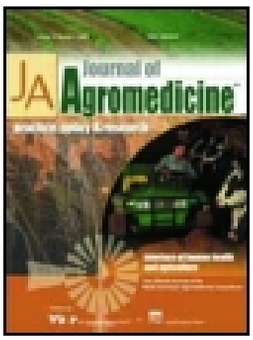

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REVIEW

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Exposures and Health Effects of Bioaerosols in Seafood Processing Workers - a Position Statement

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ABSTRACT

Occupational hazards exist in the processing of seafood both in land-based facilities as well as on board vessels. Recent findings on occupational injury and respiratory health risks among seafood processing workers were presented and discussed at the IFISH5 conference. Particular emphasis was put on the challenges that im/migrant workers encounter, the greater risks onboard factory vessels, especially where processing machinery are retrofitted to older vessels not primarily designed for this purpose, and the difficulties in assessing and preventing bioaerosol exposures and associated respiratory health risks despite recent advances in characterising agents responsible for allergic and non-allergic reactions. Based on appraisal of existing knowledge in the published literature and new findings presented at the conference, recommendations for immediate actions as well as for future research have been proposed. Among these include the importance of improving extraction ventilation systems, optimising machinery performance, enclosure of bioaerosol sources, improved work organization, and making special efforts to identify and support the needs of im/migrant workers to ensure they also benefit from such improvements. There is a need for studies that incorporate longitudinal study designs, have improved exposure and diagnostic methods, and that address seafood processing in countries with high seafood processing activities such as Asia and those that involve im/migrant workers worldwide. The medical and scientific community has an important role to play in prevention but cannot do this in isolation and should cooperate closely with hygienists, engineers, and national and international agencies to obtain better health outcomes for workers in the seafood industry.

KEYWORDS

Seafood; fish; crustaceans; bioaerosols; allergens; endotoxin; allergy; rhinitis; asthma

Introduction

The Fifth International Fishing Industry Safety & Health Conference (IFISH5) in St John's, Canada in June 2018 brought together 175 participants from over 20 countries. Sponsored by the National Institute for Occupational Safety and Health (NIOSH), Memorial University's SafetyNet, and the Food and Agriculture Organization of the United Nations (FAO), the conference focused on health and safety among workers in the commercial fishing, seafood processing, and aquaculture industries worldwide. A keynote presentation and several sessions covered various hazards found in the seafood processing industry. The scope of this paper is to report on recent studies of occupational injury and respiratory health risks among workers in vessel-based and land-based seafood processing facilities that were presented in the special session on "Exposure Assessment and Health Effects of Seafood Bioaerosols in the Fishing and Seafood Processing Industries" and related sessions at the IFISH5 conference, supplemented by relevant recent publications.

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It is not the scope of this paper to review the evidence of health effects in seafood processing or to give recommendations on how to deal with complaints reported by seafood workers, as this has been previously reviewed on a number of occasions.[1] The aim is rather to suggest ways in which key findings and recommendations can be implemented in the industry, thereby promoting a greater degree of research translation by the companies and employees (as suggested by Jeebhay in his keynote address "Occupational health and safety in the South African seafood industry – a developing country perspective") as well as to discuss future research needs in the field.

Overview

Seafood processing, which occurs on board vessels and in land-based factories, shares many hazards with farming, such as musculoskeletal strain from heavy work, exposure to bioaerosols, and seasonal work that particularly affects migrant workers. In contrast to research on farmers' health, the specific hazards associated with seafood processing have been the subject of research only in the past few decades. In the late 1600s, Ramazzini[2] mentioned how fishermen were affected by dangers at sea, cold weather, humidity, and poor diet. He ascribed chest illnesses to these factors but did not specifically mention inhaled fumes, dusts, or vapors as he did for farmers.[2] Asthma arising from inhalation of seafood allergens was more specifically described in a fisherman from Norway in 1937,[3] and in 1944 in 6 of 67 workers at a Danish mussel facility.[4] These and other early reports focused on skin and airway symptoms suggestive of asthma.[5] Despite these reports, most research on seafood allergy that followed focused primarily on the consumption of seafood in the domestic setting, with minimal focus on the handling of seafood in the occupational setting.[6,7] As seafood processing has become more common and increasingly automated in recent years, several studies have been published from industrialized countries, identifying new allergens and other components responsible for skin and airway symptoms associated with disease.[8] Occupational asthma has been more commonly associated with shellfish (prevalence range: 4%–36%) than with bony fish (prevalence range: 2%–8%).[1] Despite the importance of the seafood industry in Asia, very few studies have been reported from this continent. Subsequent to a detailed review published earlier,[1] a 12% prevalence of asthma was found in snow crab workers in Japan.[9] Few studies have also demonstrated dose-response relationships between seafood allergen exposure and occupational asthma.[8,10] Seasonal work disproportionally undertaken by women and im/migrant workers has also become increasingly important for the industry.[11–13] These workers are potentially at increased risk of developing health problems to the well-known hazards in the industry and are less likely to be investigated and face additional challenges of their own due to their precarious working conditions. However, these issues have not, until recently, been the subject of more detailed study. Despite the paucity of research in this field relative to seafood allergies in the domestic setting, fishermen and seafood processing workers commonly report work-related symptoms, a fact well-known to most industry stakeholders.

Recent studies in seafood processing

Investigations from Norway presented at IFISH5 by Aasmoe and Bang suggested that exposure to several different bioaerosol components contribute to adverse respiratory health effects among seafood processors. These include the well-known high molecular weight allergens from *fish viz. parvalbumin* and *crustaceans viz. tropomyosin* as well as lesser known allergens.[14] Their studies also demonstrated that proteolytic enzymes such as trypsin have the potential to increase airway inflammation, and these enzymes are present in the bioaerosols encountered in the seafood industry.[15,16] Reports from Norway and Newfoundland presented by Abdel Rahman demonstrated how exposure conditions on board factory vessels, influenced by lack of space and inadequate ventilation, resulted in elevated levels of not only proteins and allergens but noxious gases as well. The research from Norway generally showed lower protein levels in new compared to older vessels, probably due to improved ventilation and better enclosure of processing machinery. These studies demonstrated that their ongoing research is likely

to develop simpler methods for the detection and quantification of allergens (both mass spectrometry and immunoassays), including proteases such as trypsin. Furthermore, the importance of less well characterized allergens and their potential health relevance may also need to be considered in clinical investigations of affected workers.[8]

Swedish research data presented by Dahlman-Höglund confirmed suspicions that endotoxins could be implicated in certain forms of seafood processing activities. Previous studies have demonstrated that endotoxins may also be responsible for the respiratory complaints reported by seafood processors. While these concentrations can often exceed the recommended exposure limits for endotoxins, they have not been found to reach levels commonly encountered in animal farming. The data presented suggested that elevated endotoxin levels were likely to cause acute symptoms but were probably unlikely to be responsible for chronic respiratory complaints reported by workers. Furthermore, the research also confirmed that endotoxin levels in processing facilities varied significantly between days during the monitoring period, suggesting that single endotoxin measurements were probably insufficient to inform definitive decisions about preventive measures. However, should there be elevated numbers of workers with respiratory complaints, especially if they are associated with general symptoms such as headaches or fever, this may well suggest a putative role for endotoxins. In such situations, should endotoxin measurements be contemplated, repeated measurements on several different workdays at the facility and during different processing activities is probably required.

Studies of shellfish processors in Greenland presented by Bønløkke suggested that there may not always be a clear association between measured exposure levels and the proportion of workers with respiratory symptoms and asthma in this group. Despite relatively higher bioaerosol and allergen exposure levels among shrimp processors, the prevalence of respiratory complaints and possible cases of occupational asthma was higher among crab processors. As has been reported in previous studies, these findings suggest that, although many seafood species when processed could cause respiratory allergy and asthma, there is a great variation between species in their tendency to do so.[8] While the differences in how the seafood is processed are also important,[5] the extent to which these variations can be explained by differences in allergenicity between species remains to be clarified.

Minimal research has historically focused on dose-response relationships related to allergens and asthma in the seafood industry, partly because little is known about the major allergens implicated in its causation.[8] This has changed in the past decade, with relatively more research being conducted in allergen characterization. Jeebhay presented data from pelagic fish processing in South Africa showing evidence of clear dose-response relationships, more so with cumulative than current allergen exposures, for multiple outcomes including sensitization, work-related allergic ocular-nasal or chest symptoms, and probable occupational asthma. These relationships were modified by atopic status and, to a lesser extent, by smoking. These results further highlight the need to reduce allergen exposures to minimize the risk of sensitization and progression to allergic respiratory disease among those already sensitized.

Although earlier studies on bioaerosol exposures were conducted in the seafood processing industry in the United States,[17,18] there has been little follow-up research over the past two decades. Syron presented data in another session on two surveillance studies on Alaska's seafood processing industry, which utilized secondary data sources that mainly captured occupational injuries.[19,20] Additional findings from Syron's recent qualitative research on this industry were also presented, which highlighted the global nature of the workforce and that language barriers among the im/migrant workers in Alaska presented challenges for safety and health program managers. The long work hours (e.g., 12 or more hours per day, every day, and often aboard vessels for weeks at a time) were additional challenges for workers. Research is needed to determine the extent to which bioaerosol exposures continue to affect this vulnerable worker population in the United States and elsewhere.[21]

Discussion

Several studies in this and other sessions at IFISH5 included a large proportion of im/migrant workers and confirmed that these workers are often exposed to hazardous working conditions, both in terms of physical conditions as well as bioaerosol exposures. A considerable proportion of the Norwegian and United States (Alaska, West Coast, Gulf of Mexico and East Coast) seafood workforce comprises im/migrant workers. The Greenlandic workforce, which historically consisted of mainly local workers, appears to have increasingly transitioned into an im/migrant workforce in recent years. Anecdotal reports suggest that these im/migrant workers are more vulnerable to these health risks than local workers.

The participants of this session deliberated on the need for continued research into the causal agents of respiratory disease in the seafood industry, as opposed to recommending specific actions that could already be implemented based on the current knowledge. It was agreed that despite recent advances in molecular epidemiology in better characterizing some allergens and promising ongoing epidemiological studies, there continues to be a lack of standardized methods that can reliably determine exposures to the range of causal agents in bioaerosols in the seafood industry and explain the spectrum of respiratory health effects observed. The session explored the various challenges and how these could be addressed to support research implementation strategies.

Exposure assessment is not standardized regarding important issues such as optimal methods for collecting samples (e.g., relevant size fractions, sample time, and volume), particularly regarding which components to include (e.g., endotoxins, mold, trypsins and other enzymes, and total protein) that are clinically relevant in causing the symptoms in exposed workers. Regarding allergens, it is not clear which specific allergens should be evaluated in exposure assessments, since major allergens are yet to be identified in certain processes (e.g., canning, cooking, fileting, fishmeal production), while in other processes, allergens from micro-organisms other than the seafood itself may be of importance. This is the case with certain parasites, such as ”sea-squirt” and *Anisakis* and with the fish feed in aquaculture.[22,23] Occasionally, seafood workers also implicate components of the outer shells of crustaceans or the slime of whitefish causing their symptoms. These aspects have not been the subject of detailed study.

With regard to characterizing the health effects of occupational exposure to seafood in clinical or epidemiological studies, skin prick test (SPT) reagents have been found to be of varying quality and are often unavailable in workplace settings such as fishing vessels and seafood processing facilities located in remote settings.[7] In-vitro methods such as specific IgE measurements in blood samples may be more readily available, but they have their own challenges. Both methods are constrained in that the number of commercially available seafood reagents is extremely limited. The World Allergy Organization and the European Academy of Allergy and Clinical Immunology[24] endorse the use of SPT if extracts are sufficiently standardized. Unfortunately, for occupational allergens these are not commonly available.[25] The need for standardization is further highlighted since the alternative, a specific allergen inhalation challenge test, is not generally feasible for seafood processing workers.

Occupational exposure limits specific for bioaerosols have been very difficult to establish, as has been demonstrated in bioaerosol research in farming and other related food industries.[26] More specifically, the lack of detailed information on the dose-response relationships for inhaled seafood, until recently, has contributed to this as well. Despite these challenges, the general consensus was that actions should be taken to reduce (bio) aerosol exposure in facilities with visible exposure problems or the presence of symptomatic workers, even in the absence of exposure measurements.

It was also noted that most machinery used in the seafood processing industry appears to be produced by a few highly specialized and technologically advanced manufacturers, who are likely to supply work facilities worldwide. However, exhaust ventilation in facilities often appears to be a retrofitting exercise by various local companies prompted when there are worker complaints, suggesting that emission control is not adequately addressed in the design stage. Although the presence of unventilated vapors has often been described in the literature as early as 1944[4] and

continues even in 2016,[14] the number of scientific reports that have addressed this specific issue is very limited. This issue needs to be taken up by the industry, since primary prevention remains the key to addressing respiratory allergy and asthma in seafood processing environments.

Recommendations from IFISH5 participants

From the available information as reported in the literature and presented in the session, it is the view of the session participants that the current knowledge and understanding of the impacts of seafood bioaerosols and respiratory health effects on workers is sufficient to:

- Recommend aerosols from any seafood processing activity involving machinery, water sprays, or cooking be reduced by enclosure and local exhaust ventilation independent of the seafood species being processed, and include verification that controls have effectively reduced the exposures.
- Emphasize that measures to reduce bioaerosol levels are particularly important aboard factory vessels. Retrofitting machinery designed for factories into ships is suboptimal due to the spatial constraints resulting in poor ergonomics contributing to musculoskeletal problems as well as poor ventilation and higher aerosol levels, which increases the risk of adverse respiratory health effects.
- Suggest that local exhaust ventilation of machines used in seafood processing should be subject to standardization and international recommendations. Producers of machinery should be encouraged to develop specifications for stationing of processing machinery in fishing vessels and factories and specify appropriate ventilation systems that are coupled to these equipment.
- Require that ventilation systems be regularly monitored to ensure that they are cleaned, working optimally and are effective in controlling exposures.
- Demonstrate that non-allergic airway reactions in seafood processing environments are common and that confirmation of the presence of allergic sensitization is not always necessary to justify instituting preventive actions.
- Recommend that safety and health researchers and practitioners engage with manufacturers to design new production facilities with appropriate appraisal of past knowledge and experience of occupational exposures in similar production facilities elsewhere.
- Demonstrate that knowledge on the health risks to workers in the seafood industry is poorly communicated by the research community to the industry, as are the solutions developed between companies and factories within the industry, despite the international nature of the industry.
- Recommend that health and safety information be distributed much more effectively to management and workers through national and international organizations. This is to ensure that injury and disease prevention in general and exposure to gases and bioaerosols is reduced not only aboard vessels but also on land-based facilities. Furthermore, the focus must not only be on established local fishing communities but include im/migrant and unskilled seasonal workers across the globe.

In some areas there is a need for further research into bioaerosol exposures and respiratory health effects. In particular the IFISH5 conference highlighted:

- There are few studies from Asia, where the majority of the world's seafood is processed. More studies from this region are needed to enhance our knowledge and understanding. Similarly there is a need to focus more on the im/migrant workforce.
- There is a paucity of longitudinal studies and in particular follow up intervention studies such as the impact of ventilation systems on bioaerosol exposures. Further studies should confirm whether exposure levels are lower aboard newer factory vessels than older ones. Should this be the case, the industry should communicate solutions that led to improvements in these working conditions. It is suggested that manufacturers of seafood

processing machinery be involved in these studies where appropriate.

- Allergy often underlies the symptoms and clinical manifestations of affected workers as new important allergens continue to be identified in the domestic setting. The search for clinically relevant allergens in the occupational context is still needed to better understand the dose-response relationships for allergic sensitization and respiratory disease.
- Since allergens are not solely responsible for these airway reactions, future research should assess exposure to a broader range of bioaerosols and gasses, including but not limited to endotoxins, trypsins, total protein levels, cleaning/sanitation agents, and hydrogen sulphide and with further focus on the combined effects of these exposures. It is important that future studies utilize more developed contemporary methods to characterize workplace exposures to better evaluate the extent of exposure to other bioaerosol components (e.g., Gram-positive bacteria, fungi, or β-glucans) that have historically been less well studied than endotoxins or allergens, as these may also contribute to adverse respiratory health effects.[27]
- In cases where allergic reactions in exposed workers are suspected in symptomatic workers and require further investigation, the simplest method is generally using the SPT. Should access to standardized testing be limited or specific IgE tests for local products not available, local unstandardized products are often used in SPT. Considering the high risk of false positive and false negative results, this is not advisable unless the limitations of such "home-made" extracts are well understood and the results interpreted with caution. There is, therefore, an urgent need for a wider range of improved standardized reagents/extracts for clinically evaluating seafood allergies.
- In contexts where specific allergens are suspected, detection of these allergens in the work environment remains costly and difficult, highlighting the need for improved methods with rapid detection of a wider range of allergens. Research that compares conventional enzyme-linked immunosorbent assays with lateral-flow immunochromatographic assays and mass spectrometry, and that investigate the value of multiplex approaches based on polymerase chain reaction and nanosensor technologies is therefore needed. In occupational seafood allergy research, there is a strong need for assays to be developed that can be distributed and used in remote settings.
- The large proportion of im/migrant workers in the industry are vulnerable and difficult to reach in implementing improved preventive measures, as they are temporary workers often with limited language skills and limited health insurance. Furthermore, these workers are difficult to study and are easily replaced by companies, often producing research findings that underestimate their health risks. Furthermore, these workers may react differently to certain seafood exposures, as they are often naïve to these exposures, in contrast to the local workforce living in villages where the seafood has traditionally been caught, processed, and consumed. International cooperation is needed to better understand the health risks of these workers as this has become a global phenomenon.

Conclusion

Presentations at the IFISH5 conference confirmed that airway disease caused by exposure to seafood allergens and other bioaerosol components and precarious conditions of im/migrant workers continue to be important issues for the seafood industry, making key messages from previous reviews still relevant. It is important to minimize aerosol and seafood allergen levels, including other related bioaerosol constituents and components of bacterial and fungal origin. In seafood processing facilities, this can be done through improvements in extraction ventilation systems, machinery performance (fixing old machinery), by reducing water spray and aerosolization, enclosure of the source, and by optimal organization of the total workspace and the work itself. Presentations at the conference also demonstrated progress in analytical methods used in allergen exposure assessment, determining dose-response relationships for fish allergens, and identifying new allergens,. For workers with occupational asthma in the presence of sensitization, changing

jobs to one without exposure to the allergen or transfer to a job outside the seafood industry is recommended, should this be possible. For workers with respiratory symptoms that are not (yet) sensitized, personal respiratory protective equipment may be used as a short-term temporary measure, or for performing special operations, until an improved work environment is achieved that allows them to work without respiratory protection. Im/migrant workers with occupational allergy or asthma are more likely to be affected. Therefore, when initiating preventive measures in the industry, care should be taken to identify and support im/migrant workers to ensure they also benefit from these improvements, rather than face the risk of losing their jobs. The means for achieving these improvements are widely available, and dissemination of such tools should be strengthened through international collaboration. The medical and scientific community has an important role to play, but cannot do this in isolation and should cooperate closely with hygienists, engineers, and national and international agencies, including policy makers, to obtain better outcomes for workers in the seafood industry.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.

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