Risk of fungal infections, and construction work in hospitals

Identification of risks and implementation of management precautions

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Preface

Which hospital has not seen its buildings affected by construction works at some point in time? Whether for major construction, simple maintenance, renovation or construction, such works can considerably increase the risk of contamination of the environment, mainly the air (through the suspension of spores of filamentous fungi resulting from an increase in the presence of dust), but also the water (direct or stagnant water contamination from bacteria).

Current techniques, including molecular biology, have allowed environmental sources to be incriminated as being the origin of some nosocomial infections. Among these, invasive fungal infections resulting from filamentous fungi, such as *Aspergillus* sp., remain serious infections despite recent therapeutic progress. The risk of acquiring such infections is relevant to more fragile patients, treated with neutropenic chemotherapy or having received a graft of haematopoietic stem cells.

Although recommendations have previously been published (by the public assistance service of the Paris hospitals or by Regional Nosocomial Infection Control Coordination Centers), there was no national standard or guidebook. Already foreseen in the publication: *"Surveillance and Prevention of healthcare-associated infections",* edited by the French Higher Council for Public Health (HAS), this guidebook has now become a reality.

The French society for medical mycology (SFMM) and the French society for Hospital Hygiene (SF2H) have coordinated a group of experts in this field (mycologists, medical hygiene specialists, infection control specialists, hematologists and engineers), in order to prepare, and make available to hospitals and the relevant actors, this technical guide on the risk of fungal infections in hospitals during construction work. Above all, its aim is to provide elements, which can be used in the identification of risks, and the implementation of precautions for its management. Its production was supported by the methodological advice provided by the HAS. Among the new topics treated, we cite the implementation of a study on the impact of construction work on the infectious risk associated with filamentous fungi (pre-requisite for the identification of risk management precautions), and the provision of indicators (for the monitoring of these precautions). Emphasis is also placed on one of the essential points, which is the organization of a pluridisciplinary collaboration (and the definition of areas of responsibility), before, during and after completion of construction work. This document is particularly easy to read, as a result of the use of tables, decision trees and practical examples, which simplify the updating of written hospital procedures.

The two societies which promoted this edition are highly grateful to Jean-Pierre Gangneux and Raoul Baron for steering the production of this scientific and practical document. This acknowledgement is naturally extended to the members of the working and reading groups, and to the partner societies from which they originate.

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LIST OF ABREVIATIONS

ANAES	French National Agency for Health Accreditation and Evaluation *(Agence nationale d'accréditation et d'évaluation en santé)*
ARH	Regional Hospitalization Agency *(Agence Régionale d'Hospitalisation)*
CFU	Colony forming unit
CLIN	Committee for Nosocomial Infection Control (Consultative and follow-up body) *(Comité de lutte contre les infections nosocomiales - instance de consultation et de suivi)*
CMV	Cytomegalovirus
CSHPF	French Higher Council for Public Hygiene *(Conseil supérieur d'hygiène publique de France)*
CTINILS	Technical Committee for Nosocomial and Healthcare-Associated Infections *(Comité technique des infections nosocomiales et des infections liées aux soins)*
CVC	Central venous catheter
EIS	Environmental impact study
EORTC / MSG	European Organization for Research and Treatment of Cancer / Mycoses Study Group
FFP2	Filtering facepiece
HAS	French National Authority for Health *(Haute Autorité de Santé)*
HIV	Human Immunodeficiency Virus
HLA	Human Leucocyte Antigen
HMC	Hospital Medical Committee *(Comité Médical d'Etablissement)*
IA	Invasive Aspergillosis
IFI	Invasive fungal infection
ICT	Infection control team *(EOH = Equipe opérationnelle d'hygiène)*
ISO	International Standards Organization
NI	Nosocomial Infection
NMR	Nuclear Magnetic Resonance
PCR	Polymerase Chain Reaction (molecular biology method)
PNN	Polynuclear neutrophils *(Polynucléaires neutrophiles)*
POR	Post-operative room *(Salle de surveillance post-interventionnelle)*
R&B	Roads and Buildings *(Voirie, réseaux, divers)*
RFI	Risk of fungal infection
IR	Infectious risk *(Risque infectieux)*
TBI	Total body irradiation
TNF	Tumor Necrosis Factor
UH	University hospital *(Centre Hospitalier Universitaire)*

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Context and Method

a. Context

Invasive Fungal Infections (IFI) caused by filamentous fungi such as *Aspergillus* sp. are feared diseases despite the recent evolution of therapeutic strategies. The risk of acquiring IFI and their prognosis vary according to the level of the individual's exposure to sources of fungal spores and his or her ability to implement an effective anti-infection response.

In-house patients of healthcare establishments can contract a healthcare related IFI, especially the most at risk patients such as those undergoing neutropenic chemotherapy, or hematopoetic stem cell transplant recipients. In normal situations, precautions and hygiene measures are taken, in order to avoid the exposure of these patients to fungal spores, and of *Aspergillus* in particular. The aim is to diminish the morbidity and mortality of these diseases, thereby reducing the need for associated healthcare (extension of hospital stay, prescription of complementary examinations and use of antifungal medication).

Construction works in healthcare establishments produce airborne fungal spores and considerably increase the risk of exposure of fragile patients. It is necessary to reinforce protective measures, or even to implement specific precautions, during this critical phase. The aim of these precautions is to protect both those areas which are susceptible to dust, and patients at risk of a fungal infection.

b. Method

The aim of this working group was to provide the relevant establishments and personnel with a technical guide concerning the environmental fungal risk in healthcare establishments, during periods of construction work. This technical guide, which has a very practical purpose, is the fruit of the analysis and synthesis of available data, carried out by a multidisciplinary group, based on current knowledge as documented in the literature, as well as on numerous instances of local experience in this field. The documented research has been prioritized and structured according to each debated question. This was carried out using published and referenced articles from French and international biomedical databases, as well as 'grey literature' (all documents published outside the commercial circuit of traditional publishing). It was supplemented by the bibliographical contribution of experts from the working and reading groups, and by the references quoted in the analyzed documents. The main key words used are: nosocomial fungal infections, aspergillosis, *Aspergillus*, construction works, environmental fungal risk, air, risk management.

This group, which received the methodological support of the French National Authority for Health (HAS), included mycologists, infection control specialists, clinical doctors (infectiologists, hematologists), and engineers, all co-opted by their respective professional associations. A consumer representative was also associated with the reading group.

Our approach consisted in four stages:

I. risk characterization through analysis of the literature
II. the proposal of quantification and risk management methods
III. the proposal of impact indicators
IV. the definition of areas of responsibility within the hospitals

Question 1

Risk characterization: analysis of data found in the literature concerning the risk of fungal infections during construction work

Key words: Bibliographical analysis - Definitions and Quantification of Risks - Fungal flora

Construction work is frequent in hospitals. The handling of rubble (demolition, excavation) as well as numerous types of construction work can lead to a microbiological, in particular fungal, environmental risk, and possibly to the risk of infection for patients. The risk analysis is carried out according to the type and proximity of the construction works, the degree of susceptibility of the patients, but also according to the ecology of the floral fungus. At risk patients can potentially be housed in various types of room, protected or unprotected from the risk of environmental contamination, such that surveillance and protective measures must be implemented. These are established according to the level of risk identified for the works in question, and the type of patient involved, in order to prevent their contamination.

In order to evaluate the Risk of fungal Infection (RFI), in particular the risk of aspergillosis, it appears necessary to:

- identify the environmental fungal risk according to the type of construction work carried out in the buildings
- indentify and classify fungi released by the construction work, according to their pathogenicity
- identify patients at risk of invasive fungal infections, invasive aspergillosis in particular
- identify hospital wards and units housing patients at risk of fungal infections
- finalize this effort with an impact study.

1.a Defining the Risks

1.a.1 The Risk

The risk is defined as the combination of the probability of occurrence of a feared event (in the present case a nosocomial infection) and the seriousness of the consequences for a particular target (the patient) [CTINILS 2007].

1.a.2 The environmental fungal risk associated with filamentous fungi

This risk is defined as the identified and quantified presence and persistence of potentially harmful filamentous fungi, such as the fungi of the *Aspergillus* genus, and their spores in the environment, likely to be transferred to a patient during treatment.

This results in biocontamination or pollution of the healthcare environment with spores of filamentous fungi. The environmental fungal risk does not correspond to the risk of infection and should be considered differently.

1.a.3 The infectious risk

The risk of infection (RI) results from exposure of the host to a hazard, the microorganism, and the outcome of the host-microorganism relation that can lead to infection. The RI can be defined as the likelihood of infection following exposure to a potentially pathogenic microorganism.

This risk depends on the significance of the inoculum and virulence of the microorganism, and on

the defense capacity of the host against this microorganism. This can be summarized by the following equation:

$$\text{Risk of infection} = \frac{\text{Inoculum x microorganism's virulence}}{\text{host's resistance}}$$

To manage this RI, the microbiological risk associated with healthcare and the healthcare environment should first be considered. This amounts, in many cases, to the identification and control of the level of biocontamination in the healthcare environment, and to avoiding the transfer of contamination during care.

1.a.4 The risk of nosocomial fungal infection associated with filamentous fungi

This risk results from a combination of the environmental fungal risk, and exposure of a patient susceptible to bio-aerosols when inhaling fungal spores during hospitalization.

The RFI (Risk of Fungal Infection) is characterized by the probability of occurrence of invasive fungal infections and by the severity of its consequences for the patient.

For a hospital, this risk can be defined as an event likely to lead to a breach in the continuity of care, or a deterioration in the quality of care. Its management is defined as a regular, continuous and coordinated process, which is integrated throughout the entire healthcare institution. Through this process it is possible to identify, evaluate, and control RFIs and situations prone to RFI that have led or could have led to a nosocomial filamentous fungal infection (NI) in the patient. RFI management is an intrinsic component of the quality policy of a health care institution. This motivates each player involved in a healthcare institution to comply with the ethics of individual and collective responsibility. [ANAES 2003, Ministry of Health 2004a, Ministry of Health 2004b, LARSON 2006, 2008 ADJIDÉ a, b, c].

1.b Identification of the environmental fungal risk according to the type of construction work

Microbiological samples have identified *Aspergillus* contamination in different areas of the interior of various premises. Those which are the most strongly contaminated are [ARNOW 1991, 2006 CSHPF, HAIDUVEN 2009]:

- filters,
- fire protection equipment,
- air vents,
- air conditioners,
- dust in the spaces above suspended ceilings,
- walls and wallpaper,
- rugs.

Various authors have classified construction work into four types, A, B, C and D [Anonymous Canada 2001, Anonymous Ireland 2001, HAIDUVEN 2009] according to the increasingly large quantities of dust these will generate. One may assume that the total quantity of dust provides an indication of the quantity of fungal spores, in particular *Aspergillus* and its airborne variants [SRINIVASAN 2002].

These four types of construction work, which have been analyzed using similar methods in these studies, are presented in Table I.

Following external demolition work, an increase in the airborne concentration of *Aspergillus,* which does not start to decline until about the fifth day, and reaches its initial level on the eleventh day, has been reported [BOUZA 2002].

Smoke control circuits are sources of *Aspergillus* spores. Validation tests of smoke control systems, carried out as part of fire safety procedures, can produce clouds of fungal spores [BUSSIÈRE 2003].

Table I - Classification of construction works according to the volume of dust they produce, as defined by [ANONYMOUS Canada 2001, ANONYMOUS Ireland 2001, HAIDUVEN 2009].

Types of construction work	
Type A	**Non-invasive control work / internal work with minimum production of dust.** *Non exhaustive list* • Removal of suspended ceiling panels for inspection, limited to 1 plate/m², • painting without sanding, • paperhanging, • minor electrical work, • minor plumbing with water cutoff in the room lasting <15 minutes, • other inspection work requiring neither recesses in the walls, nor more extensive interventions on suspended ceilings.
Type B	**Short-duration, minor construction work producing small quantities of dust** *Non-exhaustive list* • Wire recesses in the walls or ceilings, with controlled production of dust for minor electrical installations or repairs on ventilation components, telephone or computer cabling, • removal of floor covering (limited area) • minor construction work on suspended ceilings, • sanding/grinding of the walls for paint removal or wallpapering involving the repair of only a small area, • plumbing work with water cutoff affecting ≥ 2 rooms for less than 30 minutes, • any construction work that can be performed by a single building trade.
Type C	**Any construction work producing moderate to high levels of dust, or requiring the demolition or removal of any fixed item (e.g. sinks, boards...)** *Non-exhaustive list* • Sand blasting / sanding of walls for painting or wallpapering; any construction work with plaster elements, • minor demolition, • removal of floor coverings and suspended ceilings, • construction of new walls; installation of new partitions, • minor construction, • minor piping or electrical wiring work in the ceilings, • minor excavation, • major wiring activities, • any activity that requires several building trades, • any plumbing work with water cutoff affecting > 2 rooms for > 30 minutes, but <1 hour.
Type D	**Major demolition, renovation, construction work / Major external construction work with significant dust production** *Non-exhaustive list* • demolition or renovation of an entire wiring system, • new construction involving several building trades, • plumbing with water cutoff affecting > two rooms, for > 1 hour, • major excavations.

1.c Identification and classification of fungi released by construction work, according to their pathogenicity

A classification of fungi according to pathogenicity has been proposed [DE HOOG 1996]:

- saprophytes or plant pathogens, exceptionally responsible for infections which are superficial or less serious in humans (BSL-1, *Biosafety level 1*);
- saprophytes or plant pathogens, capable of surviving in tissues of vertebrate hosts. Responsible for superficial or deep opportunistic infections in immunosuppressed patients (BSL-2, *Biosafety level 2*). *Aspergillus fumigatus* and other filamentous fungi responsible for opportunistic infections in immunosuppressed patients were classified in this group;
- fungal pathogens which cause severe mycosis, even among an immunocompetent host (BSL-3 *Biosafety level 3*). These mainly comprise dimorphic fungi from the onygenales order (*Coccidioids, Histoplasma* or *Paracoccidioids*).

1.c.1 Fungi which become more prevasive during construction work

All filamentous fungi can be found during hospital construction work, especially during demolition or renovations. However, some fungi are found in the air more frequently, although it is not well understood if this increase in frequency is real, or if the fungi are more easily found as a consequence of the environment and culture temperature used for their detection.

For instance, *Aspergillus* sp. was found in 17.5% to 70% of hospital samples during construction work, with a predominance of *A. fumigatus*, but also *A. niger* and *A. flavus* [CHENG 2001, BOUZA, 2002, 2007 & 2009 SAUTOUR]. It should be noted that the air collection systems were all different (IDEAL AIR with a volume of 500 l, Mas-100 biocollector with a volume of 200 l and REUTER biocollector with a volume of 1600 l). The seeded media were all Sabouraud media with an incubation temperature ranging from 30° to 37°C. When the incubation temperature was 37°C, there was a clear predominance of *A. fumigatus* because of its high thermophilia [CHENG 2001]. When the media were seeded at 30°C or 22°C, after *Aspergillus* sp., fungi of the *Penicillium* (in 8.7% to 27% of samples) and *Cladosporium* (2% to 60%) genera were the most common [BOUZA, 2002, 2007 & 2009 SAUTOUR, PINI, 2007].

Dematiaceous fungi of the *Alternaria* or *Curvularia* genera are then found in 2% to 7% of samples [PINI, 2007, 2007 & 2009 SAUTOUR]. Finally, other genera or species are found less frequently, among which *Rhizopus, Mucor, Absidia, Dreschler, Paecilomyces, Scopulariopsis, Fusarium, Sporotrichum, Acremonium, Hartrinium, Beauveria, Trichoderma*, or also yeasts.

1.c.2 Fungi responsible for invasive fungal infections

Various studies on IFI epidemiology, particularly in populations most at risk such as patients receiving a hematopoietic stem cell transplantation, have shown that *A. fumigatus* and to a lesser extent the other species of *Aspergillus*, were responsible for the vast majority of IFIs (Seattle study from 1998 to 2002 on 1248 marrow allograft patients [GARCIA-VIDAL, 2008]). Thus, of the 163 identified cases of IFI, Aspergillus was found in 142 patients (87%), *Fusarium* sp. in 6 patients (4%), zygomycetes or mucoral fungi in 5 patients (3%), *Scedosporium* sp. and *Acremonium* sp. in one patient (1%), respectively. Six patients (4%) had mixed infections with two filamentous fungi, in all cases involving *Aspergillus* sp., associated with another filamentous fungus.

In a previous study conducted by the same team from 1985 to 1999 and involving 359 patients with IFI, *Aspergillus* already was already the fungus the most frequently responsible for IFIs, in 230 patients: 67.8% of IFIs were caused, among other *Aspergillus* fungi, by *A. fumigatus*, 2.6% by *A. flavus*, 2.2% by *A. terreus* and 1.3% by *A. niger*, [MARR 2002]. The other agents involved were zygomycetes in 36 patients (14 *Rhizopus* sp., 8 *Mucor* sp., 1 *Absidia* sp., 2 *Cunninghamella* sp., and four other unidentified types), *Fusarium* sp. (31 patients), *Scedosporium* sp. (10 patients), dematiaceous fungi (5 patients infected with Alternaria sp., *Exophiala* sp., *Ulocladium* sp., *Scopulariopsis* sp.) and *Paecilomyces* sp. (1 patient).

Other teams have also reported an increase in the incidence of IFIs due to the increasing number of patients or recipients of transplants or aggressive chemotherapy, and to the change in the procedures used in the field of transplantation [NUCCI, 2003, MALANI 2007, LASS-FÖRL 2009]. These teams have placed particular emphasis on the increasing number of infections caused by fungi exhibiting resistance to conventional antifungal agents (amphotericin B and/or voriconazole). These include aspergilloses caused by *A. terreus*, *A. ustus*, *A. Lentulus*; zygomycoses caused *Rhizopus*, in particular *Rhizopus oryzae*, *Mucor*, *Rhizomucor*; scedosporioses caused by *S. apiospermum* and *S. prolificans*; fusarioses caused by

F. solani, *F. oxysporum*, and *F. moniliform*; and less frequently infections associated with other moulds (*Acremonium, Paecilomyces, Trichoderma, Curvularia genera, Bipolaris, Alternaria, Exophiala, Ochroconis*...).

1.c.3 Fungi responsible for construction-related nosocomial fungal infections

In a literature review conducted on episodes of construction-related nosocomial IFIs, a list of the fungi involved was proposed [ANONYMOUS Canada 2001]. *Aspergillus* sp. (24 references - about 180 cases) and especially *A. fumigatus* (13 references - about 65 cases) were the most frequently associated with nosocomial IFIs. Other *Aspergillus* fungi can also be at issue in nosocomial IFIs following construction work, such as *A. flavus* (8 references - about 58 cases), *A. Niger* (7 references - about 10 cases) and *A. terreus* (2 references - 5 cases). Zygomycoses (3 references - 4 cases) and IFIs caused by *Scedosporium* sp. (Reference 1 - 4 cases), *Fusarium* sp. (1 reference - 1 case), and lastly other more rarely encountered filamentous fungi, are also observed.

1.c.4 Conclusion

The fungi most frequently incriminated in construction-related nosocomial fungal infections are thus *Aspergillus* fungi, primarily *A. fumigatus*. However, recent changes in the procedures for treating transplant patients (more pronounced immunosuppression, prolonged survival of patients, pressure exerted by broad-spectrum antifungal agents used for prophylaxis and/or treatments) have been accompanied by an increased incidence of fungal infections by filamentous, "non-*Aspergillus*" fungi.

Thus, the potentially pathogenic fungi disseminated during construction work can be classified, from the most frequent to the most uncommon, as follows:

- *Aspergillus fumigatus* in most cases,
- *A. non fumigatus* (*A. flavus*, *A. Niger*, *A. terreus, A. nidulans*, and others)
- *Fusarium* sp. (*F. solani, F. oxysporum, F. moniliform*)
- Zygomycetes (*Rhizopus sp., Mucor sp., Absidia sp. Cunninghamella sp*. and others)
- *Scedosporium* (*S. apiospermium, S. prolificans*)
- *Dematiaceous* (*Alternaria sp., Exophiala sp. Ulocladium sp. Scopulariopsis sp., Curvularia sp.*)
- *Acremonium sp.,*
- *Paecilomyces sp.,*
- *Trichoderma sp.*

1.d Identification and quantification of populations at risk of invasive fungal infection

Patients at risk of fungal, especially *Aspergillus*, infections can be divided into several categories depending on the underlying pathology, level of immunosuppression and associated treatments. These categories take into account assessments, which may vary from one country to another or from one institution to another, and which need to be validated locally in terms of the type of activity and protocols in use in each particular hospital.

The data published on this subject generally identifies four categories of population [DEROUIN, 1996, MYLONAKIS 1998, SFHH 2000, Anonymous Ireland 2001, Anonymous Canada 2001, CORNET 2002, MARR 2002, TABLAN 2004, Anonymous Canada 2004, Ministry of health 2004b, APIC 2005, VONBERG 2006, GANGNEUX 2008, GARCIA-VIDAL 2008, BITAR, 2009, KONTOYIANNIS 2010, NEOFYTOS 2010].

Very high-risk populations

- Allograft of hematopoietic stem cells, especially in the case of old age, disease relapse, second allograft, pheno-versus geno-identical graft, HLA incompatibility, total body irradiation (TBI) during conditioning, according to the type of graft (placental blood versus other cellular sources, T-depleted graft), presence of a graft versus host disease, of a cytomegalovirus (CMV) disease, of iron overload;
- autografting of hematopoietic medullary stem cells;
- severe combined immunodeficiencies;
- post-chemotherapy neutropenia (with neutrophil counts [ANC] of $< 500/mm^3$) lasting more than fourteen days, or neutropenia with an ANC of $< 100/mm^3$ regardless of duration;
  - Severe bone marrow failure.

High-risk populations

- High-dose corticosteroid therapy in the treatment of acute lymphoblastic leukemia;
- post-chemotherapy neutropenia (with an ANC of $< 500/mm^3$) lasting less than fourteen days;
- solid organ transplant:
  - pulmonary: according to the characteristics of the transplanted lung, immunosuppression, colonization of the native lung and post-transplant bronchus;

- liver and kidney: postoperative course with complications (acute renal failure, severe septic conditions), re-transplantation, treatment with monoclonal antibodies;
- heart, pancreas, intestine;
- chronic pulmonary diseases treated with corticosteroids or other immunosuppressants: obstructive pulmonary disease, emphysema, bronchiectasis, uncontrolled asthma, cystic fibrosis;
- chronic granulomatous septic disease (children and adults);
- newborns in neonatal resuscitation;
- relapsed or refractory acute myeloblastic leukemia.

Lower-risk population

- Repeated and/or prolonged high-dose corticosteroid therapy;
- HIV positive patients with AIDS, with CD4 T lymphocytes + of <50/mm3;
- patients on mechanical ventilation;
- patients on dialysis;
- patients on chemotherapy;
- diabetic ketoacidosis;
- burned persons (> 50% body surface area);
- systemic diseases.

Other (to be evaluated)

- Treatment with anti-TNF agents or other monoclonal antibodies or biotherapies.

Table II - Classification of hospital wards or units with a risk of fungal infection, according to [Anonymous Canada 2001, Ministry of Health 2004b, APIC 2005, HAIDUVEN 2009].

Groups of wards	Wards or departments concerned	
	[Anonymous Canada 2001, Ministry of health 2004b]	[APIC 2005, HAIDUVEN 2009]
Area 1 **Small RFI**	• Offices • Unoccupied rooms • Public areas	
Area 2 **Medium RFI**	• All other healthcare departments (unless they are in groups 3 and 4) • Outpatient clinics (except for oncology and surgery) • Admission units	• Cardiology • Echocardiology • Nuclear Medicine • Endoscopy • Radiology/NMR • Pneumology • Functional rehabilitation
Area 3 **High RFI**	• Emergency rooms • Conventional radiology • Recovery rooms (PACU) • Labor and delivery rooms (except the operating room) • Nurseries • Ambulatory surgery • Nuclear medicine • Spa pools or physiotherapy facilities • Echocardiology • Laboratories • General medicine and surgery rooms (unless they are in group 4) • Pediatrics • Geriatrics • Extended or long-term care	• Emergency room • Labor and delivery rooms (except operating room) • Nurseries • Laboratories • Ambulatory surgery • Pediatrics • Pharmacy • Recovery rooms (PACU) • Surgical departments
Area 4 **Very high RFI**	• Intensive care units • Operating rooms • Anesthesia facilities • Oncology units and outpatient consultation services for cancer patients • Transplant and outpatient units for patients having received a hematopoietic stem cell or solid organ transplant • Rooms and outpatient consultation services for patients with AIDS or any other immune deficiency • Dialysis • Neonatology • All cardiac catheterization and angiography facilities • Cardiovascular/ Cardiology departments • Endoscopy facilities • Drugs preparation facilities • Sterile preparation rooms • Central treatment (sterilization, endoscopes)	• Intensive care units • Operating rooms • Positive pressure isolation rooms • Medical departments • Oncology units and outpatient consultation services for cancer patients • Transplant and outpatient consultation units for patients having received a hematopoietic stem cell or solid organ transplant • ***Burn patients*** unit • Central sterilization

1.e Identification and quantification of hospital wards or units at risk of fungal infection

Any person who is strongly exposed to dust-producing construction work can potentially develop a serious fungal infection, with the RFI varying according to the patient's underlying pathology. Nevertheless, the RFI also varies as a function of the hospital sector concerned, and several classifications can be found in the literature [Anonymous Canada 2001, Ministry of Health 2004b, APIC 2005, HAIDUVEN 2009]. Although the zone 3 and 4 sectors are clearly at greater risk, local internal knowledge of each hospital can nevertheless introduce nuances to these classifications, according to their specific activities and characteristics, thereby avoiding an over-estimation of the units having a RFI (Table II).

In conclusion, the finality of risk characterization is to propose measures for the prevention of exposure to airborne biological contamination during construction work, in areas in which patients with RFI are housed. They must be adapted to the level of RFI determined during risk inspections, with an impact study as described in Question 2 of the present document. This risk inspection must be carried out jointly by the clinical hospitalization ward affected by the construction work, the hospital hygiene service, the technical services, the management, and a representative from the construction company.

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Question 2

Practical management of the risk of fungal infection during construction work: implementation of an impact study and identification of risk management precautions

Key words: Practical Risk Quantification Proposals – Environmental Impact Study (EIS) – Proposed Management Measures

2.a Implementation of a construction site impact study concerning the infectious risk associated with filamentous fungi

Collaboration is needed between the Infection Control Team, biologists, the aspergillus task force (if the hospital has one) and the construction works management, in order to conduct an impact study of the hospital environment.

This joint approach must ensure that all actors share and have access to the same level of risk information. It allows the hospital manager to make useful decisions, at any stage during the construction work. This collaborative approach is necessary, to ensure that firms working in the hospital are aware of the restrictions that exist.

2.a.1 Environmental impact study in the case of construction work in a hospital

The environmental impact study (EIS) entails prior identification of the positive and negative effects, which the foreseen projects will have on the hospital environment and the health of hospitalized patients. It enables planning of the implementation of appropriate preventative measures, as well as their follow-up. This calls for the clear definition of the notion of an impact. Although the terms *'effect'* and *'impact'* are often used interchangeably to describe the consequences of a project on the environment, they do not in fact have the same meaning:

- *effect* is used to describe an objective consequence of the project on the environment: for example, construction work that emits relatively significant quantities of particulate contamination.
- *impact* is used to describe a situation in which the consequences of the project are projected onto a scale of criticality. In the case of particulate contamination, the impact can be high if fragile patients are situated nearby, or can be non-existent if this is not the case.

2.a.2 Characteristics of the impact study

The impact study is a preferred planning instrument...

Its purpose is to take environmental concerns into account, at all stages of the project, from design to completion.

It assists the partners (construction work manager, IC committee), infection control team, firms, ...) in designing a project that will take the receiving environment into account, whilst remaining acceptable in technical, human and economic terms.

… which takes all environmental factors into account

The impact study takes all components of the natural and human environment into account, which

are likely to be affected by the project. It makes it possible to analyze and interpret the relationships and interactions between factors having an influence on ecosystems, resources and the quality of care of hospitalized patients.

… whilst concentrating on the most relevant elements

The impact study tries to determine the environmental components that are likely to be significantly impacted. The relative significance of an impact will determine the elements on which any choice or decision will be based.

…and which takes the interests and expectations of those concerned into consideration

The impact study takes the opinions of all parties into consideration. In this respect, it accounts for the way in which the various parties concerned have been associated with the project's planning process, and takes the results of consultations and negotiations into consideration.

… with a view to promoting informed choices and decisions

2.a.3 Application to the case of a hospital

The EIS approach during construction work in hospitals is illustrated in Fig. 1. With the objective of producing an overview of the different expert reports made by IC specialists and technical managers, this should be implemented during project design, and viewed as an opportunity to improve the project, rather than being considered as a restriction.

Requiring scientific and technical analysis, this approach allows for the potential consequences of a construction project to be considered. It should become a cornerstone of the construction site procedures used in a hospital environment, since it is a tool for the protection of the environment, for the provision of information on the project, and for assistance with decision-making.

2.a.4 Impact study of a construction site at a hospital

The evaluation, risk quantification and preventative measures to be taken should be established jointly by a representative from the infection control team / aspergillus unit and a representative from the construction company. These measures should be organized during the initial planning phase of the construction work. Indeed, some of the measures to be taken should feature in the specifications of the call for proposals, thus allowing constructive choices and any additional costs to be included in the offers.

(I) Evaluation and environmental fungal risk quantification according to the nature and location of the construction work.

The evaluation of the impact of construction work in a building on fungal aero-biocontamination within a hospital depends on the level of particulate emission. This varies according to the extent and nature of the construction or renovation work. The levels of dust proliferation depend on the various types of building trade. These two “construction-related” parameters (size of the construction site and nature of the work) should be considered, along with the two main construction work typologies (construction of new buildings or renovation).

THE FIVE BUILDING TRADE FAMILIES

1 - Earthmoving and demolition of buildings: roadways, buried networks, earthwork, demolition, foundations, building shell infrastructure, landscaping;

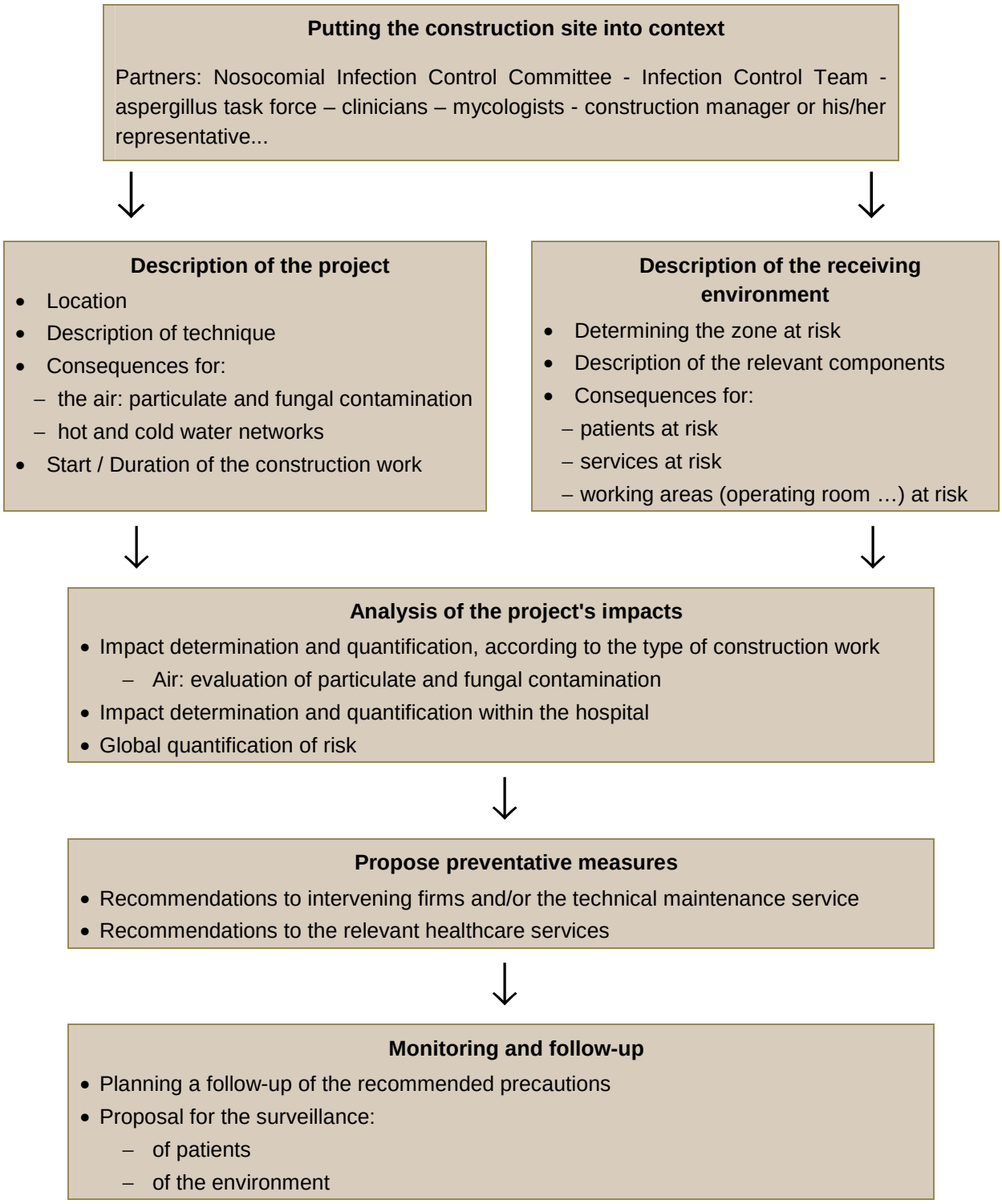
2 - Enclosure: building shell superstructure, timber or metal frame, roofing and waterproofing, outdoor joinery, facades;

3 - indoor partitioning: plastering, other timber or metal partitions, doors;

4 - technical installations: electricity, plumbing, heating, ventilation, other fluids;

5 - finishing work: suspended ceilings, wall and floor coverings, indoor joinery, installation of equipment.

Figure 1 - Practical approach to the development of an impact study in the hospital sector [CASTEL 2007].



NEW CONSTRUCTION WORK AND MAJOR RENOVATIONS

The first and second building trade families are associated with construction activities having a major impact on the environment. Most of the time, this is related to new construction work, and sometimes to major renovations of existing structures.

Such construction work, which is long term in nature, produces high to very high levels of particulate proliferation.

Family 1 is without a doubt the building trade with the highest risk of dust proliferation. Family 2 has more variable risks, depending on type of construction. Particular attention should thus be paid to timber frames rather than metal frames, to tiled rather than zinc, copper or slate roofs, because of the brittle nature of these materials.

INTERIOR RENOVATIONS

The remaining families, 3, 4 and 5, are present in the case of both new construction work and interior renovations of entire or partial structures.

Such interior renovations, which can be adjusted to the level of patient care, and have highly variable particulate proliferation rates, from moderate to high. Thus, family 3 will be a significant source of plaster or wood dust. Family 4 will present a high risk only temporarily, for instance while the systems are being reconnected to the existing networks of the renovated building. Family 5 will present a moderate risk most of the time, except during the preparation of surfaces, during sanding operations in particular.

SUCCESSIVE STAGES WITH DIFFERENT DUST PROLIFERATION RISKS

With the exception of Family 4, the periods of intervention for these building trades are staggered successively over the lifetime of a construction project. Apart from the case of construction sites of exceptional size, involving the simultaneous construction of several buildings, these tasks do not take place simultaneously. This highlights the fact that a construction site may successively involve phases of high, then moderate risk, at each stage of the construction process.

Three construction stages should be mentioned because of their high risk:

1- initial work on the construction site, involving earthmoving and demolition;

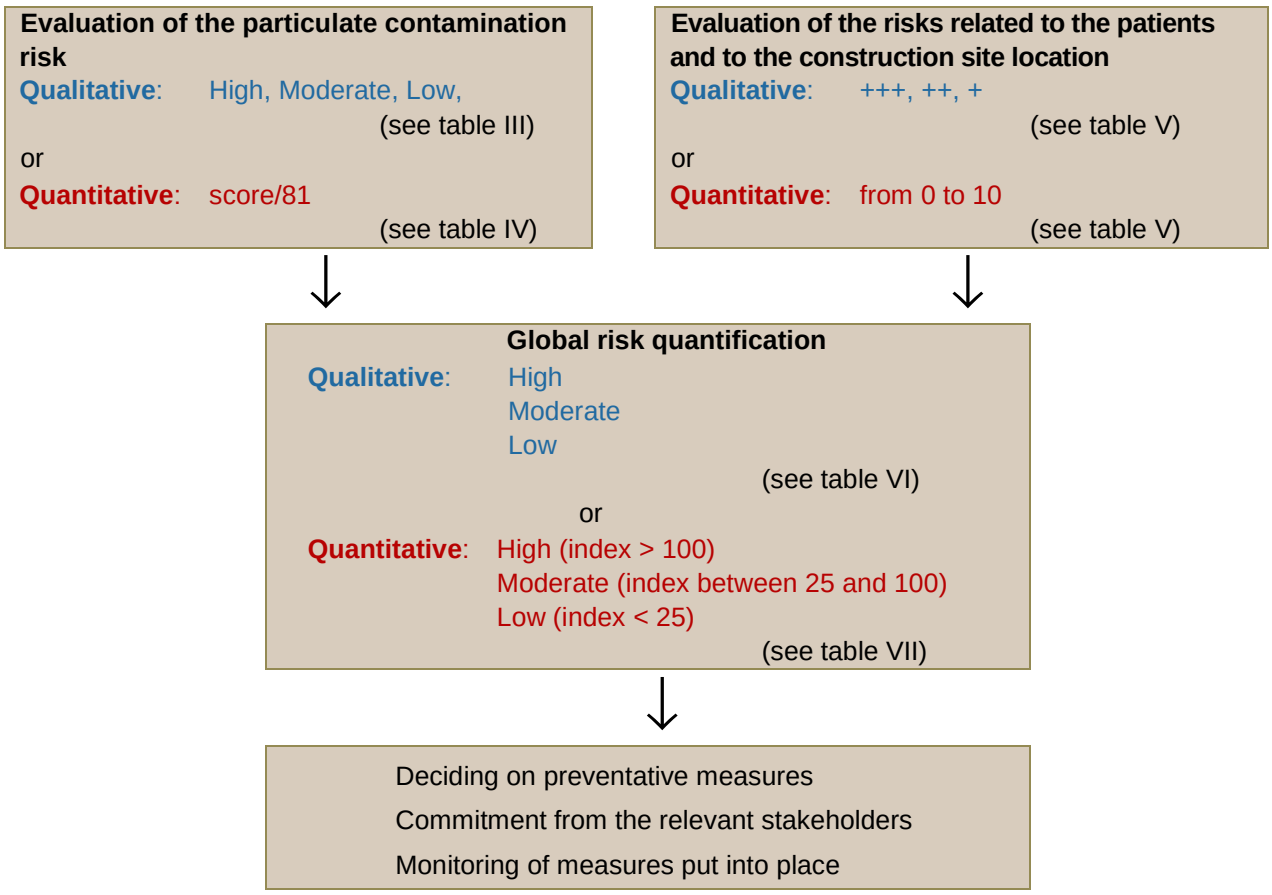
2 - followed by the enclosure, with plasterboard partitioning;

3 - at the end of the construction project, during commissioning of the technical installations, and while reconnecting them to the already operational network, in particular plumbing systems or ventilation ducts.

(II) Phases to be managed in accordance with the organizational resources of the hospital

Two tools may be used, depending on the financial means and organizational resources of the hospital:

Figure 2 Phases* of fungal infectious risk evaluation to be managed according to the organizational resources of the establishment



* Phases and tools are set out in tables III to VII

- the first, **qualitative** tool, does not require expert advice;
- the second, more detailed, **quantitative** tool, may be used if the hospital has a construction work assessment service.

This impact study is in our opinion essential, at least in the case of construction work involving a call for tender.

A/ QUALITATIVE TOOL FOR PARTICULATE CONTAMINATION RISK EVALUATION ACCORDING TO THE TYPE OF CONSTRUCTION WORK.

This evaluation tool is simple to use. The ranking grid is presented in **table III.**

B/ QUANTITATIVE TOOL FOR PARTICULATE CONTAMINATION RISK EVALUATION ACCORDING TO THE TYPE OF CONSTRUCTION WORK.

This evaluation requires close collaboration with the engineer in charge of the construction site, and may be carried out using **table IV.**

At the end of this evaluation, an overall score is given for all eighteen possible stages of the construction work. Thus, for example, demolition work is given a mark out of ten, work involving timber frames is given a mark out of three, ventilation system interventions are given a mark out of five, etc. The weighting factors were established by building professionals, on the basis of the dust proliferation produced. It was tested during two years by the University Hospital of Poitiers (France) on a large number of construction sites, in order to fine-tune the ranking grid.

This tool can be adjusted and validated by each hospital.

It is in the IC specialist's interest to gain a better understanding of the planned activities. This knowledge can be used to greatly enhance the awareness of the construction site manager.

C/ BENCHMARK FOR THE EVALUATION AND QUANTIFICATION OF "PATIENT" RISK, RELATED TO THE LOCATION OF CONSTRUCTION WORK WITH RESPECT TO THAT OF ZONES REQUIRING PROTECTION.

This evaluation is carried out by the Infection Control Team.

The priority elements to be taken into account are:

- The RFI patient population,
- The wards' proximity to the construction site.

Table V provides a qualitative and quantitative evaluation of the "patient" risk.

D/ GLOBAL RISK EVALUATION

This evaluation can be qualitative **(Table VI)** or quantitative **(Table VII).**

At this stage, the various expert studies made by the Infection Control Team and the technical managers are summarized. It will serve as a guide for the implementation of practical construction site protection measures, and for the implementation of preventative measures for RFI patients.

Table III – Qualitative tool for the evaluation of risks, according to the type of construction work [AP-HP Guide 1994, Anonyme Canada 2001, South-West CCLIN, 2006].

Contamination	Typology of construction work
High	Demolition Sandblasting of walls Ventilation system interventions Plastering (plasterboard, insulation ducts) Heavy work on roads, utilities and miscellaneous Plumbing
Moderate	Timber frame Suspended ceiling (+/- dismantling of existing ceiling) Interventions on roller blind casings Flooring (resilient, tiles or resin-based) Indoor joinery Ventilation - Air conditioning
Low	Light work on roads, utilities and miscellaneous (buried networks, earthwork) Structural masonry Landscaping Roofing (with or without tiles) Outdoor joinery (facade, outer cladding, coating) Metal frame, fitting Electricity Wall covering

Tableau IV - Quantitative risk evaluation tool according to the nature of the construction work [South-West CCLIN, 2006]

Type of work	Score
Demolition	/10
Roads, utilities & miscellaneous (heavy)	/10
Roads, utilities & miscellaneous (light)	/3
Foundations	/2
Structural masonry	/3
Timber frame	/5
Covering (with or without tiles)	/1
Outdoor joinery (façade, outer cladding, coating)	/1
Metal frame / locks	/1
Electricity / heating, ventilation and air conditioning (+/- reconnection to existing ducts)	/1
Suspended ceiling ***(+/- dismantling of the existing)***	/5
Intervention on the ventilation system	/10
Intervention on the ducts for the rolling blinds	/5
Wall covering ***(+/- dismantling of the existing)***	/1
Floor covering (resilient, tiles or resin-based floor covering)	/5
Plastering (plasterboards, insulating ducts)	/10
Indoor joinery (timber, PVC, aluminum, glass)	/5
Landscaping	/3
Total	/**81**

Table V - Risk analysis as a function of proximity of the construction work and the hospitalization sector of RFI patients

Area to be protected	"Patient" risk coefficient	
	Qualitative criterion	Qualitative criterion
• Hematology: sterile area	+++	from 5 to 10
• Hematology: standard area with high RFI patients • Organ transplants • Operating rooms or equivalent (cardiac catheterization or interventional radiology, …) • Intensive or critical care	+++	from 5 to 10
	in the case of construction work inside the building	
• Oncology • Other sectors with a protected environment: sterilization, pharmacy (restoration)	++	from 1 to 5
	in the case of nearby construction work inside the building, or in the case of exterior construction work under prevailing winds	
• Standard clinical and surgical wards • Radiology • Laboratories	+ or ++	from 1 to 5
• Offices, public spaces	+	from 0 to 1

Table VI - Qualitative ranking grid for the global level of fungal risk

Contamination	Strong	Moderate	Limited
"Patient" risk			
+++	High	High	Average
++	Average	Average	Low
+	Average	Low	Low

Table VII - Quantitative ranking grid for the global level of fungal risk

Index = score given for the contamination resulting from construction "Patient" risk coefficient	Global fungal risk
> 100	High
25 to 100	Average
< 25	Low

2.b Proposed measures for the management of the risk of fungal infection

2.b.1 Preamble, working method

The RFI preventative measures implemented during construction work of any type can be broken down into several types, according to their objectives:

- Emission reduction measures and confinement of dust in the construction site area;
- Protective measures for RFI patients, designed to distance them from the risk of exposure to bioaerosols;
- Training, awareness and education of patients, families, healthcare personnel, foremen, construction workers and other technical agents needing to be present at the construction site.
- The general approach to be used is as follows:
- make propositions based on data found in the literature, and the field experience of the multidisciplinary working group experts;
- And, for each of these propositions:

1) estimate its feasibility

ranking it from "1" for simple to implement, to "5" for difficult to implement.

2) provide levels of evidence

Category IA. Strong recommendation based on highly conclusive results from well-conducted experimental, clinical or epidemiological studies.

Category IB. Strong recommendation based on results from some well-conducted experimental, clinical or epidemiological studies, or supported by a strong theoretical rationale (or logic).

Category II. Suggested by clinical or epidemiological studies, or by theory (or logic).

Category III. Expert advice. No recommendation. Lack of evidence of efficiency.

3) estimate the importance of this measure

from "A" for very important, to "D" for a precautionary measure.

2.b.2 Determining the necessary management measures

Calendar-based planning of construction work is indispensable to the implementation of management measures.

We distinguish between:

- measures to be implemented for the containment of bioaerosols on the construction site, and to avoid their scattering towards areas in which RFI patients are housed (**Table VIII**);
- measures to be implemented in the area adjacent to the construction activities, in which RFI patients are housed, to protect them from any exposure to bioaerosols emanating from the construction site (**Table IX**).
- measures for the information and protection of persons: patients, visitors, healthcare personnel and construction site workers (**Table X**).

For each measure, the motivation for its implementation depends on the global risk quantification evaluated after the impact analysis, allowing it to be classified as having a low, average or high risk.

It is indispensable, before the beginning of construction work, to prepare the re-opening of the ward. In particular, the following aspects should be planned:

- verification of the ventilation system (cleaning of ducts, changing of filters, testing of particulate contamination …)
- bio-cleaning of the ward. Such planning is indispensable, in order to anticipate the work load it will produce (additional personnel, external service provider, …).

Table VIII - Measures to be implemented for the containment of bioaerosols on the construction site, and to avoid their scattering towards areas in which RFI patients are housed.

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Close the ward in which RFI patients are housed	• Protect RFI patients • **Implement in the case of a high level of risk**	4	II	A	• Transfer RFI patients to another sector or hospital in which the level of environmental pollution is guaranteed and controlled. As this is not always possible, planning and/or phasing of the construction work should be envisaged.	[BOCQUET 1993, Anonymous Canada 2001, Anonymous Ireland 2001, APIC 2005, South-West CCLIN 2006, HAIDUVEN 2009]
Place the area under construction under lower air pressure than the adjacent sectors	• Avoid the scattering of bioaerosols towards adjacent sectors • **Implement in the case of an average level of risk**	3	II	B	• Use efficient air extractors equipped with a highly efficient filtration system	
Erect rigid, waterproof barriers or dust-proof screens, from floor to ceiling, between the area of activity and that under construction	• Isolate the construction site • **Implement in the case of an average or high level of risk**	2	II	A	• Use materials which do not release dust which could be contaminated by filamentary fungal spores	
Minimize the re-suspension of bioaerosols in the area under construction	• Implement containment of construction site bioaerosols • **Implement in the case of a low, average or high level of risk**	2	II	A	• Ensure that the environment remains damp, in order to avoid the re-suspension of dust • Clean access roads on a regular basis • Empty waste from closed containers and/or tarpaulin covered bins • Work with closed doors • Reduce dust produced during drilling, through the use of machines and equipment fitted with a very high efficiency vacuum filtering system	
Practical application	• Isolation of the construction site using plasterboard panels screwed onto metal structures (advantages: rapidly put into place and panels can be cut with a Stanley knife), together with a doorset for access to the construction site • Installation of a 120 micron polyane film on the outside of the partition, to ensure its air-tightness • Use of 3-cm orange or gray duct tape (to be visually checked every day). To be supplemented around fluid ducting and the ceiling (ventilation/electricity/medical fluids), using 80 micron plastic film to ensure the air-tightness of the construction site • Turn off the ventilation system in the area of the construction site, and block all vents with polyane and duct tape to avoid retro-pollution and fouling of the ducts				• Installation of one or several construction site air extractors, in accordance with its surface area, if it is possible to have an external casement • During the dust-removal phase, install a high efficiency air purifier (permanently, or for the duration of construction work in the case of a limited construction area). Foresee disinfection in the absence of any persons, via an aerial route if necessary • Installation of a cloth, to be dampened several times and changed once a day, at the entrance to the construction site. Alternatively, use of a preferably synthetic, non-tearable, non-stick, easily cleanable decontamination mat.	

Table VIII - Measures to be implemented for the containment of bioaerosols on the construction site, and to avoid their scattering towards areas in which RFI patients are housed (contd.)

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Minimize the scattering towards adjacent areas of bioaerosols produced at the construction site	• Protect adjacent zones which have remained active and which still accommodate RFI patients • **Install in the case of a low, average or high risk**	1	II	B	• Remove dust attached to the soles of workers' shoes through the use of easily cleanable, non-stick, non-tearable, decontamination mats.	[BOCQUET 1993, Anonymous Canada 2001, Anonymous Ireland 2001, APIC 2005, South-West CCLIN 2006, HAIDUVEN 2009]
		2	IB	A	• Define one or more circuits for persons, equipment and consumables, so as to avoid the construction area	
	• Protect adjacent areas which have remained in activity and in which RFI patients are housed • **Implement in the case of an average or high risk**	3	IB	A	• Take particular care to avoid the scattering of bioaerosols via stairways, elevator shafts, emergency exits, or even holes / spaces around various ducts	
Practical application	• Isolate the construction site by installing: a polyane protection with telescopic poles (hence the usefulness of zip fasteners) or a partition made of plasterboard panels screwed onto a metal structure • The construction site entrance can make use of a double polyane sheet with weighting on the lower end of the interior sheet • Use of 3-cm orange or gray duct tape (to be visually checked every day). • To be supplemented around fluid ducting and the ceiling (ventilation/electricity/medical fluids), using 80 micron plastic film to ensure the air-tightness of the construction site				• Turn off the ventilation in the construction site area, and block all vents with polyane and duct tape, to avoid retro-pollution and fouling of the ducts • During the dust-removal phase, install a high efficiency air purifier (permanently, or for the duration of construction work in the case of a limited construction area). Foresee disinfection in the absence of any persons, via an aerial route if necessary • Installation of a cloth, to be dampened several times and changed once a day, at the entrance to the construction site. Alternatively, use of a preferably synthetic, non-tearable, non-stick, easily cleanable decontamination mat.	

Table IX - Measures to be implemented in the zone adjacent to construction activity, occupied by patients with a risk of fungal infection, in order to protect them from any exposure to bioaerosols arising from the construction site.

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Seal all exits opening onto the RFI sector to be protected	• Protect RFI patients housed in an area adjacent to the construction area • **Implement in case of low, medium or high risk**	3	IB	A	• Keep doors and windows closed • Seal windows, doors not used for access to the site, holes around water pipes, ventilation ducts	[Bocquet 1993, Anonymous, Ireland 2001, South-East CCLIN 2002]
Ensure sufficient and controlled air quality in hospital rooms. If necessary, relocate consultation rooms	• Protect RFI patients from bioaerosols • **Implement in case of low, medium or high risk**	3	IB	A	• Implement air processing through air filtration using HEPA filters and a sufficient hourly renewal rate to ensure eco-friendly power consumption	[Arnow 1991, Cornet 1999, Anaissie 2002, Gangneux 2002, Benet 2007]
Reduce particulate and biological contamination of the RFI patient's environment	• **Implement in case of high risk**	1	IB	B	• Apply a portable or mobile air cleaning system, using various technologies and having proven its ability to reduce, in a given volume, particulate and biological contamination • Protect RFI patient through unidirectional airflow	[Engelhart 2003, Sautour 2007, Sixt 2007, Poirot 2007, Brenier-Pinchart 2009]
Practical application	• Use 3-cm orange or gray duct tape (to be checked visually every day) Add insulation around fluid conduits and ceilings (ventilation/ power/ medical gases) using 80-micron polyane to complete sealing between the active area and the site • Plug through-holes for piping and medical gases with silicone					
Perform frequent and efficient biocleaning (validated protocol, daily frequency, fungicide having an activity on Aspergillus according to Standard NF EN-1275)	• Remove the spores deposited on surfaces • **Implement in case of low, medium or high risk**	1	IB	A	• Ensure cleanliness of surfaces and limit the time duration of spore deposition on surfaces close to the patient	[Alberti 2001, Anaissie 2002, SFHH 2009]

Table IX - Measures to be implemented in the zone adjacent to construction activity, occupied by patients with a risk of fungal infection, in order to protect them from any exposure to bioaerosols arising from the construction site (Contd.).

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Check proper functionality of air treatment	• Ensure effectiveness of pollution prevention of areas housing RFI patients to be protected • **Implement in case of low, medium or high risk**	1	II	A	• Measure moisture content, air renewal rate, temperature and pressure • Frequency to be defined according to RFI level and RFI area	[POIROT 2007, SAUTOUR 2007]
Ensure effectiveness of measures for actual protection of the RFI area through environmental monitoring	• Ensure effectiveness of pollution prevention of areas housing RFI patients to be protected • **Implement in case of medium or high risk**	2	II	A	• Measure the level of fungal contamination of the air and surfaces with validated methods • Locate samples depending on the site (adjacent to RFI patients, witness areas, ...) • Frequency to be defined according to RFI level and RFI area	[GANGNEUX 2002, GANGNEUX 2006, NIHTINEN 2007, SAUTOUR 2007]
During construction, audit compliance with measures for isolating the construction site and protecting RFI patients	• Check observance of implemented measures • **Implement in case of low, medium or high risk**	1	II	A	• Measures for isolating the construction site, protecting RFI patients, compliance with circuits, biocleaning	[South-West CCLIN 2006]

Table X - Measures to inform and protect persons: patients, visitors, healthcare personnel and construction site workers.

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Concerning the RFI patient	**The RFI patient and his/her family should be trained, made aware and educated to avoid or minimize exposure to spores of filamentous fungi**					
Raise awareness of, and inform the RFI patient and his/her family, about fungal risk, in particular aspergillus, during periods of construction work	• Insist on the importance of RFI prevention measures put in place and their observance • **Implement in case of low, medium or high risk**	1	II	A	• Explain and enforce the measures proposed • Usefulness of a written document	[Anonymous Ireland 2001]
Define paths through construction sites	• Ensure movements without RFI exposure • **Implement in case of medium or high risk**	2	IB	A	• Place signs and organize well-marked paths	[BOCQUET 1993, SFHH 2000, Anonymous Canada 2001, Anonymous Ireland 2001, South-East CCLIN 2002, MMWR 2004, BERTHELOT 2006]
Precautions in case of movement and protective isolation	• **Implement in case of medium or high risk**	1	IB	A	• Limit movements • Have type FFP2 filtering respirator, a cap, and a gown be worn if the patient is usually under protective isolation	[South-East CCLIN 2002, MMWR 2004, BERTHELOT 2006]
Protective isolation	• Any patient with very high and high risk of fungal infection • **Implement in cases of high risk**	1	IB	A	• Standard protective measures must be ensured during the construction period: prohibition of plants, food or herbs that may be contaminated with spores, decontamination protocols for food and personal effects entering the protected area	[SFHH 2000, MMWR 2004, GANGNEUX 2004, BERTHELOT 2006]
Transfer RFI patients to a sector or ward less exposed to bioaerosols	• If protective measures are inadequate or difficult to put in place sustainably • **Implement in case of high risk**	2	IB	A	• Transfer of RFI patients (with necessary precautions) or partial closure of the ward or limitation/modulation of admissions before and during construction	[BOCQUET 1993, SFHH 2000, Anonymous Canada 2001, Anonymous Ireland 2001, BERTHELOT 2006]

Table X - Measures to inform and protect persons: patients, visitors, healthcare personnel and construction site workers (Contd.).

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Primary antifungal chemoprophylaxis	• Limit the infection in patients identified with a high to very high RFI • **Implement in case of high risk**	2	II	B/C	• Prophylaxis may be discussed on a case by case basis depending on notices of compliance	[SFHH 2000, Anonymous Ireland 2001]
Diagnostic surveillance of invasive fungal infections	• Early management of invasive fungal infections in RFI patients • **Implement in case of low, medium or high risk**	1	IB	A	• Association of clinical, mycological and imaging (scanner) information • Importance of monitoring the kinetics of aspergillus antigenemia • Role of the detection of beta glucan and PCR during assessment	[SFHH 2000, MORRISSON 2004]
When visiting the RFI patient	**The transfer of spores between the construction zone and the protected zone housing the RFI patient must be reduced**					
Organize circuits outside the construction zone	• For any protected zone housing RFI patients • **Implement in case of low, medium or high risk**	2	IB	A	• Place signs and organize well-marked paths	[BOCQUET 1993, SFHH 2000, Anonymous Canada 2001, Anonymous Ireland 2001, South-East CCLIN 2002, MMWR 2004, BERTHELOT 2006]
Restrict the number of visits		2	II	B		
Raise RFI awareness		1	II	B		
Concerning healthcare personnel	**Permanent or part-time healthcare, medical and paramedical professionals should be trained, made aware and educated**					
Train, inform and educate healthcare personnel	• Increase the understanding of RFI both in everyday life and in the work environment • **Implement in case of high risk**	1	I	A	• To identify RFI patients and maintain vigilance with respect to these patients • To educate the patients and their families • To observe and enforce preventative measures	[BOCQUET 1993, SFHH 2000, Anonymous Canada 2001, Anonymous Ireland 2001, South_East CCLIN 2002, MMWR 2004, BERTHELOT 2006]
Raise awareness of the health facility's entire staff		2	I	A	• Comprehensive policy for the prevention of RFI • Enforce or impose such measures	
Regular updates on the progress of construction work	• Increase awareness on the RFI associated with construction work • **Implement in case of low, medium or high risk**	2	II	A	• Motivate caregivers to comply with protective measures	[SFHH 2000]

Table X - Measures to inform and protect persons: patients, visitors, healthcare personnel and construction site workers (Contd.)

Measure	Indication	Feasibility	Level of evidence	Importance and/or usefulness	Comments	Relevant literature
Diagnostic monitoring of invasive fungal infections and establishment of a review of morbidity and mortality in an aspergillosis unit	• Identification, early management and recording of cases of invasive filamentous fungi • **Implement in case of high risk**	1	IB	A	• Mapping of RFI patients to maintain vigilance in areas at risk • Detection of clustered cases and internal reporting	[SFHH 2000, ALBERTI 2001, MMWR 2004]
Circulation plan outside the construction site	• Reduce the transfer of spores of filamentous fungi in the protected area with RFI patients • Implement in case of low, medium or high risk	2	IB	A	• Implement clear and specific signs	[BOCQUET 1993, SFHH 2000, Anonymous Canada 2001, Anonymous Ireland 2001, South_East CCLIN 2002, MMWR 2004, BERTHELOT 2006]
Concerning construction workers	**Construction site workers should be trained, made aware and educated to observe the measures put in place for the prevention of RFI**					
Training and informing technical staff	• Better understanding of RFI, to accept being required to comply with measures for the prevention of bioaerosol scattering • **Implement in case of low, medium or high risk**	1	II	A	• Motivate the technical staff in charge of maintaining and repairing the air treatment and atmosphere purification systems	[SFHH 2000]
Training and informing workers on the construction site		3	II	A	• Advise on measures for isolating the site, circuits, and various measures to reduce the scattering of bioaerosols from the construction site towards adjacent areas	

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Question 3

Quantitative assessment of risk: proposed indicators for the determination of the impact of management precautions on the risk of fungal infection

Key words: Impact Indicators – Environmental Surveillance – Epidemiological Surveillance

3.a Environmental monitoring of the construction site and impact on management precautions

3.a.1 Checks to be made in the area affected by construction work

Measures must be taken, in accordance with the areas at risk, the patients and the facilities available within the hospital. They must be validated by the CLIN and be integrated into the sanitary notebook.

Visual checks

The hospitalization department team must carry out these checks, of which, for example, the following must be performed on a regular basis:

- doors tightly sealed (using adhesive tape for example),
- windows closed,
- ground dust collection mat checked and replaced (at least daily, and whenever it is clearly saturated),
- obvious presence of dust (clouds, footprints, dusty surfaces ...).

Checking the negative pressure in the construction zone

If a vacuum system has been installed, it must be checked in order to ensure non-contamination of areas adjacent to the construction site. Traceability must be ensured and be made available should an incident arise.

Particulate checks

These are to be made periodically during construction, only in areas with a controlled environment, and when construction has been completed. They should be made outside periods of activity. The results should be identical to those found before the construction work.

Fungal biocontamination checks of the air and surfaces

- During construction work, the so-called "protected" areas where immuno-suppressed patients reside for prolonged periods (areas equipped with a highly efficient air conditioning system) should undergo weekly monitoring of the air and surfaces.
- For other areas under construction, where RFI patients reside, a check must be planned at least at the end of the construction work, following bio-cleaning of the premises. In addition, the CLIN may propose bi-monthly or monthly monitoring, to track the overall level of airborne contamination.

Standardized methods have been proposed for environmental sampling, designed to detect fungi in the hospital sector [GANGNEUX 2002]. Fungal biocontamination checks must also be associated with bacterial monitoring, in order to verify compliance with the corresponding ISO class, if the construction work was carried out in an environmentally controlled area.

Frequency and persons responsible for checks

As shown in **Table XI**, the working group proposes a specific frequency for each type of check, based on the RFI level of the various hospital sectors, and identifies the persons who should be responsible for them.

3.a.2 Interpretation of the results in a protected unit (target values, alert thresholds)

The interpretation of the results shown in **Table XII** has been adapted from the expected values proposed by a multidisciplinary working group, in a normal situation in the absence of ongoing construction work [GANGNEUX 2002]. A good knowledge of the local ecology and the average levels of fungal biocontamination in a given hospital, established by regular monitoring, can allow these expected values to be refined internally.

In protected areas, the critical values in the patient's room are as follows:

- air sampling: target value = alert value = no fungal spores
- sampling of surfaces: target value = alert value = no Aspergillus spores.

If the expected result is not consistent with the target value in a protected area, it is necessary to:

- conduct thorough biocleaning in contaminated rooms (including bathroom and airlocks);
- verify correct management of the room's doors and windows, airlocks ...
- check the maintenance and servicing of air ducts and/or rooms in the ward (clean ducts, protection ...);
- check quality of the filtration system (pressure drop ...);

(Table XII).

- ensure maintenance of air vents (cleanliness ...);
- then perform a new fungal check +/- particle counting.

In the case of a return to a fungal level which is normal, or considered as such, the frequency of monitoring should be increased to confirm this return to normality. If the results remain unsatisfactory, a thorough investigation must be initiated, and measures be taken by the ICT and the aspergillosis team to protect patients (through biocleaning, followed by disinfection with a fungicide disinfectant which complies with the NF-EN 1275 standard).

3.a.3 Compliance audits in the construction area, monitoring by means of "works sheets" or "fungal risk" sheets

Establishing fast auditing or "Quick Audits" is recommended whenever construction work is being monitored (Figure 3).

3.a.4 Surveillance in other zones of the hospital

In the absence of air conditioning, and despite the strict application of general hygiene practices (or even when additional air cleaning devices are installed), it is difficult to interpret the results provided by monitoring efforts

Table XI - Proposed frequency of environmental monitoring to be implemented, and responsibilities.

Overall quantification of risk	Monitoring Frequency and persons in charge				
	Visual Healthcare Unit	Pressure Technical Staff	Particulates ICT	Airborne contamination ICT/Laboratories	Surfaces ICT/Laboratories
High "Protected" area	Once daily	Once daily	End of construction	Once weekly and at the end of construction work	Once weekly and end of construction work
High Other areas	Once daily	Once daily	—	Period to be defined by the CLIN** and end of construction work	End of construction work
Average	Once daily	—	—	—	End of construction work
Low	Once weekly	—	—	—	—

ICT: Infection Control Team (or internal or external sampler)

*Technical Department or Biomedical Department (Work Supervisor)

**For information and according to the duration of construction work, once or twice monthly.

Figure 3 - Proposal for a Quick Audit Sheet, according to [Carter 1997]

Quick Audit Sheet

Ongoing construction work: ……

Department …… **Date** ……

Barriers put in place			
Signs displayed?	Yes ☐	No ☐	NA ☐
Doors	Yes ☐	No ☐	NA ☐
Common premises: properly closed	Yes ☐	No ☐	NA ☐
Rooms: properly closed	Yes ☐	No ☐	NA ☐
Clean floor surface, no conspicuous dust	Yes ☐	No ☐	NA ☐
Air conditioning			
Windows shut in the construction area	Yes ☐	No ☐	NA ☐
Negative pressure functional	Yes ☐	No ☐	NA ☐
Construction area			
Rubble removed in covered containers	Yes ☐	No ☐	NA ☐
Cleaning of construction site	Yes ☐	No ☐	NA ☐
Movement			
Restricted to workers	Yes ☐	No ☐	NA ☐
Restricted to required care staff	Yes ☐	No ☐	NA ☐
Waste disposal duly performed	Yes ☐	No ☐	NA ☐
Persons outside the department (visitors…) are informed of precautions to be observed	Yes ☐	No ☐	NA ☐
Clothing			
Compliant with regulations in areas providing access to the construction site (e.g. operating rooms, high-risk units…)	Yes ☐	No ☐	NA ☐

If not compliant, by whom: care staff ☐, technical staff ☐, other ☐

Specify: ……

NA: Not Adapted to the situation

Regular monitoring in sentinel areas may be proposed by the CLIN, to measure the impact of management measures on the transfer of environmental risk from the construction site to adjacent areas. This can be done through visual monitoring and/or fungal control. Several practical examples can be cited: (i) monthly monitoring of airborne bio-contamination

in the lobbies of three care units close to an excavation site showed the effectiveness of site containment (Rennes University Hospital experiment);

(ii) at the Besançon University Hospital, weekly monitoring of fungal contamination of the main hospital corridors and those of a hematology department was conducted from 2002 to 2009 (3474 air and 1737 surface samples). In particular, these actions allowed at 40 CFU/m^3 of air, for potentially pathogenic fungal species, and the monitoring of any change in these species, were used as indicators for the mobilization of

construction

the degree of exposure experienced by patients accessing departments, and going to the radiology department or to the pharmacy (to pick up medication), to be determined. In this study, a threshold set

teams in charge of the health units under study [HOUDEROUGE 2009].

Table XII - Proposed interpretation of the results of fungus-oriented environmental monitoring, according to [Gangneux 2002].

Area	Local	Air sampling	Surface Sampling
Protected (with air conditioning)	Patient's room	No fungal spores	• Under laminar flow: no fungal spores • Other areas: tolerance for very rare Colony Forming Units (CFUs) of fungal spores per sample with no *Aspergillus**
	Common areas	Tolerance for very rare CFUs per sample with no *Aspergillus***	Tolerance for very rare CFUs per sample with no *Aspergillus****
Other areas	Patient's room and common areas	Expected results difficult to define in a non-protected environment. Only changes in biocontamination over time, occurring during construction work, or changes in comparison with baseline levels measured before the construction began, will be interpreted.	Expected results are difficult to define consistently and unequivocally. Only changes in bio-contamination over time, with respect to a baseline level, will be considered to be associated with the risk management effort.

By way of indication, in a normal situation in the absence of construction work,

*A tolerance of 2 CFUs/sample is accepted for a 25 cm^2 surface sample,

** A tolerance of 2 CFUs/sample is accepted for a one m^3 air sample,

*** A tolerance of 5 CFUs/sample is accepted for a 25 cm^2 surface sample.

3.b Epidemiological surveillance of cases and impact on construction work

3.b.1 Analysis of the relationship: "environmental fungal pollution and the risk of fungal infection"

Numerous descriptive studies reveal a correlation between the occurrence of aspergillosis outbreaks, or an increase in the rate of aspergillosis, and construction work. Several literature reviews or guides dealing with the prevention of aspergillosis provide details of the types of construction work involved and the likely origin of fungal pollution (see Question 1).

a) Relationship between quantitative environmental contamination and risk of aspergillus infection

Although the relationship between construction work and aspergillus risk is well established, qualitatively and descriptively, it is still very difficult to establish in quantifiable terms, given the highly fluctuating nature of fungal contamination and the influence of measurement uncertainties. In a review of twenty-four outbreaks during which measurements were made of airborne contamination, the measured values varied significantly (0 -> 235 CFU/m^3), depending on the outbreak and the sampled sites [VONBERG 2006].

To this must be added the difficulty in statistically demonstrating the existence of a relationship between frequent and highly variable events (fungal contamination), and rare events such as invasive aspergillosis, the rates of incidence of which have been modified by primary prophylaxis and empirical treatment practices.

Three approaches could help characterize this relationship and attempt to define a level of contamination above which the risk of aspergillosis would be increased.

COMPREHENSIVE STUDY OF EPIDEMICS

This approach is, a priori, more efficient, but in practice very few studies of epidemics include both clinical and mycological data obtained on a continuous basis. The most relevant is probably the study of

ARNOW et al. [ARNOW 1991], which involved a six-year clinical and mycological follow-up, during which one aspergillosis outbreak occurred and was brought under control. The authors were able to observe that the airborne concentration of Aspergillus was < 0.2 CFU/m^3 in pre- and post-epidemic periods, versus 1.1 to 2.2 CFU/m^3 during the epidemic outbreak.

Table XIII - Summary of protocols for the study of the relationship between environmental fungal contamination and the rate of invasive aspergillosis

Authors	Follow-up duration (months)	Clinical department	Measurement of airborne contamination	Number of invasive aspergillosis cases	Correlation between contamination rate and IA*	Comments
HOSPENTHAL 1998	13	Oncology	Yes	6	No	
MAHIEU 2000	11	Neonatal (3 departments)	Yes	0 cases of IA Measurement of pharyngeal carriage	No	Efficacy of HEPA air purifier
ALBERTI 2011	48	Hematology (3 departments)	Yes 12900 samples (3100 from the air and 9800 from surfaces)	64	Yes	Correlation between IA risk and use of conventional rooms
LAI 2001	6	Hematology	Yes	6	No	Efficacy of HEPA air filtration
FALVEY 2007	120	Hospital	Yes 1523 air samples	1	No	
PINI 2008	14	Hematology	Yes twice/month i.e. 270 samples			
	7	Yes During construction	3 cases of IA during construction / High rate of *Aspergillus*			
RUPP 2008	84	Hematology	Yes 972 air samples	45	No	

IA: Invasive Aspergillosis.

STUDY OF THE IMPACT OF AIR TREATMENT MEASURES

Several air conditioning processes allow airborne fungal contamination to be reduced, and several studies have shown that a reduction in the incidence of aspergillosis can be observed in units benefiting from such air conditioning. Through these studies, it would be possible to indirectly estimate the level of contamination associated with a lower rate of aspergillosis. It is on this basis, SHERERTZ et al. [SHERERTZ 1987] concluded that there is no risk of aspergillosis when the airborne contamination from Aspergillus is < 0.009 CFU/m^3 (some experts consider the calculation method to be debatable). Similarly, RHAME et al. [RHAME 1984] consider the risk of aspergillosis to be significantly reduced in marrow transplant recipients when the concentration of A. fumigatus is <0.9 CFU/m^3.

More recently, the study by ARAUJO et al. [ARAUJO 2008] demonstrated the major clinical, environmental and economic impact of the implementation of systems providing controlled clean air in areas where severely compromised patients (immunocompromised, marrow transplant recipients) are hospitalized.

The first period (before the system's installation) lasted fourteen months, during which a total of 198 admissions were recorded. The second period (following installation) was of the same duration, with 205 patients admitted. Six confirmed cases of fungal infection, with two deaths, occurred during the first period. No confirmed or probable fungal infection was observed during the second period. Fungal

contamination of the air was reduced by 50% (during the first week of ventilation), and by 95% (in the following weeks) during the second period. Moreover, the patients' hospital stays were reduced by an average of three days in the second period. The consumption of antifungal drugs was reduced by approximately 60%, with a marked decrease in the cost of antifungal therapy (-17.4%) during the second period.

THE PROSPECTIVE APPROACH (**Table XIII**)

This is the only possible approach to a rigorous analysis of the relationship between environmental contamination and the incidence of aspergillosis, but is subject to a number of challenges and biases:

- uncertainty and variability of fungal contamination measurements;
- difficulty in diagnosing invasive aspergillosis;
- difficulty in confirming the nosocomial nature of the infection (in order to relate it to contamination of the hospital environment);
- low rate of aspergillosis and difficulty or lack of relevance of the statistical analyses.

In the literature, one can find only a few prospective studies of this type that are sufficiently comprehensive in terms of the duration of the monitoring period and the observed incidence rate. Their results diverge, depending on the methodology used, and the conclusions are sometimes different.

HOSPENTHAL *et al.*, 1998

A 54-week prospective study in oncology, covering air contamination only: six cases of aspergillosis during the observation period, unrelated to airborne contamination, but with no statistical analysis performed.

MAHIEU *et al.*, 2000

An 11-month study showing no relationship between fungal contamination of the environment and infection or carriage rates in a neonatal unit, during a period of construction work (with HEPA protection).

ALBERTI *et al.*, 2001

A 4-year prospective study in three hematology departments. Through a time series analysis of 64 cases of aspergillosis considered to be nosocomial and 12900 air or surface samples, significant and directional links were revealed between the occurrence of cases and contamination of the air and surfaces by Aspergillus or other filamentous fungi, in the three studied wards, in particular in the common parts of these wards. This correlation is no longer significant if values > 2 CFU/m^3 are removed from the analysis, which could mean that the risk threshold is 2 CFU/m^3.

LAI *et al.*, 2001

This study was restricted to a period of several months following the completion of construction work, and showed no relationship (no statistical analysis was performed) between air contamination and colonization rate of marrow transplant patients.

FALVEY *et al.*, 2007

A follow-up study of airborne contamination covering a ten-year period, revealed 48 transient increases in contamination (sporadic bursts), with one possibly related case of aspergillosis. The incidence rate data for aspergillosis was not specified.

PINI *et al.*, 2008

A fourteen-month study, in which an outbreak was suspected in relation to cases of aspergillosis during a period of construction work, and in association with an increase in the airborne concentration of fungi. The increase in the concentration of Aspergillus in the corridors appeared to be correlated with the occurrence of aspergillosis.

RUPP *et al.*, 2008

A prospective study, covering a period of seven years in a hematopoietic stem cell transplant unit. Weekly monitoring of air contamination and the analysis of related cases of aspergillosis (45 cases), occurring within 14 to 28 days, depending on the level of contamination (greater than 15 CFU/m^3, between 5 and 15 CFU/m^3, and negative), were carried out. Due to the lack of a significant difference in incidence rate between the different periods, the authors concluded on the poor predictive value of mycological analyses, and low benefits of weekly monitoring.

b) Effect of site protective measures on the reduction of environmental fungal contamination and number of cases

In most cases, multiple protection measures are taken during construction work of any kind, so that the effectiveness of individual measures is difficult to assess.

A small number of studies have attempted to implement such an assessment:

- reduction in air contamination or aspergillosis incidence rate, following the installation of a central air conditioning system with HEPA filtration, in care units [Sherertz 1987, Benet 2007], or in units equipped with HEPA filters, compared with non-equipped units [Cornet 1999]. The benefit of HEPA filtration on mortality and the incidence of fungal

infections is, however, questioned in a meta-analysis covering 16 studies [Eckmanns 2006];

- reduction in fungal contamination of the air by means of protective barriers, the use of a portable HEPA unit, and the application of "copper-8quinolinolate" [OPAL 1986];
- reduction in air and surface contamination in rooms equipped with Plasmair level of contamination maintained at < 5 CFU/m3, equivalent to that observed in an area with no construction work [Sautour 2007, Bergeron 2007] ;
- significant reduction in airborne contamination by Aspergillus in a neonatal unit using mobile filtration units from Medic CleanAir Forte, Willebroek, Belgium [Mahieu 2000];
- reduction by 2/3 in air contamination in rooms equipped with an Enviracaire® air purifier which can reduce the "fungal pressure", but does not eliminate contamination peaks [Poirot 2000];
- reduction in contamination through the use of a NSA 7100A / B mobile unit, associated however with a negative opinion concerning the systematic use of these devices, as a consequence of their associated disturbances (noise, heat) [Engelhart 2003].

Several other studies are less targeted, and reveal a certain degree of efficiency for combined measures, in terms of the fungal contamination of the environment, or a reduction in the incidence of aspergillosis [LOO 1996, ARNOW 1991, ARAUJO 2008].

Indirectly, the effectiveness of protective measures was also considered to be good with respect to the observed absence of a significant relationship between the number of construction sites and fungal contamination of the environment by Aspergillus, or the incidence of invasive aspergillosis in hematology departments [BERTHELOT 2006].

A summary of the protocols used to study the relationship between environmental fungal contamination and the incidence of invasive aspergillosis is proposed in Table XIII.

3.b.2 Benefits of epidemiological surveillance of invasive fungal infections

The rigorous and exhaustive epidemiological surveillance of fungal infections during periods of construction work represents:

- the final indicator for the beneficial effects of preventive measures;
- a tool for the detection of grouped cases and/or epidemics, allowing corrective measures to be considered.

a) Creation of a local structure for epidemiological surveillance

Several recommendations emphasize the value of a local structure for the epidemiological surveillance of invasive aspergillosis (aspergillosis committee, aspergillus unit, or other denominations) during periods of construction work, or better still on a permanent basis, for the prospective analysis of cases [MMWR 1997, SFHH 2000, Anonymous Canada 2001]. The French consensus conference thus emphasizes the importance of establishing a specific operational task force dedicated to the surveillance of aspergillosis. This task force must combine all of the competences directly required for its prevention, and should include all of the following actors: infection control specialists, mycologists, representatives of the wards in which the patients at risk are hospitalized, engineer in charge of construction, health-safety coordinator, and representatives from the administration. As a result of its multidisciplinary composition, the task force combines the roles of interface and coordination, thereby providing input to the specifications, information and training associated with the protective and corrective measures, and the surveillance and reporting of cases. Similarly, the Health Canada guide 2001 explains that "it is essential to have a multidisciplinary team which establishes clear communication channels", to ensure that the "communication plan is observed throughout the full duration of the construction project". This guide adds that "the protection of patients relies on the acceptance of measures for the prevention of fungal infections, and on the way in which they are implemented. Achieving these objectives requires a strong commitment, in-depth understanding, and the continued collaboration of all personnel involved".

In practice, many hospitals have already implemented such a task force, often in the form of a CLIN subcommittee. The most relevant experience indicates the need for diversity and complementarity of the actors in this committee: infection control team, clinicians from the wards at risk, mycologists or biologists, radiologists, anatomic pathologists, pharmacologists and construction engineers [BOCQUET 1995, DEROIN 1996, BIENTZ 1999, FAURE 2002, KAUFMANN-LACROIX 2004]. A permanent organization permits the epidemiological observation of cases (including discussion of the relevance of making an external report), and also the rapid implementation of a crisis centre in the case of an epidemic alert.

Some particular cases have been published. During periods of construction, in the absence of an

epidemic context, the organization established at the Saint-Etienne University hospital (France) emphasized the advantages of a truly multidisciplinary strategy, and showed that between 1993 and 2001, a significant reduction was achieved in the incidence of IA in an adult hematology ward [BERTHELOT 2006]. The incidence decreased from 1.19/1000 patients to 0.21/1000 patients, following an improvement to the air filtration system, the implementation of specific hygiene measures whenever there was construction work, the use of high filtration masks, and the monitoring of air contamination by taking air and surface samples. In a global analysis covering a four-year period, the team from the Saint-Louis hospital in Paris demonstrated that there was a significant correlation between fungal contamination of the environment (air/surface) and the incidence of IA [ALBERTI 2001].

b) The investigation of clusters of cases or epidemics

Many IA epidemics have been reported in the scientific literature [HOPLINS 1989, HUMPHREYS 1991, IWEN 1994, KRASINSKI 1985, LENTINO 1982, LOO 1996, MEHTA 1990]. Only the team of IWEN et al. in 1994 showed, thanks to aerobiological monitoring, that the epidemic outbreak in their hospital was correlated with an increase in the quantity of filamentary fungal spores in the air. Using an air-sampling method based on a box sedimentation technique, and swabs to take surface samples, the authors showed that there was an increase from 0.43 CFU/h/box for the basic rate, to 2.44 CFU/h/box (p=0.02) at the beginning of the construction work, followed by a decrease to 0.80 CFU/h/box (p=0.02) following the application of hygiene measures. These results were correlated with those given by the surface samples. In the rooms with a high level of biocontamination, five new cases of IA were reported. Similarly, PINI et al. evaluated the aspergillus contamination during and after renovation work in a hematology ward over a period of two years (2002-2005) [PINI 2007]. In this paper, the authors note seven probable and/or possible cases of IA, in their opinion correlated with an increase in the airborne concentration of *A. fumigatus*. In reality, there was on only one occasion an increase, to a level of 1.99 CFU/m^3, in the concentration of *A. fumigatus* in limited access rooms. The remaining data was related to the corridors, where there was an increase in the concentration of *A. fumigatus*, between 2.98 and 4.17 CFU/m^3. It is difficult to determine whether there was a simultaneous increase in the incidence of IA, since the incidence rates, and the usual number of cases, were not specified. Finally, ARNOW et al. monitored the air for a period of 77 months and showed that the level of *A. fumigatus* contamination could increase from $\leq$ 0.2 CFU/m^3 to 1.1 - 2.2 CFU/m^3, with an IA incidence rate increasing from 0.3% to 1.2% [ARNOW 1991].

In the hygiene guides of most French hospitals, it is pointed out that an investigation can be requested by the CLIN or the ICT aspergillus committee in the following situations: a significant increase in IA, or even following the report of a nosocomial IA. The proposed procedure then includes the various steps described by GACHIE [GACHIE 2000]: exhaustive search for any other cases, measurements of the level of air and surface contamination, and description of the spatial localization of cases. The preparation of a map allows a malfunction of the air treatment systems to be suspected, and/or a localized source, potentially related to construction work, to be identified (cf. Question 1: hospital construction work producing environmental fungal pollution). In some circumstances, the environmental investigation does not necessarily allow a precise cause to be determined [POIROT 1986, LEENDERS 1996].

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Question 4

Areas of responsibility for fungal risk in the case of construction work, and impact of grouped cases on the organization of construction work

Keywords: Responsibilities – nosocomial infection – external reporting.

4.a Defining areas of responsibility for fungal risk in the case of construction work

Construction work leads to a considerable increase in the risk of environmental contamination. However, the unavoidable nature of such works and the need to ensure continuity in hospital care implies prior evaluation of the risk of hospital environment contamination, and the proposal or reinforcement of preventive measures, to ensure their continuity, and whenever applicable the management of alerts and crisis situations. The completion of these different steps may require additional personnel, ranging from healthcare professions to technical trades. The purpose of this reinforcement is to ensure satisfactory implementation of the additional work arising during the construction work.

In order to ensure correct harmonization of the various processes, the responsibilities of each person, during each step, must be clearly defined.

In each hospital, a consensus is needed in order to define the different responsibilities, as summarized in **Table XIV**.

4.b Impact of grouped cases or of an epidemic on the organization of construction work

According to the recommendations of the US Centers for Disease Control and Prevention [MMWR 1997], whereas the discovery of one single case may or may not initiate an investigation, this becomes a requirement as soon as two temporally and spatially grouped cases occur.

In order to correctly implement the surveillance and initiate the required actions (Figure 4), it is necessary to define, on the one hand what is meant by aspergillosis or any other invasive fungal infection, and on the other hand its nosocomial character. These steps must therefore be implemented by calling on all of the relevant disciplines (clinical, hygiene, mycology, etc.), under the auspices of the CLIN or the aspergillus unit if it exists.

a) Definition of invasive aspergillosis and more generally of IFIs

These were recently updated in the context of the EORTC/MSG international working groups, and are provided in the Appendix [DE PAUW 2008].

b) Definition of its nosocomial character

An infection is qualified as being nosocomial when it is associated with care carried out in a hospital.

A case of invasive aspergillosis is recognized as being nosocomial when it occurs during or following hospitalization, and was neither present nor incubating at the time of the patient's admission to hospital. These criteria are difficult to appreciate as a result of a poorly known and variable incubation time, ranging from several days to three months, according to different studies.

The two most frequent situations are:

Table XIV – Summary of areas of responsibility during periods of construction work in a hospital

Areas of responsibility	Actors	Validation	Management of anomalies
Analysis of impacts	Management CLIN-ICT	Management CLIN-ICT	
Preventive measures	Management CLIN-ICT	Management (decision-making) CLIN-ICT	
Construction work monitoring:			
• Measures relevant to construction companies	Management	Management CLIN-ICT Companies	Management CLIN-ICT Companies
• Measures relevant to the medical sector	Head of cluster Head of department Executive	CLIN-ICT Head of cluster Head of department Executive	Management CLIN-ICT Head of cluster Head of department Executive
Environmental surveillance			
• Repair and maintenance of protective systems (air-treatment, …)	Management ICT	Management CLIN-ICT	Management
• Monitoring and analysis of results	ICT Laboratories	ICT Laboratories	CLIN-ICT
Epidemiological monitoring of cases, investigation of grouped cases	CLIN-ICT-aspergillus unit Head of cluster Head of department Executive Laboratories	CLIN-ICT Head of cluster Head of department Executive	CLIN-ICT-aspergillus unit Head of cluster Head of department Executive

- the nosocomial character is excluded, when the patient is hospitalized with an already established diagnosis, or with the presence of signs at the time of admission;
- the nosocomial character is considered to be possible when diagnosed signs appear in patients having been hospitalized for at least seven days.

c) When should an internal report be made?

Invasive aspergillosis and other proven or probable IFI, whose possible nosocomial character is collegially recognized (by clinicians, the CLIN and/or the aspergillosis unit), must be internally reported (**Table XV**).

d) What actions should be proposed in the case of an internal report?

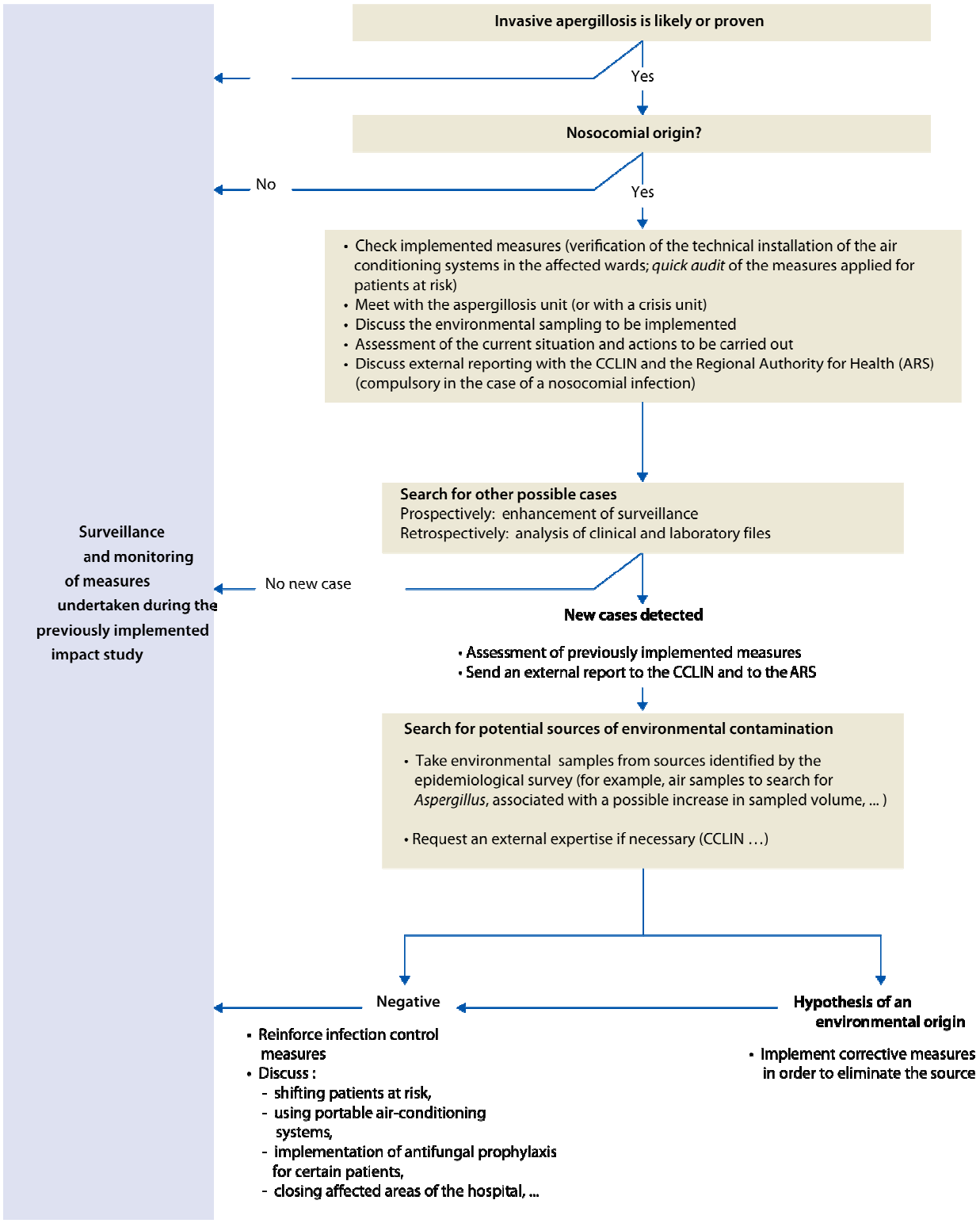
It is essential to:

- Ensure that the patients at risk are provided with suitable protection (especially when construction work is being carried out nearby).

Table XV – When should an external report be made?

Diagnostic classification of an IFI according to the EORTC	Nosocomial character	Reporting
IFI possible	excluded	-
	possible	-
IFI likely	excluded	-
	possible	Reporting to be considered by the CLIN
IFI proven	excluded	-
	possible	Systematic reporting

Figure 4 - Actions to be implemented following a declaration to the CLIN of a case of invasive aspergillosis during construction work.



- Search for other possible cases:
  - prospectively: implementation or reinforcement of the surveillance of new cases of IFI among hospitalized patients;
  - retrospectively: on the basis of mycological, histological and pharmaceutical data;
- If no other new cases are reported, revert to normal surveillance and previously existing protocols in the units at risk;
- If new cases are detected, an environmental survey must be undertaken in order to localize the source of contamination, i.e.:
  - analysis of the hygiene procedures, and verification of the technical installations of the air treatment system in the affected wards is imperative;
  - sampling (air and/or surface) must be carried out on all premises where Aspergillus and other fungi could develop. As a result of the transience of the aspergillus cloud, surface contamination is more significant than the presence of aspergillus spores in the air;
  - depending on the outcome of isolation, typing analysis could be envisaged, in order to compare the strains found in patients with those in the environment (these analyses are complex and require a large number of samples over a long period of time, for the results to be meaningful. According to the present state-of-the-art, the contribution of molecular biology to the investigation of grouped cases of invasive aspergillosis is often disappointing. In the large majority of cases, a common source of contamination can indeed only be demonstrated using these methods. This does not however remove the possibly nosocomial character of the infection (an identical strain in the patient and the environment, or in several patients, when demonstrated using an appropriate technique, may be a strong indicator, but does not provide proof). Currently, the routine use of molecular biology techniques is not recommended, with the exception of the case of specific epidemiological protocols or studies;
  - if no source of contamination can be detected in the environment, the hygiene procedures and technical verification of the air treatment system in the relevant wards must be carried out systematically, in order to identify weaknesses or other aspects requiring improvement.
- Any investigation must be initiated in accordance with a procedure defined by the CLIN, either by the risk management executive, or the vigilance committee if it exists, or by another existing structure (risk directorate or risk observatory, for example).
- Following this analysis, if one or more infections have been confirmed as being directly related to the construction work, they must be **externally reported to the territorial directorate of the regional health agency and the inter-regional CCLIN)**, as provided by decree n° 2001-671, of July 26th, 2001.

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Conclusions - Perspectives

The present guide has been produced in response to the need expressed by hospitals, for a practical document to be made available, defining procedures for the assessment and management of the secondary fungal risk resulting from construction work in hospitals.

This report was produced by summarizing various sources of data which are often highly scattered in the literature, and the opinion of professionals who, in medical, technical and administrative terms, have been confronted with the management of this risk. From this comparison, consensual recommendations validated by a reading group were produced, partially on the basis of totally validated evidence, and more generally from practical experience and common sense.

The empiricism of some measures, even when they are supported by "in-the-field" experience, undoubtedly result from a lack of investment in research into the prevention and management of environmental risks in the hospital.

It is important to identify the main avenues of improvement to be considered, with a view to improving the management of the risk of fungal infection.

All of the risk analysis steps are relevant:

- **The identification of hazards**, whilst taking into account the need to improve the means of identification and quantification of fungal contamination in the air and on surfaces. The current mycological tools are specific, but poorly adapted to the real-time management of risks. The use of molecular biology or proteomics, and the development of atmospheric sensors for the identification of fungal spores, could be extremely helpful.
- **The relationship between exposure and infection**, with in particular the definition of a risk threshold, is a fundamental aspect which needs to be investigated, either with experimental models, or by prospective analysis of contamination and the incidence of cases in exposed sectors. The comparison of repeated, but low-level exposures and of a high single exposure event would be of great interest, as is the case for other organic or chemical pollutants in the environment.
- **The quantification and management of the risks** associated with construction work in general, and with the airborne fungal risk in particular, is still based on an empirical methodology, despite the existence of mathematical tools, in the form of probabilistic predictive models or exposure/risk grids.
- **The means which can be used for the prevention of exposure,** whether physical or physico-chemical, are scarce, often poorly adapted to the hospital context and inadequately validated. In this field, we are of the opinion that it is essential to develop industrial partnerships, in order to take advantage of the experience and resources acquired in other fields of environmental protection (agri-food sector, building, transport), and to create tools or methods, which can be used in hospitals.
- **Finally, communication on the subject of fungal risk,** a key element in the assessment of the management of this risk, still remains insufficient and inaccurate, both internally with healthcare personnel, and also in the exposed population.