

The General Directorate

Maisons-Alfort, 19 October 2016

Revised OPINION **of the French Agency for Food, Environmental** **and Occupational Health & Safety**

on mould in buildings
 Cancels and replaces the previous opinion of 20 June 2016

ANSES undertakes independent and pluralistic scientific expert assessments.
ANSES's public health mission involves ensuring environmental, occupational and food safety as well as assessing the potential health risks they may entail.
It also contributes to the protection of the health and welfare of animals, the protection of plant health and the evaluation of the nutritional characteristics of food.
It provides the competent authorities with the necessary information concerning these risks as well as the requisite expertise and technical support for drafting legislative and statutory provisions and implementing risk management strategies (Article L.1313-1 of the French Public Health Code).
Its opinions are made public.
This opinion is a translation of the original French version. In the event of any discrepancy or ambiguity the French language text dated 20 June 2016 shall prevail.

On 14 January 2014, ANSES received a formal request from the Directorate General for Health (DGS) and the Directorate General for Risk Prevention (DGPR) on the issue of mould development and the associated production of mycotoxins in buildings.

1. BACKGROUND AND PURPOSE OF THE REQUEST

In the last few years, increasing attention has been paid to the issue of indoor air quality with, in particular, the establishment of monitoring that is gradually becoming mandatory in certain establishments open to the public.

During the second National Conference on Air Quality in October 2013, the Ministries in charge of Ecology and Health launched the Action Plan on Indoor Air Quality. Reflecting the concerns expressed during the Environmental Health round table at the Environmental Conference of September 2012, this plan provides for short-, medium- and long-term actions to improve indoor air quality. These were incorporated in the third National Environmental Health Action Plan (PNSE 3) and constitute the indoor air component, following on from the previous National Environmental Health Action Plans (PNSE 2004-2008 and 2009-2013).

In this framework, ANSES was asked to conduct a review of knowledge on exposure of the population to mould present in indoor air. The request focuses especially on the following four themes:

- Knowledge of the health effects associated with mould;
- Review of methods for measuring mould in indoor air, dust deposited on the ground and materials;

- Assessment of the buildings concerned (building type, number, parameters of mould development, etc.);
- Assessment of exposed and/or at-risk populations (prevalence, qualitative assessment of exposure, vulnerable populations).

The problem of mould in buildings is broad and can be understood from different perspectives depending on the type of "building", the type of "population" (children, the elderly, etc.), the geographic area or the socio-economic context.

In order to define the scope of the expert appraisal, the DGS and the DGPR were asked to express their priorities.

As a result of this, the expert appraisal focused on housing, firstly because of the time spent inside it and secondly, due to the availability of contamination data (campaign by the Indoor Air Quality Observatory (OQAI)). In second place, consideration was to be given to establishments open to the public (EOPs) covered by monitoring of indoor air quality, with priority given to those hosting children and to educational institutions (EOPs referred to in Paragraphs 1, 2 and 3 of R. 221-30 of the French Environmental Code). Other EOPs covered by the monitoring scheme could then be studied.

The goal of the expert appraisal was to conduct an overall review of all buildings concerned, not restricted to derelict housing or economically vulnerable people. The request concerns France as a whole, but priority in this expert appraisal was given to mainland France. Due to the type of housing and the fungus-related issues involved, the situation in the overseas territories will be examined in a specific expert appraisal at a later date.

While the request specifically targeted the risks associated with exposure of the general population, the review of the health effects associated with mould nevertheless took into consideration the diseases associated with exposure in the occupational framework.

2. ORGANISATION OF THE EXPERT APPRAISAL

The expert appraisal was carried out in accordance with French Standard NF X 50-110 "Quality in Expert Appraisals – General Requirements of Competence for Expert Appraisals (May 2003)".

It falls within the sphere of competence of the Expert Committee on Assessment of the risks related to air environments (CES Air). ANSES entrusted the expert appraisal to a dedicated working group. The methodological and scientific aspects of the work were presented to the CES between February 2014 and April 2016. The work was adopted by the CES on Assessment of the risks related to air environments at its meeting on 14 April 2016.

The expert appraisal work drew on a synthesis and critical analysis of the data published in the literature (scientific articles, institutional reports, measurement standards).

The collection of information needed to carry out this expert appraisal also drew on hearings with different stakeholders, in particular associations and institutions, in order to collect their experiences and expectations on the issue of contamination of housing by mould. Three themes were selected to organise the hearings in the form of debates bringing together several actors involved with each theme:

- "Health"
- "Administrative procedures"
- "Work in buildings"

Data were collected from the Regional Health Agencies (ARs) in connection with their activities, in particular in the framework of the regional environmental health action plans (PRSEs) and their

missions to combat unsanitary living conditions governed by the French Public Health Code (Articles L.1311-4 and L.1331-22 to L.1331-31).

Lastly, an international consultation took place with national agencies or authorities in the areas of health and/or occupational safety (Europe, North America) in order to learn about the practices implemented abroad associated with exposure to mould, including the applicable regulations, as well as to identify the research and development themes in this area (metrology, exposure, toxicology and epidemiology).

ANSES analyses the links of interest declared by the experts prior to their appointment and throughout the work, in order to avoid potential conflicts of interest with regard to the matters dealt with as part of the expert appraisal.

The experts' declarations of interests are made public via the ANSES website (www.anses.fr).

3. ANALYSIS AND CONCLUSIONS OF THE WG AND THE CES

In everyday language, the term "mould" refers to the spots appearing, for instance, on food or in the home, which correspond to an advanced stage of development of microscopic fungi. Favourable conditions are necessary for their development in indoor environments, mainly the presence of moisture in the different building elements (partition walls, insulating material, false ceilings, etc.), which may be of different types (board, paper, fabric, etc.).

There is a huge variety of fungal species (probably several million), which develop in different conditions. Moulds produce reproductive structures called spores or conidia that, once released, are primarily found in suspension in the air and ensure the moulds' dispersion. In mycology, the method of spore production, observed directly under the microscope, is the main identifier of fungal genera and species. Moulds are also capable of synthesising chemical substances (mycotoxins and microbial volatile organic compounds (mVOCs)) which are contained in the spores or released directly into the air.

- **Health effects of mould in indoor environments**

Epidemiological data: The health effects of exposure to mould found in indoor environments have mainly been studied in children. There are few data on adults.

Concerning the respiratory effects, the results of the expert appraisal support the findings of the reviews by the Institute of Medicine (IOM) and the World Health Organisation (WHO) published respectively in 2004 and 2009. The association between exposure to mould and the occurrence of respiratory effects is confirmed essentially for asthma in children. The observed presence of mould in living areas and a mould odour, whether or not studied jointly with damp, are associated with the development of asthma in young children with strong arguments to suggest causality. Exposure to *Penicillium* (shown in culture after air sampling) is associated with the aggravation of respiratory symptoms.

In the general population, it is not possible to conclude from the epidemiological data as to whether there is an association between exposure to mould in indoor environments and the risk of asthma in adults. However, studies concerning adults exposed in their workplace (buildings having suffered significant water damage) indicate the existence of an association between exposure to damp and mould and the incidence and prevalence of asthma. Most of these data come from Finland, following the recognition of asthma induced by exposure to damp and mould in the workplace as an occupational disease.

For rhinitis, the existence of an association between exposure to visible mould and the risk of allergic rhinitis has been established, but other longitudinal studies are required to assess the causality.

Concerning neurological effects, initial data suggest an association between long-term exposure to mould (> 2 years) of children in early childhood and impaired cognitive function.

Other effects that have been studied in the general population, such as sick building syndrome¹ and psychological effects, are poorly documented.

Lastly, the epidemiological studies presenting a quantitative characterisation of exposure are heterogeneous (diversity of measurement methods) and cannot be used to define a health threshold².

Toxicological data: The identified data complement the findings presented in the reports of earlier studies (WHO 2009; IOM 2004). The animal studies analysed make it possible to confirm:

- the central role of inflammatory responses in inducing respiratory effects,
- the importance of the sensitisation status in the intensity of the inflammatory response,
- the induction of cytotoxic effects associated with exposure to fungal metabolites,
- the immunosuppressive power of β -glucans.

The potential role of exposure to mould in the development or exacerbation of respiratory allergies, asthma in particular, is described in the studies: induction and increase of bronchial hyperreactivity, exacerbation of asthma-like symptoms. The involvement of mould sensitisation in the severity of the pulmonary inflammatory and allergic responses has also been observed in several studies. Some studies offer estimates of the allergenicity threshold related to the exposure of animals to mould by the respiratory route and it appears that the dose-response relationship for triggering the allergic response is specific to each species-host pair. Interpretation of the results observed in animal studies with a view to transposing them to human exposure is subject to several limitations (levels of exposure, differences in inter-species sensitivity, methodological differences such as the protocol for sensitising animals).

¹ Sick Building Syndrome (SBS) is a group of non-specific symptoms affecting the skin, mucous membranes, respiratory system and/or central nervous system.

² A health threshold corresponds to a level of concentration below which no effect on health is expected for the general population.

Most of the available toxicological data concern the effects induced by the species *Stachybotrys chartarum* and its toxins, including extra-respiratory effects (genotoxic potential and haematotoxic, cardiovascular and neurosensory effects).

Referring to the categories of evidence used by the WHO and the IOM, the table below compares the conclusions of this expert appraisal with those of these two organisations.



Summary of the conclusions of the IOM (2004), the WHO (2009) and the present expert appraisal concerning the links between the presence of mould or other agents in damp environments and the occurrence of health effects

Health effect	Conclusions of the IOM (2004) Presence of mould or other agents in damp environments and occurrence of health effects Analysis of epidemiological studies, mainly cross-sectional, published until the end of 2003	Conclusions of the WHO (2009) Damp environments and the occurrence of respiratory effects Analysis of epidemiological studies, mainly cross-sectional, published from mid-2003 to 2007	Conclusions of the present expert appraisal Exposure to mould and occurrence of health effects Analysis of the meta-analyses, systematic reviews and longitudinal studies published from 2007 to 2015	
			In children	In adults
Asthma development	<p>Sufficient evidence to establish an association: Wheeze</p> <p>Limited evidence suggesting an association: Lower respiratory illness in otherwise-healthy children</p> <p>Inadequate or insufficient evidence to establish an association: Asthma development Lower respiratory illness in otherwise-healthy adults</p>	<p>Sufficient evidence to establish an association: Asthma development Wheeze Current asthma</p> <p>Inadequate or insufficient evidence to establish an association: Ever-asthma</p>	<p>Sufficient evidence to establish a causal relationship</p>	<p>Sufficient evidence to establish an association Asthma associated with exposure in the workplace Limited evidence suggesting an association in adults in the general population</p>
Asthma exacerbation	<p>Sufficient evidence to establish an association: Asthma symptoms in sensitized asthmatic persons</p>	<p>Sufficient evidence to establish an association</p>		
Allergic rhinitis	<p>Not assessed individually</p> <p>Sufficient evidence to establish an association: Upper respiratory symptoms (sore throat, conjunctivitis, allergic rhinitis and symptoms of irritation of the nasal passages such as congestion or runny nose)</p>	<p>Limited evidence suggesting an association: Upper respiratory symptoms</p> <p>Limited evidence of an association: Allergic rhinitis</p> <p>Inadequate or insufficient evidence to establish an association: Allergy or atopy</p>	<p>Sufficient evidence to establish an association</p>	
Other observed effects	<p>Sufficient evidence to establish an association: Hypersensitivity pneumonitis in susceptible persons for bacteria or moulds of indoor environments Cough</p> <p>Inadequate or insufficient evidence to establish an association: Dyspnea (difficulty breathing) Airflow obstruction (in otherwise-healthy persons) Mucous membrane irritation syndrome Chronic obstructive pulmonary disease Inhalation fevers (non-occupational exposures)</p>	<p>Sufficient evidence to establish an association: Cough Dyspnoea Respiratory infections</p> <p>Limited evidence suggesting an association: Bronchitis</p> <p>Inadequate or insufficient evidence to establish an association: Altered lung function</p>	<p>Not assessed individually</p>	
Neurological effects	<p>Inadequate or insufficient evidence to establish an association: Neuropsychiatric symptoms</p>	<p>Not assessed</p>	<p>Limited evidence suggesting an association: Impaired cognitive function in children for long-term exposure (> 2 years) to mould in early childhood</p>	
Psychological effects			<p>Inadequate or insufficient evidence to establish an association: Sick building syndrome Psychological effects</p>	
Other effects	<p>Inadequate or insufficient evidence to establish an association: Rheumatologic and other immune diseases Acute idiopathic pulmonary haemorrhage in infants (haemosiderosis) Skin symptoms Gastrointestinal problems Fatigue Cancer Reproductive effects</p>	<p>Not assessed</p>	<p>Not assessed</p>	

Sufficient evidence of a causal relationship: The available evidence is sufficient to conclude that there is a causal link between the presence of mould or other agents in damp indoor environments and the observed effect; this means that the exposure may be responsible for the effect in question, at least in some people, under certain circumstances.

The following criteria must be met: strength of the association, dose-effect relationship, plausibility and biological coherence of the association, timescale of the association.

Sufficient evidence to establish an association: The available evidence is sufficient to conclude that there is an association between the presence of mould or other agents in damp indoor environments and the effect in question; it has been possible to rule out the role of chance, bias and confounding factors in the observed association with a sufficient level of confidence.

Limited evidence suggesting an association: The available evidence suggests the existence of an association between the presence of mould or other agents in damp indoor environments and the effect in question; the level of evidence is limited by the fact that it is not possible to rule out the role of chance, bias and confounding factors in the observed association with sufficient confidence.

Inadequate or insufficient evidence to establish an association: The available studies are of insufficient quality, lack coherence or have a statistical power that is too low to be able to conclude as to whether or not there is an association. Or, there are no studies on the association in question.

- **Methods of measuring mould in the indoor environment**

Many qualitative methods have been identified for assessing contamination by mould, whether for management or research purposes: estimate of the surface area, identification of a mould odour, presence of damp, development of contamination indices based on emissions of volatile organic compounds (VOCs). There are also a multitude of quantitative measurement methods, relating to both sampling (surface, air, dust, materials) and analysis. They can target the fungi itself, its constituents or the substances emitted. This multiplicity complicates the characterisation of exposure and is a major limitation for the standardisation and validation of these methods, as well as for the determination of thresholds aiming to prevent the occurrence of health effects, given furthermore the biological diversity of fungal organisms.

International standards which have become national standards were recently introduced for taking samples from air, surfaces and materials. Concerning air sampling equipment, according to the literature few changes have been noted over the last 10 years; solid medium impactor systems are the most widely used but are based on short sampling durations. New devices based mainly on the collection of spores in a liquid medium have been proposed in recent years and make it possible for samples to be collected over a longer time interval and the liquid sample to be recovered directly, enabling a diversity of subsequent analyses to be conducted. Systems for sampling surfaces or materials (adhesive, "contact" box, swab) have not evolved and are limited to characterisation of the sampled zones.

Concerning dust samples, electrostatic devices that collect dust through passive sedimentation are now available alongside the existing devices that collect dust using suction. This type of sampling system is simple to implement in situ over long periods of time, and is inexpensive. However there are too few data currently available to be able to interpret the results and the device also has to undergo a full assessment for validation.

Culture analysis, using samples from air, surfaces, materials or dust, is the most widely used and requires expert assessment for the morphological identification of species. It is also covered by a standard, which should not only enable the methods to be harmonised but also facilitate the aggregation and comparison of data produced by the entire scientific community at the international level. Other more recent analytical techniques, such as MALDI-TOF mass spectrometry and molecular identification by sequencing, are proposed for species identification. They partly do away with the need for this expert assessment but are not widely used and are dependent on the quality of the reference databases. Indeed, there is a bias for identification because of competition between the species that can be cultured on the agar medium, mainly due to the variability of development conditions of fungal species. The main analytical developments draw on recent progress in molecular biology techniques that make it possible to identify the non-culturable species and cells that are dead (nonviable) but potentially allergenic. They are essentially based on the implementation of polymerase chain reaction (PCR) methods in real time for the detection and quantification of targeted species. This nucleic acid amplification technique requires the use of specific primers, implying a prior choice of species to be detected. Conversely, metagenomic approaches (NGS) help identify all species and characterise the fungal diversity without preconceptions, but for the moment are not routinely applicable and require skills in bioinformatics.

Non-specific methods (beta-D-glucans, electronic nose, ATP-metry, NAHA, particle count, mVOCs) have been little used in recent years because they do not provide information on the species present and are not always correlated to the overall contamination of an environment.

Concerning the specific methods, some have disappeared (box sedimentation, impaction on an adhesive medium and electrostatic precipitation) and others have lower performance and limited development prospects (molecular biology assay using gel (DHPLC, DGGE, etc.)). The recent developments in both sampling (impaction in liquid medium, electrostatic collectors) and analysis

(molecular biology techniques) open up interesting research prospects for relating the characterisation of fungal flora to health data.

- **Knowledge on the situation and the factors favouring mould development in buildings**

The review of the French situation drew on data from different surveys focusing on housing and documenting fungal contamination by searching for visible signs such as blistered paintwork, stains on the ceiling or at the base of the walls, or a damp or musty smell in a building. Visible mould is found in 14 to 20% of French housing, depending on the sources. In Europe and North America, it is estimated that at least 20% of housing is concerned by the presence of mould.

To go further than visual observation, the Indoor Air Quality Observatory (OQAI) has data for different parameters for assessing mould development in housing, energy-efficient buildings and schools. The analysis of the data from the national housing campaign as well as the data in the literature have helped better understand the determinants of fungal contamination and exposure to mould in housing.

A comprehensive understanding of the technical issues related to buildings is needed in order to explain the development of mould in the indoor environment. The critical points are ventilation, insulation and heating, on which comprehensive action is needed.

Phenomena related to the presence of damp in building envelopes and ventilation systems (condensation or parasitic intrusion, via cracks, capillary rise, etc.) are responsible for the appearance of mould. The parameters of wall temperature and excess/low air pressure are also very important and must be considered in parallel.

Experimental work mainly concerns the type of materials that promote mould proliferation as well as modelling to predict mould growth. Materials containing cellulose are conducive to mould development as well as other bioavailable substrates: wallpaper, plasterboard, construction products with easily degradable raw materials, permanently elastic seals, etc.

No pragmatic solution for prevention and remediation is put forward in the literature. Each element is studied separately and macroscopic interaction phenomena (thermal bridges, envelope faults, absence of or poor sizing or regulation of ventilation, etc.) only form a very minor part of the research themes related to mould in the indoor environment.

Improving knowledge among building stakeholders in identification of the causes and proposed effective actions to remove or reduce damp and mould in buildings should be a priority of French public action. Particular attention should be paid to the two practical issues: the construction of new buildings and the renovation of old ones.

- **Characterisation of at-risk population groups**

This expert appraisal focused on groups of individuals most at risk in terms of the health effects in relation to the issue of mould in the indoor environment by considering their individual vulnerability or risk of overexposure due to their socio-economic characteristics.

The findings highlighted the social inequalities of health caused by conditions of substandard housing that are not limited to exposure to mould. The socio-economic characteristics of the occupants of a dwelling, leading to fuel poverty or over-crowded living conditions, are major factors. For example, the problem of mould is most frequently encountered in population groups such as single-parent families or low-income households. Other factors can play a substantial role, such as what the housing is used for (refuse management, animals, etc.), or the geographical situation, with the fungal species most commonly found in housing differing according to the regions, both in France and in the United States where studies have been conducted.

In light of the susceptibilities with regard to exposure to airborne fungal contaminants, children, asthmatics, people who are atopic or hypersensitive, immunocompromised patients or those with chronic respiratory diseases (COBP) are more likely to develop pathologies when exposed to mould than the rest of the population, with this risk being determined by their physiological state or immunological status. Particular vigilance is needed with regard to these at-risk populations.

- **Management of the health risk associated with mould in housing abroad and in France**

At the international level, in certain countries the regulatory framework and public policy guidelines are able to partly address damp and the presence of mould in the indoor environment. The examples of the Nordic countries studied offer many lessons illustrating the regulatory characteristics and possible means of intervention. For example, since 2006, Sweden has made it mandatory to check ventilation in housing every three years and is planning to introduce mandatory inspection and declaration by a certified expert of the level of damp and the presence of mould during real-estate transactions.

For the characterisation of contamination of housing by mould, two distinct approaches have been observed in other countries, the first based on sampling and culture analysis, and the second on prevention and remediation of problems of mould development without measurements being taken:

1. Guidance values for mould ranging from 100 to 1000 CFU.m⁻³ were proposed in the 1980s and 1990s either by government or institutional bodies, or by private-sector professional organisations or experts. The indoor air concentration of fungal flora of 1000 CFU.m⁻³ is regarded as a concentration that can be qualified as abnormal due to potential contamination requiring investigation. This level also corresponds to the value of the 95th percentile of the mean levels compiled from the literature data following impactor air sampling and culture analysis as identified in the framework of this expert appraisal. An example of implementation of a regulation relating to identification of the presence of mould in indoor air was provided by Portugal, based on concentration levels to be complied with depending on the species considered, following sampling and culture analysis.
2. When measurement taking is not recommended, guidelines provide recommendations or rules likely to help in the assessment and remediation of contamination. Different levels of mouldy surfaces have also been proposed and associated with the implementation of remediation measures. For the reference standards of the WHO, Canada, and the city of New York, three levels are proposed: low level, a maximum surface area of between 0.3 and 1m²; medium level, a surface area of between 1 and 3 m²; and the highest level, a surface area of between 3 to 9.3 m². In the report by the French High Council for Public Health (CSHPF) published in 2006, the proposed levels are similar to those of the WHO, with an additional very low level (<0.03 m² or approximately half an A4 sheet).

In France, the regulations are focused on overall management of housing without a specific requirement concerning mould contamination. Different notions of housing are defined by the regulations: unhealthy, unfit and indecent. These concepts have been developed in separate objectives involving different managers and actors. It is a complex area, with many actors involved and where responsibilities are often poorly defined and associated with difficulties in working together and exchanges between actors in the same territory.

According to feedback from the field, in the framework of missions to combat unhealthy housing, problems of mould contamination are primarily assessed by a visual inspection during the visit to a dwelling by an employee of the Regional Health Agency (ARS) (health technician or engineer) or municipal hygiene and health service (SCHS), or an indoor environment adviser (CEI). This assessment is generally one parameter among many for characterising unhealthy conditions. Supplementary action has been taken in a few French regions³ involving public actors and advisers (CEI/Housing and Health Adviser) for assessing housing. Advisers can therefore take mould samples using adhesive tape or swabs on mouldy surfaces, and using bio-impactors for analysing indoor air.

The feedback from the field indicates that the skills of the professionals responsible for assessing fungal contamination in housing are heterogeneous and/or insufficient; the required qualifications need to be defined and harmonised.

³ Before implementation of the territorial reform

Work to remediate damp and mould regularly fails because of a lack of training for building professionals in this area and the inability or reluctance of owners to make the necessary financial investment.

In general terms, with regard to the problem of mould, the level of knowledge among the different professional actors involved in preventing the development of fungal contamination (the construction, renovation and remediation fields) and/or in managing the risks for exposed populations (health professionals, social actors with regard to reporting; professionals responsible for assessing fungal contamination of buildings) is a key factor for reducing exposure to mould and the associated health effects.

■ Conclusions of the CES

The CES Air stresses that exposure to mould in indoor environments constitutes a major public health challenge because of the large proportion of housing concerned (between 14 and 20%, depending on the sources), the established effects on respiratory health and the identification of at-risk populations. On the basis of the results of the expert appraisal, the CES Air concludes that:

- Many methods for assessing fungal contamination are available. They include consideration of the contaminated surface area, more sophisticated methods that may or may not be dependent on culturing, and contamination indicators such as the perception of a mould odour, the measurement of humidity, etc. There is currently no consensus on the choice to be made between them, whether the aim is management or research.
- There are international standards (ISO 16000-16 to 21) that specify the requirements in terms of air, surface and material sampling, as well as counting by culture. If they were used systematically, this would enable the harmonisation of methods and facilitate the aggregation and comparison of data produced throughout the scientific community.
- The recent developments in both sampling (liquid cyclone, electrostatic sensors) and analysis (molecular biology techniques) open up interesting research prospects for the characterisation of fungal flora.
- The earlier work by the WHO (2009) and the IOM (2004) concluded that there is an association between mould exposure and respiratory effects. More specifically, and according to data produced subsequent to this work, the association between exposure to mould and the occurrence of respiratory effects is established mainly for the development and exacerbation of asthma in children, with strong arguments to suggest causality.
- Exposure to damp and mould in the workplace (buildings having suffered water damage) is associated with the incidence of asthma in adults. It was decided to extrapolate this association to other living areas concerning exposure of the general population, in light of current scientific knowledge and in spite of the uncertainties and limitations associated with these studies.
- There is an association between exposure to mould and the risk of allergic rhinitis, but other longitudinal studies are needed in order to reach any conclusion on causality.
- It is not possible, in the current state of knowledge, to define a health threshold below which no effect on health is expected for the general population. Indeed, on the one hand there is a great diversity of exposure indicators linked to health effects, which have given conflicting results, and on the other hand it is difficult to comprehend the mechanisms of action involved and the underlying susceptibility of individuals in the case of respiratory symptoms (in particular immuno-allergic predispositions).
- At-risk populations have been identified. They concern:
 - Populations that are potentially overexposed due to unfavourable socio-economic characteristics such as fuel poverty or over-crowded living conditions;
 - Populations with individual vulnerability due to their physiological state or immunological status: the very old and very young, those with a pre-existing pathology, an atopic predisposition or immune system deficiency.
- The development of mould in the indoor environment depends mainly on technical issues related to buildings such as ventilation, insulation and heating, which should be considered from an overall perspective.
- The Nordic countries have proactive public policies to address the issue of mould. For example, since 2006, Sweden has made it mandatory to check ventilation in housing every

three years and is planning to get certified experts to conduct mandatory inspections during real-estate transactions.

- In France, the problem of mould involves multiple actors in the area of housing. Different notions of substandard housing, developed with different objectives, are defined by the regulations: unhealthy, unfit and indecent. This involves different managers and actors with no specific requirements concerning management of contamination of housing by mould.

■ **Recommendations of the CES**

In view of the conclusions reported above, the CES Air believes it necessary to formulate recommendations for prevention, and proposes different management options.

I. Recommendations concerning prevention of the development of fungal contamination in buildings:

The CES Air recommends in the first place implementing training and information initiatives to raise awareness about the issue of mould, among all professionals involved in operations related to buildings (design, construction, renovation and remediation).

The CES Air emphasises in particular the need to increase awareness among remediation professionals about the health risks they incur during their activities and to introduce preventive measures to limit their exposure.

The trades concerned include industrial companies, engineers, architects, technical design offices, companies, contracting authorities and prime contractors, artisans, etc. These different actors need to be encouraged to work in a cross-cutting way with an overall vision of the technical issues related to buildings including insulation, ventilation and heating.

Drawing in particular on the feedback from the international consultation and on the hearings, the CES Air suggests that the following actions be included in the regulations:

- Integrate, for example in the next thermal regulation (RT 2020), a systematic check of the operation of ventilation systems in the final certificate.
- For new constructions, check the relative humidity and search for the existence of thermal bridges by conducting *in situ* measurements in the inhabited phase over the first winter period. An acceptable rate of relative humidity would be between 40 to 60% (over a range of temperatures between 18 and 22°C).
- Add to the energy certificates necessary for real-estate transactions a declaration concerning the assessment of the effectiveness of the ventilation and the presence or absence of mould.
- Make it mandatory to conduct a periodic check of the effectiveness of the ventilation (condition of the ventilation grilles, operation, air flow value, quality of filtration, for example).
- Introduce certification or a professional label for the expert assessment and inspection of renovation work in housing with mandatory national training. These certified people could then carry out a diagnosis of the housing, and propose work with an overall vision of the design elements mainly by integrating the insulation, ventilation and heating aspects, and also the inspection of new or renovated buildings with regard to mould development.
- Make it mandatory to assess the vulnerability of construction materials with regard to mould development before their placing on the market, on the basis of the existing standards. The labelling of construction materials could then be supplemented to provide information for downstream users. Vigilance is needed to avoid encouraging industrial companies to resort to biocidal products.

- Provide financial aid to encourage work to be carried out to insulate housing, to be granted on condition that a prior assessment of the associated ventilation and heating needs is carried out.

The CES Air also calls for the implementation of information measures aimed at the general population to encourage it to play an active part in the prevention of mould development in housing. For this purpose, the CES Air recommends that:

- For owners and co-owners:

A logbook on servicing and maintenance of buildings and common areas, if appropriate, be introduced in both public and private housing.

- For occupants:

An information leaflet presenting the rules on use and upkeep be issued when they first arrive in the housing, whether it concerns the rental or purchase of a dwelling.

- For local communities:

Technical advice aimed at assessing concomitantly the thermal and hygrometric characteristics of the housing be offered to citizens.

In terms of overall communication initiatives by the public authorities, the CES suggests that:

- Information campaigns be conducted on indoor air quality in buildings in France, with a particular focus on the prevention of mould development, for example through the updating and renewal of actions by INPES⁴.
- Events be organised at local level on the public health issue of exposure to mould in buildings, such as for example workshops, conferences, debates, etc.

II. Recommendations concerning assessment of exposure and management of the fungal risk for exposed populations

The CES Air recommends that:

- Exposure to mould be taken into account explicitly in housing management, clarifying the responsibilities of each of the various stakeholders. In addition, existing regulatory schemes distinguishing between unhealthy, unfit and indecent housing should include the harmonised and explicit management of mould.
- All occupants have a single point of contact for reporting fungal contamination in their home, primarily targeting at-risk populations; for example through the provision of a standardised reporting sheet in local town halls (with an online interface also available) as is the case in Sweden.
- Training be proposed to health professionals and social actors to raise awareness of their role in identification, reporting and management, especially for people who are overexposed due to unfavourable socio-economic characteristics⁵.

Concerning management strategies aimed at at-risk populations, the CES Air reiterates that these populations are defined as follows:

- Children or adults suffering from chronic respiratory pathologies or symptoms (including asthma or rhinitis);

⁴ <http://www.prevention-maison.fr/>

⁵ Generally, people living in substandard housing do not suffer just from mould exposure and may also be in a situation of social isolation

- Immunocompromised patients at high risk of invasive fungal infection from filamentous fungi (haematological malignancy, in particular bone marrow or organ transplant);
- Children from birth;
- Populations at risk due to overexposure: people suffering from fuel poverty or over-crowded living conditions.

For these populations, the CES Air proposes:

- initiating, for assessment by health and social actors, investigations in the home following a report taking into account:
 - a. the context related to the housing (presence of visible mould, damp, water damage or musty smell) and/or
 - b. the medical context (clinical signs or aggravation/exacerbation of symptoms, return home for immunocompromised patients having undergone a transplant);
- when an investigation in the home has been initiated, conducting an assessment of the mouldy surface areas and/or taking samples in order to characterise the fungal flora (surfaces, air, dust) associated with a characterisation of the fungal diversity. Those currently able to undertake this investigation are public actors (SCHS, ARS⁶) or advisers (CEI or Housing & Health Adviser). The CES notes that at the present time, the existing schemes for taking samples are insufficient.
- lastly, if warranted by the contamination assessment, searching for the causes of this development and remediating them, with a follow-up to check the effectiveness.

The table in the annex supplements these recommendations by breaking them down into specific approaches depending on the at-risk populations, with the involvement of different potential actors. For these at-risk populations, housing contaminated by mould should be integrated in procedures for combating unhealthy conditions, and shorter time periods should be applied for the requirement to conduct works and for substitution in case of failure of the owners, depending on the at-risk population considered.

More specifically, concerning the contamination assessment, the CES suggests the following methods:

- Observing the extent of the cumulated mouldy surfaces in the rooms in the housing⁷ (excluding basement, attic, garage, etc.):
 - < 0.2 m² (equivalent to three A4 sheets): low level of contamination - cleaning by the individual except for people with chronic respiratory diseases and immunocompromised individuals⁸ (cohort study highlighting an increase in the risk of asthma for this third level of classification);
 - 0.2 - 3 m²: medium level of contamination for which remediation work is necessary, preferably by a building professional;
 - > 3 m² - insalubrity criterion: high level of contamination for which intervention by a professional with certification for remediation is necessary.
- Fungal samples and analysis to be carried out according to the following requirements:

⁶ ARS = Regional health agency / SCHS = Communal service of hygiene and health

⁷ INSEE definition: habitable rooms (including the kitchen if its surface area exceeds 12 m²) as well as annex rooms that have not been transferred to third parties (staff accommodation, etc.). Excludes rooms used only for professional purposes as well as hallways, corridors, bathrooms, etc.

⁸ For people with chronic respiratory diseases and immunocompromised individuals, cleaning could be done by relatives or friends or professionals.

- Sampling protocol based on the recommendations of the EN ISO 16000-19 standard "Sampling strategy for moulds";
- Air sampling by impaction following the recommendations of the EN ISO 16000-18 standard "Detection and enumeration of moulds - sampling by impaction" for sampling and the EN ISO 16000-17 standard "Detection and enumeration of moulds - culture-based method" for counting.

Given the fact that it is impossible to define a health threshold below which no effect on health is expected for the general population, the CES Air suggests the following management methods for interpreting results:

- Concentrations of fungal flora above 1000 CFU.m⁻³, measured in indoor environments by impaction and on culture, are regarded as abnormally high and a search for the causes and intervention by a professional with certification for remediation is then recommended. This concentration level resulted from the compilation of data from the literature and corresponds to the value of the 95th percentile of the mean levels measured in housing and establishments open to the public. This value is not a health threshold, and lower concentrations can still cause disease or symptoms;
- Counting and identifying the species present, and interpreting the results according to the known health effects of the moulds present in order to assess the risks, may help physicians in the interpretation of symptoms.

The CES Air advises supplementing air sampling by any other type of sampling (materials, surfaces, dust, etc.) to help determine the source of contamination or the species present.

In particular, it would be useful to define a sampling protocol for the collection of sedimented dust. For example, this protocol could be based on suction sampling techniques (1 m² suctioned for 2 minutes) or by electrostatic collector.

Overall, the CES recommends the establishment of a database of the different measurements made in France in order to centralise and analyse the data with a view to constituting regional and national references. It could be associated with an existing database, for example the one on the quality of indoor air or ambient air.

As with the proposed measures for at-risk populations, the fungal risk should be taken into account in occupational health prevention. Accordingly, and in the particular case of this expert appraisal, the occupational health services should take the fungal risk in buildings into account with the support of the present recommendations. The presence of visible mould, signs of damp, water damage or a mould odour in work premises, especially in the tertiary sector, is an important signal to be considered in the framework of the medical supervision of workers.

More broadly, the CES Air recommends that asthma caused by exposure to mould in the workplace be better recognised as an occupational disease.

III. Research recommendations:

In terms of scientific monitoring and research, the CES Air recommends:

- continuing studies seeking to characterise the French situation in terms of mould contamination in buildings and initiating specific studies to characterise the situation in the overseas territories:
 - The proposed questionnaires for characterising housing should be supplemented by specific, individualised questions on the mould odour, the presence of visible mould and the surface area concerned.

- The recent developments highlighted in this expert appraisal should be implemented: for example, sampling methods using electrostatic collectors, liquid cyclone, or individual samplers, followed by a culture analysis, by real-time PCR or high-throughput sequencing. The collapse in fungal biodiversity should be studied to determine any possible additional malfunction.
- Fungal contamination of new energy-efficient buildings should be monitored over several years.
- considering the relevance and feasibility of implementing a surveillance system enabling the use of French data to estimate the frequency of pathologies associated with exposure to mould in indoor environments, and to describe these pathologies. This would help make available the information acquired and more comprehensive references for assessment, management or research.
- encouraging the pursuit of longitudinal epidemiological studies, incorporating a component on housing quality, including the presence of mould:
 - measurements should be conducted, in the epidemiological studies, for characterising different levels of exposure as well as more detailed identification of fungal species, in order to study the dose-response relationships;
 - interventional studies are also necessary to assess the effectiveness of the remediation work.
- conducting toxicological studies to assess the effects of exposure to air or dust from housing contaminated by mould, related to the presence of the different fungal species and their constituents (spores, mycotoxins, allergens, mVOCs) while insisting that mixtures be taken into account and dose-response relationships be identified.

Lastly, in the field of human and social sciences, the CES recommends:

- conducting surveys on the consequences of a specific exposure to mould in buildings in the area of mental health and social isolation, as well as the impact on representations of one's self and one's health. Indeed, housing as a determinant of health plays a dynamic role in a process of decreasing security or social integration.
- for populations suffering from fuel poverty or over-crowded living conditions, implementing studies on the perception and use of existing schemes and recommendations for the proper use of a dwelling. This will help identify the obstacles and levers for action in order to increase the effectiveness of the available information.

4. AGENCY CONCLUSIONS AND RECOMMENDATIONS

The French Agency for Food, Environmental and Occupational Health & Safety endorses the conclusions and recommendations of the CES on Assessment of the risks related to air environments.

This expert appraisal on mould in buildings carries on the Agency's expert appraisal work on the health risks associated with indoor air contaminants. It clearly highlights the fact that exposure to mould in indoor environments constitutes a major public health challenge given the large proportion of housing concerned, the proven effects on respiratory health and the identification of at-risk population groups.

In particular, the expert appraisal highlighted population groups that are at risk due to individual susceptibility, including immunocompromised patients or those suffering from chronic respiratory pathologies who are more likely to develop pathologies when exposed to mould than the rest of the population.

Sustained efforts must therefore be made to reduce exposure to mould in buildings. They should focus on preventing mould development in buildings and preventing the health consequences, especially on the most vulnerable and/or overexposed population groups.

Concerning the prevention of mould development, the Agency recommends strengthening the coordination between actors in the various sectors (construction, energy, etc.) and the authorities and other public actors, to improve consistency in risk management. This mainly concerns informing the public and training professionals. In particular, the interrelationship between the technical issues associated with buildings, including insulation, ventilation and heating, needs to be more effectively taken into account by all the actors concerned. It is also necessary to facilitate access to information for occupants (tenants, owners, etc.) on effective measures for preventing mould development in housing, as well as for the actors likely to advise and assist them in this approach.

Concerning the prevention of health consequences associated with mould development in buildings, the Agency recommends changing the regulations to specifically take into account the fungal risk in housing. In particular, this involves facilitating the collection and processing of reports made by occupants relating to mould development in buildings, and regulating the conditions of investigations by establishing thresholds for action or guidelines for prevention or remediation. Lastly, the Agency suggests conducting a comparative study of the expected costs of the different strategies for preventing fungal risk in buildings, in light of the estimated benefits for the community.

Roger Genet

KEYWORDS

Moisissure, Champignon microscopique, Environnement intérieur, Bâtiment, Santé, Exposition, Exposition risque environnement, Méthode mesure, Populations sensibles

Mold / Mould, Fungi, Indoor pollution, Indoor environment, Building, Interiors (building), Health, Environmental exposure, Measurement methods, Vulnerable populations



ANNEX

More specific proposals for managing the fungal risk for at-risk populations corresponding to the population sub-groups more likely to develop health effects due to exposure to mould

	At-risk population	Reporting		Evaluation of the situation for assessment by health and public actors (SCHS, ARS) or advisers (CEI or Housing and Health Advisor) during the investigation in the home	Actions
		Potential actors	Criteria		
Populations with individual sensitivity (pre-existing pathologies, age)	Children or adults suffering from chronic respiratory diseases (including asthma or rhinitis)	Health professionals (paediatricians, pulmonologists, allergists, general practitioners), Health visitors, Social actors	Presence of visible mould, damp, water damage or mould odour reported and/or clinical signs / clinical evolution	<ul style="list-style-type: none"> Assessment of the mouldy surface area Taking of samples for the qualitative and/or quantitative characterisation of the fungal flora (surfaces, air, dust) and characterisation of the fungal diversity 	Work for dealing with the cause and mould development + checking effectiveness Unhealthy conditions order
	Immunocompromised patients at high risk of invasive fungal infection from filamentous fungi (haematological malignancy, in particular bone marrow or organ transplant)	Hospital professionals (haematologists, transplant doctors)	Information on the housing in relation to the presence of visible mould, damp, water damage, mould odour reported before the operation/pre-transplant interview or during the follow-up of a bone marrow transplant or organ transplant	<ul style="list-style-type: none"> Assessment of the mouldy surface area Taking of samples for the qualitative and/or quantitative characterisation of the fungal flora (surfaces, air, dust) and characterisation of the fungal diversity, mainly for the identification of fungal genera (pathogenic heat-tolerant species: <i>Aspergillus fumigatus</i>, Mucorales) 	Work for dealing with the cause and mould development + checking effectiveness Assistance + cleaning of living areas Unhealthy conditions order Completion of the work before returning home (hospitalisation in an intermediate care home during the renovation period) + visit after remediation.
	Children from birth	Health professionals (general practitioners, paediatricians, pulmonologist- allergists) Health workers Social actors Kindergarten/school staff Hospital professionals	Presence of visible mould, damp, water damage or mould odour reported at home or in a crèche/school	<ul style="list-style-type: none"> Assessment of the mouldy surface area Possible taking of samples for the qualitative and/or quantitative characterisation of the fungal flora (surfaces, air, dust) and characterisation of the fungal diversity 	Work for dealing with the cause and mould development + checking effectiveness Unhealthy conditions order
Overexposed populations	Populations at risk due to overexposure - people suffering from fuel poverty or over-crowded living conditions	Health professionals Social actors	Presence of visible mould, damp, water damage or mould odour in the dwelling	<ul style="list-style-type: none"> Assessment of the mouldy surface area Possible taking of samples for the qualitative and/or quantitative characterisation of the fungal flora (surfaces, air, dust) and characterisation of the fungal diversity 	Work for dealing with the cause and mould development + checking effectiveness Unhealthy conditions order