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Exposure to flour dust in the occupational environment

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Exposure to flour dust can be found in the food industry and animal feed production. It may result in various adverse health outcomes from conjunctivitis to baker's asthma. In this paper, flour dust exposure in the above-mentioned occupational environments is characterized and its health effects are discussed. A peer-reviewed literature search was carried out and all available published materials were included if they provided information on the above-mentioned elements. The hitherto conducted studies show that different components of flour dust like enzymes, proteins and baker's additives can cause both non-allergic and allergic reactions among exposed workers. Moreover, the problem of exposure to cereal allergens present in flour dust can also be a concern for bakers' family members. Appreciating the importance of all these issues, the exposure assessment methods, hygienic standards and preventive measures are also addressed in this paper.

Keywords: flour dust; flour allergens; wheat proteins; baker's asthma; exposure assessment

1. Introduction

The American Conference of Governmental Industrial Hygienists (ACGIH) defines 'flour' as a complex organic dust containing cereals like wheat (*Triticum* sp.), rye (*Secale cereale*), sorghum (*Panicum miliaceum*), barley (*Hordeum vulgare*), oats (*Avena sativa*), rice (*Oryza sativa*) or corn (maize) (*Zea mays*), or a combination of these, which have been processed by milling.[1] Whereas the term 'flour dust' refers to particles coming from finely milled cereal or non-cereal grains, 'grain dust' consists of particles produced during grain harvesting and handling, excluding milling. Flour dust usually contains various components which play an important role in dough improvement, such as a variety of enzymes (α -amylase, cellulase, hemicellulase, malt enzymes, xylanase, protease, lipase, glucoamylase, glucose oxidase, lipoxygenase), additives (baker's yeasts, egg powder, milk powder, sugar), flavorings, spices, chemical ingredients (preservatives, antioxidants, bleaching agents) but may also comprise of storage-related contaminants, such as microbes or mites. Grain dust may contain dry plant particles (non-grain plant matter) such as fungi (mainly from *Fusarium*, *Aspergillus*, *Cladosporium* and *Alternaria* genera) with their mycotoxins, bacteria with their fragments (including endotoxins) and excretions (proteolytic enzymes), mites, insects, rodent excrements, sand and residues of pesticides. As grain dust has different health effects from flour dust, it will not be included in this paper.

2. Biological and physical characteristics of flour dust

In terms of biological activity, cereals belonging to the family *Poaceae* are the most important. While particles derived from wheat (*Triticum* sp.), barley (*Hordeum* sp.), rye (*Secale cereale*) and oats (*Avena sativa*) have high allergenic potency, the flour dust coming from corn (*Zea mays*) is much less reactive.[2] Important flour dust sensitizers, however, derive also from non-cereal grains such as soy (*Glycine hispida*), buckwheat (*Fagopyrum esculentum*) and peas (*Pisum sativum*). The main cereal grain used in the bakery industry is wheat. The wheat seed is composed of endosperm (80–85%), husk and germ. During the milling process, the endosperm is separated from husk and germ and reduced to small ($\leq 6 \mu\text{m}$) particles.[3] Wheat flour contains starch and four groups of proteins: glutelins (glutenins), water-soluble albumins, prolamins (gliadins) and globulins. Glutenins and gliadins form complexes called gluten. Albumins and globulins have shown the strongest allergic potency among wheat proteins, but allergic potency of globulins, prolamins and glutelins should be considered in occupational risk assessment as well.[4] According to Sander et al.,[5] wheat flour contains 40 allergens at least, which can cause adverse health effects in exposed workers. Proteins with potential allergenic activities represent about 10–15% of wheat grain dry weight. Wheat protein allergens have a mass of about 12–17 kDa, but the mass of their major types belonging

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to the α -amylase/trypsin inhibitor family varies between 12 and 15 kDa.[6,7] The fungal α -amylase (FAA; naturally present in small amounts, 0.1–1 mg/g flour, in wheat or derived from *Aspergillus oryzae* or *Aspergillus niger*, being usually added to improve baking characteristics), thioredoxin, plant lipid transfer protein, serine proteinase inhibitor, thaumatin-like protein, acyl-coenzyme A (CoA) oxidase, fructose-bisphosphate aldolase, glycoprotein with peroxidase activity, triose-phosphate isomerase and prolamins are the main factors associated with asthma among bakers and other workers exposed to baking flour.[5,8–11] Allergenic activity of purified enzymes was proved by both *in vitro* [12] and *in vivo* experiments, however, it was not dependent on cereal species. Allergens from different cereals can demonstrate chemical and functional similarities, which may end up in allergic cross-reactivity. Its degree is closely related to their taxonomic affinity and appeared to decrease in the following order: wheat, triticale, rye, barley, oats, rice and corn.

The aerodynamic sizes of flour dust particles vary between ≤ 4 and $30 \mu\text{m}$ (the biggest particles are usually formed as agglomerates of smaller ones).[13,14] Their kinetics in the lungs follows the pattern of other particulate aerosols of a similar type and their deposition within the respiratory tract is determined by the particle size, shape, density as well as by the respiration volume. According to Lillienberg and Brisman,[13] flour dust has a bimodal distribution reaching its peaks around 5 and $15\text{--}30 \mu\text{m}$ for fine and coarse dust particles, respectively. More than 50% of the airborne flour dust particle mass has an aerodynamic diameter over $15 \mu\text{m}$; however, in dusty areas up to 20% of these particles have smaller aerodynamic sizes characteristic of respirable fraction $\leq 4 \mu\text{m}$. [15] Most particles greater than $10 \mu\text{m}$, and up to 80% of particles between 5 and $10 \mu\text{m}$, are trapped in the nasopharyngeal region due to inertial impaction and centrifugal condensation resulting from the anatomic formation of these parts of the respiratory tract (the airstream has the highest velocity here). Particles trapped and deposited in the upper parts of the respiratory tract are usually removed within a few hours by the mucociliary system or as a result of expectoration. Massive exposure may lower the ability of macrophages to eliminate particles, which may result in penetration of dust into the interstitium.[15,16] Particles with diameters above $0.5 \mu\text{m}$ are deposited by sedimentation and impaction, which take place in bronchi, bronchioles and alveoli, where the air velocity is low and the probability of deposition is directly proportional to the residence time. Particles deposited in the lower respiratory tract, where ciliated epithelium is not present, are removed much slower, i.e., from several dozen to several hundred days.[16]

The type of interactions between the bioaerosol particles and human cells depends on the place of their deposition and is conditioned by their retention time in the respiratory tract. Inhaled particles with aerodynamic diameters equal or above $10 \mu\text{m}$ cause eye or nose irritations.

Particles with sizes between 5 and $10 \mu\text{m}$ may provoke asthmatic reactions. Particles below $5 \mu\text{m}$ may evoke an *allergic alveolitis* type of reaction.[17] The experiments carried out by Houba et al. [18] revealed that α -amylase, one of the major flour dust sensitizers, is usually present in particles with aerodynamic diameters above $9 \mu\text{m}$.

3. Health effects

Three groups of workers have an increased risk of adverse health effect appearance when exposed to flour dust: (a) workers with a flour sensitization after repeated exposure to low levels of flour dust; (b) workers with an atopic status or an allergic constitution; and (c) workers with pre-existing asthma or those with more general respiratory symptoms. Epidemiological reports have showed that asthma, conjunctivitis, rhinitis and dermal reactions are the major health effects of flour dust exposure. From among these outcomes, baker's asthma is the most severe and frequent manifestation of occupational allergy.[19,20] In Poland, occupational asthma was diagnosed among 44.5% of bakers reporting respiratory symptoms at the workplace.[21] Baker's asthma represents approximately 20% of all occupational asthma cases in France.[22] In the UK and Norway, exposure to grain and flour dust is the second commonest reported cause of this type of occupational disease.[23,24]

Baker's asthma results from immunological sensitization following allergic reactions to specific occupational airborne allergens. According to Baatjies and Jeebhay [25] and Baur et al.,[26] the prevalence of sensitization to wheat flour allergens (WFAs), α -amylase and flour contaminants derived from storage mites (*Acarus siro*, *Glycyphagus domesticus*, *Lepidoglyphus destructor*, *Tyrophagus longior*, *T. putrescentiae*) among bakery workers varies from 5% to 28%, 2% to 32% and 11% to 33%, respectively. Other authors reported sensitization to several *Aspergillus*-derived enzymes with prevalence of 8%, 11% and 13% for glucoamylase, xylanase and cellulase, respectively.[27] It should be clearly stated, however, that both the absence of standardized extracts of flour dust allergens and the use of different methods for skin prick testing may hamper direct comparison of the study results. The process leading to the development of baker's asthma is not entirely understood. The investigation carried out by Pavlovic et al. [28] revealed the presence of atopy among 18% of bakers. A symptomatic sensitization to flour and other bakery ingredients appears relatively quick, i.e., within the first year of exposure, while mean latency periods for work-related cough or dyspnea are 4.3 and 17.6 years, respectively.[29] One of the primary mechanisms is immunoglobulin E (IgE) immediate hypersensitivity reaction, generally developing shortly after exposure to the antigen, which can be evidenced by positive skin tests or serum radioimmunoassay tests.[30] Sander et al. [5] investigated the variability of IgE antibody patterns among wheat flour-sensitized bakers

and identified the most frequently recognized WFAs using an immunoblotting technique. As it was shown in that study, each patient had an individual IgE-binding pattern with 4–50 different protein spots in the immunoblots. There was also a big interindividual variation of IgE-binding patterns of wheat flour proteins. Sutton et al. [31] analyzing sera of most sensitized bakers found that IgE antibodies reacted with several flour allergens; however, individual reaction profiles showed large variability. Genetic factors seem to be also important in the development of work-related respiratory symptoms and sensitization to wheat flour dust. Data obtained in the study among Korean bakers revealed that Toll-like receptor 4 (TLR4) and β 2-adrenergic receptor gene polymorphisms may be involved in allergic sensitization to flour dust and contribute to the development of baker's asthma.[32]

Conjunctivitis (red, inflamed, itching eyes) and rhinitis (frequent sneezing, rhinorrhea and nasal obstruction) are less severe types of allergy to flour dust. These symptoms can be induced either immunologically (allergic reaction mostly mediated by IgE-type antibodies) or by non-specific irritation. Symptoms induced by irritation are reversible, whereas immunologically induced sensitization is persistent, even after cessation of occupational exposure to flour dusts. According to Page et al.,[19] rhinitis is common among bakers and usually precedes asthma. In several studies, the authors have found positive relationships between the risk of rhinitis and the flour dust exposure level.[33–36] Moreover, as it was shown in an Italian study among bakers and pastry makers, skin sensitization was significantly associated with atopy, cigarette smoking and work seniority. Age and gender have not been reported to be determinants of sensitization of this type.[37]

Different types of contact dermatitis (i.e., irritant, allergic) among bakery workers have been reported by many authors from the beginning of this century and all those occupational skin diseases are still a serious problem in the working environment. There are a variety of agents that have been identified as potential dermal sensitizers and allergens, including cereal flour, dough improvers like FAA, cellulase and xylanase enzymes, cinnamon oil/cinnamic aldehyde, certain emulsifiers, baker's yeast, bleaching agents (benzoyl peroxide) and antioxidants (propyl gallate). As studies show, sensitization to FAA among bakers and millers is usually more common than sensitization to flour dust.[38,39] According to Morren et al.,[40] among bakers exposed to FAA, 22% had an immediate wheal-and-flare reaction and 6% also delayed eczematous reaction. Even in high dilutions, α -amylase powder still gave strong reactions in the prick test.

Although first studies suggesting that workers in bakeries have higher risks of developing nasal or other respiratory tract cancers were published in the early 1980s,[41] the evidence for a biological relationship between nasal cancer and inhalation of flour dust still

remains inconclusive. According to Laakkonen et al.,[42] an exposure to organic dusts is unlikely to be a major risk factor of respiratory cancer. No associations were seen between exposure to flour dust and laryngeal [43] or lung cancers.[42] A recent SYNERGY study among bakers, pastry cooks and confectionary makers from 16 countries did not suggest an increase of lung cancer risks in baking-related professions as well.[44] On the other hand, suggestive evidence was found that exposure to grain dust among millers may increase the risk of laryngeal cancer.[42] In a French case-control study comprising 207 cases and 409 controls, significant excesses in risk of squamous nasal cell cancer were noted for bakers, pastry cooks and grain millers.[45] In both Swedish and Danish cohort studies, more nasal cancers and significantly increased mortality rates for cancer of the respiratory tract were observed among bakers and pastry makers, especially among those working in small plants.[46,47] An occupational basis for the origin of nose and paranasal sinuses squamous carcinoma has been also suggested.[48]

Exposure to flour dust can also lead to pathological abrasion of hard teeth tissues. The dust adhering to the teeth surface and gum edge creates a specific coating, which causes hard tooth tissue earlier abrasion. The results of Bachanek et al.'s [49] study showed that teeth abrasion was present in about 94% of flour mill workers and the most frequently damaged teeth were maxilla (20%) and mandible (41%) incisors.

4. Occupational exposures to flour dust

Cereal flour is one of the basic materials used in the food industry and animal feed production. Taking into account the character of occupational activities in those branches, the most severe exposure to flour dust is usually observed in bakeries and grain mills. A significant exposure to flour dust occurs also in pasta factories, pizza bakeries, confectionery (cake and cookie factories), restaurant kitchens, malt factories, animal feed plants and in agriculture.

The level of exposure is conditioned by the size of the production enterprise and varied depending on the working area within the factory grounds. In baking and milling industries, the observed concentrations of total flour dust varied from a few up to more than 400 mg/m³ in the case of peak exposure.[34,50–54] According to Bachmann and Myers,[54] average total dust concentrations among South African milling workers fluctuated from 1.3 mg/m³ for millers, through 3.5 mg/m³ for cleaners, sweepers and bag handlers, to 17.6 mg/m³ for shovel workers and grain packers. Similar average concentration levels were obtained by Kakooei and Marioryad [55] among Iranian flour mill workers reaching 11.1, 12.6, 16, 11.4 and 9.5 mg/m³ of total dust for millers, packers, sweepers, sift and washing operators, respectively. Awad el Karim et al. [56] noticed average total dust concentrations of 1.4, 1.6, 2.2, 2.7, 3.5 and 3.6 mg/m³ in wheat store, packing, rollers,

wheat cleaning, sacks and plan sifter rooms, respectively. According to Talini et al., [57] the highest total dust concentrations of 0.4, 5.8, 6.9 and 8.7 mg/m³ were noticed at flour mill, grain cleaning, packing and unloading areas, respectively. However, the maximal concentrations of respirable dust at some workplaces in flour mills can even reach 160 mg/m³. [53]

In both small- and large-scale bakeries, exposure levels have been found to be the highest during mixing and baking stages; however, in larger bakeries additionally during receipt and opening of flour containers. [58] Elms et al. [59] studying work conditions in UK bakeries observed differences in the concentrations of inhalable dust exposure. The highest dustiness levels were observed in large size bakeries (with median dust concentrations of 7.6 mg/m³) followed by medium (5.2 mg/m³) and small-micro size plants (2.2–3 mg/m³). The same situation is true in the case of α -amylase for which exposure in large industrialized bakeries was higher than in small traditional bakeries. [18] The most severe conditions are usually observed during dispensing, mixing or dough-making tasks. The concentrations for total dust and its inhalable fraction range from 0.4 to 86 mg/m³ and from 0.4 to 37.7 mg/m³, respectively. [8,11,13,18,50,60–67] The tasks performed by oven workers also involve risk of exposure to high concentrations of both inhalable (0.1–8.7 mg/m³) and total flour dust particles (0.1–37.6 mg/m³). [11,13,14,18,57,60,68] In a pasta manufacturing plant, the highest flour dust concentrations of 13, 3.1 and 0.2 mg/m³ for inhaled, thoracic and respirable fractions, respectively, were observed during dough kneading on the manual production line. [69] The concentrations of α -amylase in the air of crisp bread bakeries can reach 229.3 ng/m³. [18] Airborne concentrations of cellulose and xylanase in flour mills and crisp bread factories can approach 180 and 200 ng/m³, respectively; however, according to Vanhanen et al., such high concentrations of xylanase are associated with natural xylanase activity of wheat. [8,70]

Exposures to high concentrations of flour dust are frequently observed; however, they usually have a short-term character and the duration of peak concentrations (2–6 peaks/h on average) usually takes from 30 s to 4 min. Lilienberg and Brisman [71] examined the occupational peak exposure for dough makers and bread formers. From among different activities, dough mixing as well as tipping and manual handling of flour were the dustiest tasks. Cleaning the bins in bakeries and maintenance cleaning in mills have given peak values (total flour dust) of 390 and 458 mg/m³, respectively. [34] Meijster et al. [72] studying exposure to total dust in industrial and traditional bakeries, factories producing ingredients for the baking industry (i.e., pre-mixes based on flour or other bulk and specialized additive mixtures for bread or pastry) and flour mills recorded the maximal concentrations on the extremely

high levels reaching 292, 318, 627 and even 1837 mg/m³, respectively.

Mounier-Geysant et al. [73] suggest that concentration of flour dust may depend on season being greater in winter than in summer. Average personal exposure of bakery and pastry apprentices to 2.5 μ m particulate matter (PM_{2.5}) were 0.71 and 0.35 mg/m³ as well as 0.5 and 0.29 mg/m³ in winter as well as summer seasons, respectively. The same trend was noted for personal exposure of workers to PM₁₀ (1.1 and 0.47 mg/m³ as well as 0.63 and 0.44 mg/m³ in winter as well as in summer, respectively).

The risk of adverse health outcome occurrence is closely related to the flour dust exposure levels. [14] DeMers and Orris [74] showed that US bakers appeared to have markedly higher mortality rates than expected, suffering from the typical asthma-like symptoms, such as cough, wheezing and shortness of breath. Such effects were observed among bakery workers exposed to flour dust concentrations between 2 and 5 mg/m³, but they may also occur at lower levels. According to the Dutch Expert Committee on Occupational Standards (DECOS), [75] an additional sensitization risk for wheat and other cereal flours (expressed as 8-h time-weighted concentration) is equal to 0.1%, 1% and 10% for an occupational exposure to 0.012, 0.12 and 1.2 mg/m³ of inhalable dust, respectively. The Swedish investigations carried out among bakers showed significant relationships between the risk for asthma and rhinitis and dust concentrations (of 3 and 1 mg/m³, respectively). [33] Studies by Houba et al. [64,76] revealed that there is a statistically significant relationship between inhalable dust fraction and wheat allergen exposures and the risk of sensitization among bakery workers. The increased risk of sensitization is visible at wheat flour dust concentration of 2 mg/m³. Sensitization is still prevalent when flour dust concentrations reached 1 mg/m³ and its reduction to the negligible level is achieved when the concentrations of inhalable dust and wheat allergens are reduced to 0.5 mg/m³ and 0.2 μ g/m³, respectively.

A recent study by Tagiyeva et al. [77] showed that the problem of exposure to cereal allergens derived from flour dust concerns not only workers but their family members as well. In a situation of such para-occupational exposure, family members are exposed to sensitizers, which are 'taken home' by bakers on contaminated skin and clothes. A high exposure to WFA and FAA resulted in allergic sensitization which was noticed when bakers wore, changed or cleaned working clothes and shoes inside their living places. It was also shown that wheezing symptoms and asthma were more prevalent among children whose fathers were occupationally exposed to flour dust. The study by Tagiyeva et al. included also the workplace evaluation as well as bakers' vehicles and homes demonstrating that after routine hygiene measures bakers leave workplaces with WFA and FAA on their hands, forehead and shoes. All these allergens are also present in their cars, which

prove that contaminants from work sources are transferred into the home environment and may be responsible for asthma episodes among family members. Potential sensitization of bakers' family members due to α -amylase associated clothes, shoes and other bakery textiles has been also reported by Vissers et al.[78]

5. Exposure assessment methods

Quantitative characterization of flour dust and allergens is usually done based on air or settled dust sampling. If their concentrations are established based on measurements of PM_{2.5} or PM₁₀ fractions, a gravimetric analysis according to Standard No. EN 12341:2014 may be used as a reference method.[79] As different filters (e.g., Teflon, PVC, glass) and samplers (e.g., ChemPass, IOM, MAS-100 NT, Millipore cassette, PAS6) are usually used for flour dust sampling, a detailed interpretation and comparison of measurement results is difficult. For example, there is a linear correlation between the IOM sampler and the traditional Millipore cassette; however, the IOM collects almost twice as much flour dust as the conventional total dust sampler. Personal sampling should generally be considered as it measures direct workers' exposure. Stationary sampling gives usually lower dust concentrations than the personal approach and rather reflects the general area situation.[13] As it was earlier mentioned, exposures to high concentrations of flour dust in the bakery industry are frequent but have a short-term character. The peak exposures are strictly related to work activities and as such may be essential in the progress of sensitization.[18,71] As flour dust concentrations vary considerably, the exposure assessment in this type of occupational environment should have an individual character.[55] Due to this fact, personal air monitoring should take place during the whole working period (8-h time weight average, TWA).

As opposed to allergen levels, monitoring of flour dust has certain limitations due to the fact that its level may only partially correlate with the actual allergen concentrations. Studies show that the correlation between concentrations of flour dust and wheat allergen is moderate at best or poor for FAA.[25] For aeroallergen monitoring, a simple and reliable analytical technique is indispensable. At present, airborne dust sampling on a filter, with its subsequent elution and measurement of allergen concentration in the eluate by specific immunoassays is the most commonly used method. There are a few methods evaluating allergen content in flour dust. These immunoassays measure allergen levels in samples using antibodies. One of them is enzyme-linked immuno-sorbent assay (ELISA), in which allergens bind to specific antibodies (anti-wheat IgG4 serum pool from bakery workers).[80] Another one, developed by Sandiford et al.,[81] is a method for measuring airborne WFAs using polyclonal rabbit IgG antibodies in a radio-allergo-sorbent-test (RAST). Bogdanovic et al.[82] described the sandwich enzyme immunoassay method

with affinity-purified polyclonal rabbit IgG antibodies for measurement of α -amylase allergens. ELISA has replaced RAST in many laboratories, as it offers comparable sensitivity without the problems of the short half-life associated with radioactive materials. The antibodies used in the tests may be derived from pooled sera from sensitized patients or from experimentally sensitized animals. The latter can be either polyclonal antibodies that recognize a range of epitopes, or monoclonal antibodies, consisting of one clone of a specific antibody. However, the high specificity of a monoclonal antibody-based ELISA – depending on the recognition of a single epitope – could also be a disadvantage of such method. If in flour dust mixtures, the epitope is masked, the actual allergen exposure level may be underestimated. The ELISA method combines a high sensitivity with high specificity with avoiding the risk of false-negative results associated with the use of monoclonal antibodies. There are several advantages of using polyclonal antibodies, i.e., the polyclonal method is technically easier, cheaper, less disturbed by epitope losses and can be made very sensitive (several allergens may be present and detected).[83,84] Polyclonal techniques may be considered for routine monitoring, as they measure the total spectrum of allergens in wheat flour; however, when a precise assessment of specific allergen (e.g., α -amylase) is necessary, a more specific method using monoclonal antibodies should be considered.[85]

6. Hygienic standards and threshold limit values

Epidemiological studies focusing on dose–response relationships as well as personal exposure to inhalable flour dust, wheat and α -amylase allergens in flour mills and bakeries have been widely analyzed. So far, there is no evidence for establishing threshold limit values (TLVs) for flour dust characterizing sensitization of exposed individuals, which is needed to identify a no-observed adverse effect level (NOAEL). A retrospective study suggests that the risk of developing nasal symptoms starts to increase at flour dust concentrations of 1 mg/m³, while the risk of asthma increases at the level above 3 mg/m³. [86] The Scientific Committee on Occupational Exposure Limit Values (SCOEL) suggests that exposure \leq 1 mg/m³ of inhalable flour dust would protect the majority of exposed workers from the onset of disease and the envisaged symptoms would be mild. However, concentrations of < 1 mg/m³ may trigger symptoms in already sensitized workers.[87] Several studies clearly show that complete protection against sensitization to airborne flour dust allergens at low exposure levels is difficult to achieve. In Sweden, a recommended limit value for flour dust exposure is 3 mg/m³ (8-h TWA). The remaining Nordic countries (i.e., Finland, Iceland and Norway) have set their exposure limit at 5 mg/m³ for organic dust.[1] In the UK, a maximal exposure level is equal to 10 mg/m³ (8-h TWA) and 30 mg/m³ (15-min TWA). ACGIH recommends a TLV for inhalable

flour dust of 0.5 mg/m^3 (8-h TWA). In some Canadian provinces, flour dust with the exposure limits of 10 and 5 mg/m^3 for total and respirable dust, respectively, have been established.[1] In Germany and Denmark, occupational exposure limits (OELs) for flour dust have been set at 4 and 3 mg/m^3 , respectively. Maximum exposure limit (MEL) for flour dust in Greece is 10 and 5 mg/m^3 for inspirable and respirable fractions, respectively.[58] In Poland, there is no TLV for flour dust, but there exist the highest acceptable values for organic (animal and plant) dusts. These values are equal to 2 mg/m^3 for thoracic and 1 mg/m^3 for respirable fractions in the case that dust contains 10% or more of crystalline silica as well as 4 mg/m^3 for thoracic and 2 mg/m^3 for respirable fractions in the case that dust contains less than 10% of crystalline silica. Due to the fact that the OEL protecting all workers cannot be identified, the proper preventive measures, good manufacturing practices and efficient health surveillance systems should be introduced in bakeries and other environments contaminated with flour dust.

7. Preventive measures

The best method of preventing adverse health outcomes would be to provide a working environment free from the hazards. While it is not usually possible to eliminate completely the risk caused by biological agents, its reduction to the lowest level should be established as an ultimate target. To reach that goal, the collective prevention measures based on the STOP principle may be used. This prevention strategy combines four elements, i.e., systemic (S), technical (T), organizational (O) and personal (P) measures.[88–90] Systemic measures may include procedural risk control by designing suitable systems of work and maintaining plant and equipment in safe and hygienic conditions (e.g., cleaning of workplaces must be considered an integral part of operations and it should be carried out properly in order to minimize flour dust generation, workplaces should be designed with easy-to-clean surfaces, storage places for private and working clothing should be separated; regular cleaning and changing of working and protective clothes should be scheduled; facilities to wash hands (or take a shower) when leaving the workplace should be provided; eating, drinking or smoking at the workplace should be avoided, etc.). Technical measures may cover minimization of the release of flour dust (e.g., fast delivery, short storage times or immediate processing of critical materials), machinery guarding/fencing/shielding and other equipment to reduce dust emissions, avoidance of manual processing and controlled atmosphere in workplaces with air filtration or air conditioning. Organizational measures may be achieved by isolation of workstations (e.g., automatically closing doors, sluice), restriction of entrance to areas with high contamination levels to an operational minimum number of workers, workers' information

and training to promote safe working habits, medical surveillance (preventive medical check-ups, monitoring of exposure and record-keeping); proper labeling, safe storage, procedures for safe transfer, handling, use and disposal of materials being used, etc. Personal measures may focus on respiratory protection, personal protective equipment (clothes, gloves and goggles; however, such equipment should be used as the last possible prevention measure only when eliminating or reducing the level of risk to an acceptable level is not possible).

The basis for the preventive measures for bakers is an involvement and cooperation between an occupational hygiene consultant and a specialist of occupational medicine.[58] The main goal of medical surveillance in such cases is prevention of adverse health outcomes by lung function monitoring (spirometry, methacholine challenge test) and allergy tests (skin prick tests, measurement of specific IgE antibodies).[86] DECOS recommends to control both FEV_1 (volume that has been exhaled at the end of the first second of forced expiration) and FVC (the vital capacity from a maximally forced expiratory effort) lung function parameters when an exposure to flour dust is expected and/or should be assessed. As a part of medical surveillance, an individual case health management should also be introduced among bakery workers.[25] For example, bakers with rhinitis and sensitization to flour or FAA should be identified and relocated to working areas with less exposure. Sensitization to flour or FAA among bakers (with no respiratory symptoms) suggests their annual re-examination. Allergen-specific immunotherapy and other immunomodulatory treatments, such as anti-IgE monoclonal antibodies (omalizumab) may solve some of such health problems and benefit the patients, especially those with uncontrolled severe baker's asthma.[10] Due to the fact that atopy is an important risk factor for developing baker's allergy, the identification and exclusion of atopic workers may be also one of the possible strategies for prevention.[91] A surveillance program carried out by Meijer et al. [92] demonstrated that the use of a simple questionnaire model can help to predict the probability of flour sensitization and work-related allergy among bakers or, at least, accurately detect individuals with an elevated risk of such adverse health outcomes. As it was shown, 90% of bakery workers with asthma could be effectively identified in this way. Hence, this method might be considered and incorporated into the already existing medical surveillance systems reducing the level of healthcare expenditures.

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