 officers and 721,000 ratings (http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade/number-and-nationality-of-world's-seafarers).

Like in 2006, we made a systematic research in the scientific literature and our personal cases.

Work-related asthma includes OA and work-aggravated asthma. Occupational asthma can be immunoglobulin E (IgE)-mediated, have an unknown pathophysiological mechanism or be irritant OA which again consists of reactive airways dysfunction syndrome (RADS), not-so-sudden onset asthma, or low-dose irritant asthma [7].

EPIDEMIOLOGY

ASTHMA DUE TO SEA PRODUCTS

The dominant aetiological factors for OA are seafood with higher prevalences associated with exposure to arthropods (crab and shrimp) than to molluscs and fish. Most OA to those exposures are IgE-mediated subsequent to sensitisation to the protein content in sea products [1]. In some cases, biological agents such as endotoxins, dinofla-

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gellates associated with seafood or agents used in seafood preparation, could cause OA. We deal with the mechanisms in the pathophysiology chapter.

Studies and case reports of OA in maritime environments are summarised in Table 1.

CRUSTACEANS

Exposure to crustaceans, and especially snow-crab, are the most studied aetiologies. Occupational asthma due to snow-crab (*Chionoecetes opilio*) was firstly published by Cartier et al. in 1984 [8], IgE sensitisation in 1986 [9] and improved spirometry, hyperreactivity and specific immunoglobulin G (IgG) after cessation of exposure in 1998 by Malo et al. [10]. The detection of snow-crab antigens in air samples was reported in 1997 [11]. In 1994, Endelman [12] already reported a significant rate (70%) of asthma-like symptoms on processing personal on a fishing boat. More recently, Beaudet et al. [13] found the prevalence of OA in 4–6% of fishermen from 5 crab-processing vessels. In 2 studies of a population of 303 and 215 Canadian snow-crab processing plant workers, respectively, the prevalence of OA was 16% [14, 15]. In a case reviews of the Washington telemedicine service, we published 4 cases of probable snow-crab OA in fishermen [16].

King crabs (*Paralithodes camtschaticus*) and common crabs (*Cancer irroratus*) are the two other identified species of crab that has been linked with OA, with prevalences of 9% and 7%, respectively [14, 17].

For crustaceans, a high prevalence of OA due to prawn (*Nephrops norvegicus*) has been found in process-workers [18]. A lower rate was shown for shrimps (*Gammarus et Artemia salina*) in 1 study [19], and in case reports in processing workers [20] and in aquaculture technician [21]. Case reports have shown that sensitisation to lobster (*Homarus vulgaris et americanus*) was mediated through cooking steams [22, 23].

MOLLUSCS

Asthma has also been linked to exposure to bivalves. A prevalence of OA from 20% to 23% has been recorded for workers who opened mussels (*Perna canaliculus*) [24] and a prevalence of 2% among clam processing workers [25, 26] and scallops (*Pecten maximus*) in restaurant workers [27, 28].

Tomaszunas et al. [29] described an asthma incidence of 1% per year related to exposure to cuttlefish in Polish fishermen. Another case report of OA due to octopus particles has been more recently published for a woman and a man, who were working in seafood factories [30]. For squid (*Loligo vulgaris*) a case-report described OA, rhinitis and contact urticaria in a man who were working in a frozen-seafood company and in 2 French cooks [31, 32].

Most OA related to fish are case-reports of sensitisation secondary to inhalation of wet aerosols in fish processing workers and fishmongers, but no case has been described in fishermen [33].

Occupational asthmatic reactions to salmon have been demonstrated with prevalence of 8% among automated salmon processing workers [34]. In a study including 70 workers of a Norwegian salmon-processing company, wheezing was noted in 5.7% on Mondays, and 7.1% of workers have been diagnosed with asthma [35]. In a closed study, 3 cases of OA to salmon were found in a population of 26 salmon-processing workers [36]. Sole, hake, plaice, cod, herring, pilchard, anchovy, swordfish, sole, pomfret, yellowfin, shark and tuna exposure have been related to OA [2, 33]. The link between trout exposure and OA is unclear [37]. New cases of OA caused by turbot in 3 Spanish fish-farm workers have been published in 2010 [38]. Two epidemiological studies underline the variation in prevalence of work-related symptoms of OA in fish-processing industries with 1.8% in South Africa and 42.8% in Norway [39, 40].

WORMS

Several studies have indicated the parasite *Anisakis simplex* that infects fish in a larval stage as an aetiology for asthma [41–43]. The first symptoms for the diagnosis of an infection by this parasite are mainly gastro-intestinal ones. An Italian study published in 2000 found sensitivity to Anisakis in 50% of fishermen versus 0% in control subjects [44]. Some asthma cases were also recorded during exposure to larva of *Chironomus thummi thummi*, which is used as baits and food for tropical fish [45], as well as to mosquito larva (*Echinodorus plasmosus*), which can be found in aquariums [46].

OTHER SEA PRODUCTS

Nine per cent of Japanese spiny lobster fishermen presented asthma related to a coral species (*Dendronephthya nipponica*) [47]. Other species have also been associated with asthma, such as the marine sponge *Dysidea herbacea*, and an invertebrate from the *Ascidiacea* class living on oyster shells (*Styela plicata* — better known under the name of Hoya) that has caused an asthma prevalence of 29% in a population of oyster-workers [48, 49]. A case of asthma due to seaweed in a thalassotherapist was published more recently [50].

ADDITIVES AND TOXINS

Preservatives used in fish and seafood processing may also cause OA. Sodium metabisulphite is a chemical preservative used during fishing for processing of fish and crustaceans. Case reports of OA due to sodium metabisulphite have been described in fishermen (lobster fisherman,

Table 1. Case-reports and studies on occupational asthma in maritime environments

Agent	Workplace	REF	Number of subjects	Prevalence (%)	Cutaneous (% +)	Other immunological test (% +)	Bronchial challenge (% +)	Other
Crabs								
King crab	Processors	14 es	186	13	60% of 15 workers	Precipitins 60% of the 15 workers	ND	Spirometry
Snow crab	Processors	8 es	303	16	22%	ND	72%	Peak-flow of 6 tests
	Processors	67 es	825	5.5	ND	ND	ND	ND
	Processors	15 es	215	15.8	+ 18.3%	+ IgE 14.3%	ND	PEF
	On vessels	59 es	51	U	43% crab blood symptomatic workers	ND	ND	Spirometry
	Processors	67 es	107	19	ND	RAST: 6–8%	ND	ND
	Processors	68 es	205	9–50	15–50%	RAST	ND	ND
Common crab	Processors	17 cr	29	7	25% workers with symptoms	ND	14% of 14	Spirometry Methacholine
Several species	On vessels	13 es	82	4–6	ND	ND	ND	ND
	Processors	69 cr	46	Incidence 2%/month	ND	ND	ND	ND
Lobsters	Cook	23 cr	1	ND	+ lobster, oyster, clams	ND	+	Spirometry
Lobsters + shrimps	Fishmonger	19 cr	1	U	+ lobster, prawn, crab	RAST + lobster, shrimp	+ lobster, shrimp	ND
	Cook	22 cr	1	U	+ lobster	ND	–	ND
Prawns	Processors	18 es	50	36	26%	RAST 16% Precipitins 62%	100% of 2 tests	ND
					Workers with symptoms			
Shrimps								
Shrimps	Laboratory technician	21 cr	1	U	+ shrimp	RAST + shrimp, crab	+ shrimp	ND
	Plant fish-food	20 cr	1	ND	+ gammarus	ND	+ shrimp	Spirometry
Gammarus	Processors	54 cr	2		+ crab, shrimp	RAST + shrimp	+ shrimp	
	Processors	40 es	132	> 24 WRAS	+ shrimp 20.3%			
Shrimps and clams	Processors	25 es	56	Shrimp: 5 Clam: 2	+ shrimp 16% + clam 7%	RAST + Shrimp: 14–16% Clam: 5–7%	67 (3 tests)	Methacholine
					Of all workers			
Clam	Medical student	26 es	1	U	+	ND	+	ND
Mussels (?)	Mussels openers	24 es	224	20–23	ND	ND	ND	Peak-flow
Scallops	Cook	27 cr	1	U	+	RAST +	+	ND
Cuttlefish	Fishermen	29 es	66	Incidence 1%/year	ND	ND	ND	ND
Squid	Frozen-seafood	31 cr	1	U	ND	ND	ND	ND
Abalone	Fisherman	27 cr	1	U	ND	ND	+	ND

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Table 1. (cont.) Case-reports and studies on occupational asthma in maritime environments

Agent	Workplace	REF	Number of subjects	Prevalence (%)	Cutaneous (% +)	Other immunological test (% +)	Bronchial challenge (% +)	Other
Fishes								
Several species	Plant workers	33 es	51	2	23%	IgE tot	ND	Nasal test
					Sole, cod, tuna, sardine, salmon, herring			
	Fish processors	39 es	594	1.8	+ 6%	IgE + anchovy (5/15) + pilchard (4/15)	ND	Methacholine
	Fishmongers	70 es	64	2/64 WRAS	+ shrimp 12.5%, spiny lobster 10.9%, crab 3.1%		ND	Spirometry
	Smoking fish plant	30 cr	1	U	+ tuna, salmon, sole		+ raw tuna, sole, salmon	ND
	Fish processors	40 es	387	> 14.1% WRAS	ND	– salmon	ND	ND
Salmon	Plant workers	34 es	291	8%	ND	RAST: 9%	ND	Spirometry
	Frozen-fishes	1 cr	U	+ raw salmon, trout, sardine		ND	+ salmon	ND
	Processors	40 es	211	> 13.2 WRAS	ND	+ cod 2.7%	ND	ND
	Processors	35 es	70	7.1	ND	IgE + salmon 2.9%	ND	Spirometry
Turbot	Fish-farm workers	38 cr	3	U	+ turbot, cod, sardine, hake	IgE + turbot	+ turbot 3 cases	PEF
Trout	Trout-fileting	37 es	8	U	ND	RAST: 100%	ND	ND
Anisakis simplex								
	Chicken farm	41 cr	1	U	+	RAST +	+	ND
	Fishmonger	41 cr	1	U	+	RAST +	+	U
	Frozen fish	42 cr	1	U	+	Immunoblot	ND	Spirometry
	Cook	45 cr	1	U	+	RAST +	+	Methacholine
Worms								
Several species Galleria mellonella Calliphora vomitoria Tenebrio molitor	Worms farm	50 es		4	32% +	RAST: 71% on 17 workers	ND	ND
Lucilia caesar Galleria mellonella Tenebrio molitor	Fishmonger Worms farm	14 cr		U	13 test 92% Lucilia caesar 15% Galleria mellonella 23% Tenebrio molitor	RAST 13 tests 92% Lucilia caesar 23% Galleria mellonella 7% Tenebrio molitor	ND	Spirometry Methacholine
Lombricus terrestris	Fishmonger	1 cr		U	+	RAST	ND	ND
Eisenia foetida	Fishmonger	1 cr		U	+ Eisenia foetida – Tenebrio molitor	RAST	ND	Nasal test

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Table 1. **(cont.)** Case-reports and studies on occupational asthma in maritime environments

Agent	Workplace	REF	Number of subjects	Prevalence (%)	Cutaneous (% +)	Other immunological test (% +)	Bronchial challenge (% +)	Other
Marphysa sanguinea	Fishmonger	1 cr		U	+ Marphysa sanguinea - Lumbricus terrestris	RAST histamine release	ND	Nasal test
Marine sponges								
Dysidea herbacea	Laboratory technician	48 cr	1	U	ND	RAST Dysidea herbacea 6 species of sponges 2 coral species	ND	ND
Coral	Spiny lobster fishermen	47 es	72	9%	100% on 2 test	RAST 50% coral and spiny lobster	ND	ND
Hoya	Oyster aquaculturists	49 es	1413	29%	82% on 511 test	RAST 89%	82% 17 test	ND
Seaweed	Thalassotherapist	50 cr	1	U	ND	ND	+	ND

cr — case report; es — epidemiological study; IgE — immunoglobulin E; Methacholine — methacholine test with spirometry; ND — not done; RAST — radio-allergosorbent test; U — unknown; WRAS — work-related asthmatic symptoms; REF — number of reference; PEF — peak expiratory flow

trawlerman, and prawn fishermen) [51–53]. Two cases have been recently published in France in shrimp-processing workers [54]. Even “natural” additives such as garlic, mustard and anise, which are often used in fishery industry, are well known OA triggers [55]. Marine toxins like histamine or bacterial toxins found in seafood are other agents with the potential to cause respiratory diseases [2, 56]. Another risk was cockroach contact. Cockroaches are detected ashore as well as on board ships all over the world. In 2005, in Hamburg, 10.6% of ocean-going ships investigated were infested by cockroaches that are well-known causes of airway allergy [57].

PATHOPHYSIOLOGY

In the maritime world, and more specifically for seafood, OA is mostly immunologic and IgE-mediated with sensitisation to an antigen present in marine organisms or to an associated agent present in the matrix.

Since we published our first review in 2006, a number of crustaceans, fishes and other seafood allergens have been identified with sensitisation through ingestion. By contrast, for inhalation, few new findings have been published. The major allergenic proteins found in those studies are high molecular weight proteins like tropomysosin and arginin kinase for crustaceans and parvalbumin for fish [2]. The pathophysiology of OA from seafood stems from inhalation and immune sensitisation to those proteins from, e.g. meat, endolymph, exoskeleton, or blood, which is aerosolised during work processes [55]. The occurrence of cross-reactivity may cause allergic reactions to multiple species of seafood. Crustaceans are reported to be more allergenic than fish [4].

Recently, it was also demonstrated that digestive enzymes like trypsin from visceral contents in salmon, herring and king crab can stimulate inflammatory processes in the airways [2]. For associated agents with respiratory actions, we have earlier described aetiologies like sea-squid and anisakis, but some marine toxins (histamine, endotoxin), chemical additives (sodium metabisulphite, formaldehyde), spices and gases products during decomposition like hydrogen sulphide can also be responsible of acute respiratory diseases [2, 58].

Fishermen with asthma due to exposure to sodium metabisulphites have negative skin prick tests and specific IgE tests, while positive bronchial challenge tests and specific bronchial challenge tests proves the relation to sodium metabisulphite [51–53]. Similar findings apply to asthma in shrimp-processing workers, in which the radio-allergosorbent test (RAST) levels for common allergens and sodium metabisulphite were negative while peak-flow monitoring and specific bronchial challenge are positive [54]. These findings lead to the conclusion of irritative OA, but it is well-known that exposure to respiratory irritant agents in the workplace can cause work-aggravated asthma and be a risk factor of developing OA. Sodium metabisulphite is a specific example in maritime environments for exposure to an irritant agent [3]. A case-report published in 2014 by Uriarte et al. [59] described the case of a 38-year-old woman who had been working in a Spanish seafood-packing factory. They performed two specific inhalations, one with only sodium metabisulphite and the other with raw squid. Both of them were positive with late asthmatic responses. Sensitisation to shrimp, octopus, and fish was confirmed by skin test and specific IgE, but unfortunately nothing was mentioned about prick or specific IgE testing for sodium metabisulphite.

Another particularity of seafood workers and fishermen is endotoxin exposure at work. In studies of crab processing, the total and respirable concentration of airborne endotoxin was 32.6 (Endotoxin Unit/m^3 [EU/m^3]) and 15.6 EU/m^3 [14]. More recently, levels between 5.8 EU/m^3 and 29.9 EU/m^3 have been reported in shrimp processors [3, 40]. Fish processors are also exposed to endotoxins with levels of airborne concentrations in the range between 6.8 EU/m^3 and 136 EU/m^3 [2]. The role of exposures to endotoxins in OA is not yet well-characterised for work-related respiratory symptoms. Recently, Shiryaeva et al. [35] found levels of endotoxin of 29 EU/m^3 in salmon-processing plants and more specifically, a very high level of airborne endotoxin was found in water from the transport tank (779 EU/mL) [36].

Recent studies underline the presence of high levels of endotoxin in several plants, and in a salmon-processing plant high atmospheric levels of mould spores (*Penicillium notatum*, *Aspergillus aspergillus* and *Cladosporium herbarum*) were found when filleting fresh salmon [36].

Also in a Croatian study, high levels of dust mites, and especially Pyroglyphid mites, have been measured in bed samples of fishing boats [60]. Moulds may also be responsible of respiratory diseases.

In Norwegian salmon-processing workers, Shiryaeva et al. [35] found a change in respiratory symptoms and pulmonary test with significant associations with total Protein levels on Mondays only. Associated with the healthy worker effect a tolerance effect is suggested for the first time in seafood workers and needs further investigations [35].

Typically, wet aerosols encountered in the processing of fresh seafood products constitute the exposure and subsequent sensitisation. However, exposure may also occur by vaporised allergens inhaled during the cooking of crab and lobster [8, 11–14, 17, 22, 23].

Atmospheric allergen concentration is the major professional risk factor responsible for the development of OA in the commercial fishing industry [16]. Most high-risk work stations for snow crab workers are boiling, butchering stations, body leg stations; concentrations of allergens in atmosphere in those stations on vessels have been measured as 1,657 ng/m^3, 7,443 ng/m^3 and 5,061 ng/m^3, respectively [9, 61, 62]. Although, only 25% of snow crab plant employees work at butchering stations, these stations account for 70% of asthma cases thus highlighting the importance of atmospheric allergen concentration [13]. In fish-processing, a total inhalable concentration of allergen of 5,100 µg/m^3 has been shown [2].

Some physical factors, like cold air, high physical activity, hypertonic saline aerosols, may trigger respiratory symptoms [63].

Atopy is the most important host risk factor for OA related to work with crabs, prawns, cuttlefish, pilchard and anchovy, while smoking is a risk factor for asthma caused by work with prawns, crabs, pilchard, anchovy and salmon [2].

For others exposures, the influence of atopy and smoking is unknown because our knowledge of these is based on publications with few cases related to the maritime environment.

ASTHMA DUE TO PRODUCTS TRANSPORTED BY VESSELS

Since 2006 and the publication of our first review [1], limited research relating to aetiologies of OA in the maritime environment have been published. We suggest you to read the paper published in 2006 and the exhaustive review, which was recently published by Baur and Bakehe [7] on other allergens causing OA and irritant-induced OA.

In a study of silo port workers we did not found cases of OA but 37.5% had occupational rhinitis and 50% of workers were sensitised to grain [64].

Baur et al. [65] have described chemical exposures and associated health effects of fumigants in containers. Fumigants like bromomethane, hydrogen phosphide, 1,2-dichloroethane, trichloronitromethane and ethylene oxide and gases released from goods transported by containers like formaldehyde, benzene, and toluene have been well documented in freight container air samples. Occupational asthma from formaldehyde has been reported in industry and laboratory work as well as in port workers and seafarers, e.g. the manufacture of fish meal requires the use of formaldehyde, which may spread to the work environment and the surroundings [7].

Bromomethane, hydrogen phosphide, 1,2-dichloroethane, and chloropicrin are irritants for the respiratory tract and similar to sodium metabisulphite can cause work-aggravated asthma [66–68].

After banning the use of tributyltin, new chemical products have been developed for antifouling paints. Some of these are known to be agents that can cause OA. The paints may contain high concentration of copper or lower concentrations of zinc or aluminium as well as chlorothalonil [68] for fungicidal and algicidal actions. Isocyanates, epoxy resins and other resins are also used in coating paints [7].

RECOMMENDATIONS FOR PREVENTION, TREATMENT AND MEDICAL SURVEILLANCE

In a population of seafarers and workers in seafood processing, we must be careful with respect to exposure to agents that can cause OA.

At the first examination, we have to search individual risk factors of OA such as atopy, asthma, smoking and a history of ingestion-related allergy with seafood. It is estimated

Table 2. Recommendations for medical survey

Examination	Questionnaire	Clinical examination	Paraclinical examinations
First examination	Atopy Asthma Smoking habits Ingestion-related allergy with seafood and fishes	Dermatological Otorhinolaryngological Pulmonary	Spirometry if signs of allergy: • prick tests (common and occupational agents) • RAST with total IgE • methacholine respiratory test
Regular examination	First signs of eczema, rhinitis or asthma	Signs of eczema, rhinitis or asthma	Spirometry every 4 years or if signs of allergy: • prick tests (common and occupational agents) • RAST with total IgE • methacholine respiratory test

IgE — immunoglobulin E; RAST — radio-allergosorbent test

that 7% of workers with ingestion-related seafood allergy develop asthma symptoms after exposure to respiratory seafood allergens [39].

Previous and actual dermatological and upper and lower airway symptoms and signs including rhinitis and conjunctivitis must be noted at the medical examination.

For paraclinical tests, it's useful to have an initial spirometry or peak expiratory flow assessment.

The medical surveillance should to detect the first symptoms or clinical signs of OA or rhinitis. If workers have respiratory symptoms, a diagnostic scheme should be done with further immunological tests (prick-tests, standard and specific, RAST and total IgE and respiratory tests with methacholine test, and, if necessary to confirm the aetiology, a challenge test). It has been demonstrated, that the prognosis of OA does not only depend on the duration of exposure and level of exposure, particularly after onset of symptoms (summarised in Table 2).

Treatment is a combination of medications and reduced or removed exposure and, if necessary, work withdrawal. Malo have demonstrated that in a population of snow-crab processing workers, following work-withdrawal, a plateau of improvement was reached after a mean of 1 year for spirometry and after 2 years for non-specific bronchial hyperreactivity [10].

Studies in Canada and South Africa have shown that the main occupational risk factors are the atmospheric allergen concentration and the exposure dose (duration and level) of the causative substances [1–4]. Gaddie et al. [18] and Douglas et al. [34] illustrated this in prawn- and salmon-processing plants, respectively, with no new cases of OA and fewer asthma symptoms after reduction of the atmospheric levels of the causing substances. Moreover, Gautrin et al. [15] have shown in 2010 that cumulative exposure to snow crab allergens is positively associated with OA and allergy in a dose-response manner.

Other environmental factors like humidity level, cold air, and exposure to respiratory irritants are also contained in the prevention scheme.

As demonstrated by Gaddie et al. [18], Orford et al. [14] and Douglas et al. [34] in their studies, the level of atmospheric exposure to is correlated with the development of OA. So, collective prevention by an adequate ventilation to reduce atmospheric concentrations of causative agents is the most relevant and effective action.

CONCLUSIONS

This up-dated review of the diverse aetiologies of OA in maritime environments underlines the relevance for health services dealing with seafarers, dockers, and employees in the maritime food-processing industry in addressing occupational respiratory, dermatological, and rhinitis symptoms. Most studies have suggested or confirmed an IgE-mediated OA to seafood allergens.

Some studies underline high exposures of environmental allergens like moulds and mites in occupational settings [59, 66]. However, more knowledge on those professional exposures is needed.

In France, the acknowledgement of asthma as occupational disease has appeared only since 1999 for seafarers. Major studies of OA conducted in seafood workers bring up new and essential findings. But few studies have been conducted in seafarers and fishermen. We need more knowledge about the prevalence and distribution of OA and the risk factors for OA in these trades.

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