DAMPNESS IN BUILDINGS AS A RISK FACTOR FOR HEALTH EFFECTS. EUROPEAN MULTIDISCIPLINARY REVIEW OF THE ENTIRE LITERATURE (EUROEXPO)

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ABSTRACT
The scientific literature on health effects associated with "dampness" in buildings including literature between 1998 and 2000 has been reviewed by an European group (EUROEXPO). The groups consisted of scientists with experience from medicine, epidemiology, toxicology and engineering. Of the 104 reviewed articles 52 were excluded as they were judged as background papers or "non-informative" or "inconclusive" or the study did not present data on exposure, health effect or analysis of the association between exposure and health. The review groups concluded that "dampness" in buildings is a risk factor for health effects such as cough, wheeze, asthma, general symptoms and airway infections among atopics and non-atopics, both in domestic and public environments. However, the literature is inconclusive in respect of causative agents in such buildings. Suggested causative agents are mites, microbiological agents and organic chemicals from degraded building materials.

INDEX TERMS
Review, Indoor environment, Damp buildings, Mite exposure, Health effects

INTRODUCTION
In an earlier consensus work (NORDDAMP) the literature (prior to July 1998) on dampness in buildings (mite-exposure not included) and health was evaluated (Bornehag et al. 2001). The review showed that "dampness" in buildings appears to increase the risk for a number of health effects, such as cough, wheeze, and asthma. Relative risks are in the range of OR 1.4-2.2. The group concluded that the evidence for a true association between "dampness" and health effects is strong. However, the literature was not conclusive as to what agents in indoor air relating to "dampness" are responsible for the health effects. Mites in dwellings can explain some, but probably not all, of the health problems. The aim of this review has been to update the NORDDAMP review (1998-2000) and to include articles dealing with mite-exposure. Another aim was to include experience and questions from other parts of Europe.

METHOD
In light of earlier consensus work (Andersson et al. 1997, Ahlbom et al. 1998, Bornehag et al. 2001) a group of nine European scientists was established for the task, i.e. the EUROEXPO-group. The invited scientists had documented expert knowledge in at least one of the following areas: occupational medicine, building hygiene, HVAC engineering, building physics, microbiology, allergy or epidemiology. The review included only peer-reviewed articles (original articles) published in scientific journals. A literature search including pet-exposure and health effects (not reported here) was carried out in Medline and PubMed. Publication dates from 1998/01/01 to 2000/04/30.

The literature search identified 547 articles. Of these 443 were excluded, from abstracts, as they were reviews, case studies, and studies of occupational exposures or because they did not

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present data on both exposure and health effects or an analysis on associations between exposure and health. Consequently, the review group has scrutinized 104 articles.

Before the review seminar, all 104 articles were distributed to the group. A "reporter" presented each article with comments from an "assessor" after which the article was discussed and evaluated on the basis of the following criteria:

-Is exposure and health effects charted and described in a relevant manner, with respect to e.g. time of exposure (e.g. infancy, childhood years, actual exposure)?
-Is the selection of the investigated persons satisfactory?
-Is the statistical analysis including control of "confounders" and effect modification satisfactory?

Of the 104 reviewed articles 52 were excluded as they were judged to be background papers or "non-informative" or "inconclusive" or the study did not present data on exposure, health effect or analysis of the association between exposure and health. The term "non-informative" indicates that the article lacks essential information concerning exposure or health effects or that the analysis did not consider possible confounding from other factors. The term "inconclusive" indicates that data processing or reporting makes it impossible to draw conclusions concerning the relationship between exposure to "dampness" and health effects. It should be pointed out that many of the studies excluded have had other objectives than investigating associations between "dampness" and/or mite-exposure and health. Furthermore, 12 studies were excluded as they dealt only with pet-exposure and health effects. Finally, a proposal was made for a consensus statement concerning all the articles scrutinised. Consequently, 40 studies have formed the foundation for the conclusions.

When articles were discussed, anyone of those present who was author or co-author of the article concerned left the room. The group agreed on the position taken regarding each article, concerning both the relevance of the article to the issues at hand, and the conclusions that can be drawn from the article.

RESULTS

Due to the risk of bias, the ideal study would include independent observations of health effects and exposure. Objective tests of health effects, such as results of e.g. blood tests (total and specific serum IgE), skin prick tests (SPT), lung function tests and measurements of bio-markers (e.g. blood eosinophil count, eosinophil cationic protein (S-ECP)) should not be influenced by recall bias. Also, signs of e.g. bronchial obstruction diagnosed by physicians could be deemed as independent observations. Similarly, assessment of exposures made by independent experienced inspectors (observed) or exposure measurements of dampness related agents provide methods to reduce information bias reported in the literature.

In the following presentation the studies have been divided into one or more of 4 categories depending on the type of data for exposure (i.e. self-reported and/or inspections (observed) and exposure measurements) and health effects (i.e. self-reported and/or clinical findings including physician diagnoses).

Dampness in buildings and health effects

Twenty-eight studies present data on dampness in buildings and its association with health effects.

In 15 studies data from self-reported dampness and self-reported symptoms were presented. In 13 of these studies a positive association was found between reported dampness in buildings and health effects (typically asthma and wheezing). In 2 studies such an association was not

seen (Wickens et al. 1999; Ponsonby et al. 1999). In the study by Wickens et al. (1999) high mite exposure may have contributed to the negative association.

Associations between self-reported dampness and objective health outcome (signs and tests) were found in 6 studies. Self-reported dampness was associated with doctor diagnosed health outcome such as current asthma and severity of asthma (Lindfors et al. 1999; Norbäck et al. 1999; Wever-Hess et al. 2000). In two studies there was an association between "dampness" and sensitization (Lindfors et al. 1999; Schafer et al. 1999A). However, Rönnmark (et al. 1999) found no association between "dampness" and atopic asthma. In five out of six studies in this group an association between self-reported "dampness" and clinical outcomes was reported.

In five studies data on observed "dampness" (inspected) and/or "dampness"-related exposures and self-reported symptoms were reported. One study included inspections of dampness (Koskinen at al. 1999) and showed an association between dampness and symptoms. Exposures that were reported to be associated with symptoms were fungal extra cellular polysaccharides (EPS) in dust (Douwes et al. 1999), mould spores (Garret et al. 1998) and glucanes (Wan et al. 1999B). In four of the five studies positive associations between exposures and self-reported health symptoms were reported.

Associations between reported dampness and/or dampness-related exposures and clinical findings were reported in three studies. Exposure to fungal genera was showed to increase the risk for sensitization in children (Garret et al. 1998) and airborne microbes were associated with inflammatory markers in nasal lavage in adults (Hirvonen et al. 1999). In one study observed "dampness" was associated with doctor diagnosed bronchial obstruction in children (Oie et al. 1999).

Mite-exposure and health effects
Eighteen studies presented data on mite-exposure in buildings and health effects such as sensitization, lung function and symptoms.

In five studies data on mite-exposure and symptoms were reported. Five intervention studies showed that preventive measures reduced the mite exposure (Shapiro et al. 1999; Warner et al. 2000; Moon et al. 1999 and Nishioka et al. 1998; Cloosterman et al. 1999). However, in only one of these studies was there an improvement in symptoms (Moon et al. 1999). In two case-control studies on children, mite-exposure and current asthma were investigated. Sporik et al. (1999) showed an association between current exposure and asthma; however, Wickens et al. (1999) found no such association

In 16 studies there were data from mite-exposure and clinical findings including sensitization. Interventions were shown to decrease the risk for sensitization (Nishioka et al. 1998) and bronchial hyperreactivity (BHR) (Shapiro et al. 1999; Warner et al. 2000). However, Cloosterman et al. (1999) reported that allergen reduction did not improve clinical conditions of mild allergic asthmatics and Julge et al. (1998) found no association between indoor allergen exposure and atopy in children. Seven studies reported that exposure to mites and cockroaches increased the risk for sensitization (Eggleston et al. 1998; Sporik et al. 1999; Ricci et al. 1999; Holm et al. 1999; Nahm et al. 1998; Warner et al. 1999; Warner et al. 1998). In four studies mite- and cockroach exposure were associated with decreased lung function (Weiss et al. 1998; Jalaludin et al. 1998; Tunnicliffe et al. 1999; Nicolai et al. 1998).

DISCUSSION
The review shows that "dampness" in buildings is a risk factor for health effects among atopics and non-atopics, both in domestic and public environments. The association between both self-reported and observed dampness respectively and symptoms are in the same range as

in the earlier review (Bornehag et al. 2001) which means that dampness approximately doubles the risk for symptoms.

The risk is increased for both children and adults; however, most of the studies concerned children. Furthermore, the main part of the studies has a cross-sectional design and very few longitudinal (prospective) studies were identified, thus decreasing the possibility to draw conclusions on causative mechanisms.

Concerning dampness-related exposures, the review found some indications that mould spores were associated with both symptoms and sensitization. Such results were also seen in the NORDDAMP review. However, the literature is still not conclusive with respect to causative agents in damp buildings. Concerning mites it seems clear that such exposure increases the risk for sensitization. However, the results reported did not show that interventions improved health in a conclusive manner. One reason for this could be that the intervention time was to short.

One question is why there are no new findings concerning associations between dampness-related exposures and health. The OR´s for reported associations between measured exposures and clinically diagnosed health effects are in the same range as associations between more diffuse self-reported indicators for dampness and health. This is an indication that the causative agents have not been identified. It should be pointed out that most studies have investigated microbiological agents, not chemical substances related to dampness.

In total, the conclusions on an association between dampness and health accord well with the earlier review made by NORDDAMP (Bornehag et al. 2001). The discussion in NORDDAMP on different kinds of bias is still valid which means that there is good evidence for a true association between dampness and health. Bias or confounding may have contributed to some, but probably not all of the associations reported. Suggested causative agents in damp buildings are:

Mites: Exposure to mites has been shown to increase the risk of sensitization and allergic disease. In all studies where adjustment for mite exposure has been made the association between dampness and health decreased but remained mainly significant. The OR for the association between dampness and health seems to be almost the same all over the world with very different climate conditions and different prevalence of mite infestation. So, mite exposure cannot explain all health effects related to damp buildings.

Microbiological agents: The possible role of microbes/moulds as a (major) causative agent for dampness-related health effects is unclear and the literature is not conclusive. The prevalence of sensitization to mould allergen is low; however, there is a possibility of yet unrecognized fungal allergens. Furthermore, agents of microbial origin may act as odorous, irritant and toxic substances.

Organic chemicals: A high moisture content in materials can give rise to degradation procedures with emission of substances as a result. Such compounds can give rise to odour, irritation and maybe allergic reactions. However, the literature concerning dampness-related health effects from such compounds in relevant concentrations is inconclusive.

General conclusions

The review has shown that there is a strong need for multidisciplinary reviews in scientific journals on articles including associations between indoor environmental factors and health effects. It is essential to carry out more real multidisciplinary studies including competence from all relevant disciplines. The studies should include not only a cross-sectional design, but also longitudinal prospective designs and intervention studies. The recommendation to the general public is to remediate damp buildings and to avoid mite exposure.

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REFERENCES
Andersson, K., Bakke, J. V., Björseth, O., Bornehag, CG., Clausen, G., Hongslo, J. K., Kjellman, M., Kjärgaard, S., Levy, F., Mölhave, L., Skerfving, S., Sundell, J. (1997) TVOC and health in non-industrial indoor environments. Report from a Nordic scientific consensus meeting at Långholmen in Stockholm. Indoor Air 1997;7:78-91

Ahlbom A, Backman A, Bakke JV, Foucard T, Halken S, Kjellman M, Malm L, Skerfving S, Sundell J, Zetterström O. 1998. "Nordpet". Pets indoors- A Risk Factor or Protection against Sensitisation/Allergy. A Nordic Interdisciplinary Review of the Scientific Literature Concerning the Relationship between Exposure to Pets at Home, Sensitisation and the Development of Allergy. Indoor Air 1998;8:219-235.

Bornehag, CG., Blomquist, G., Gyntelberg, F., Järvholm, B., Malmberg, P., Nielsen, A., Pershagen, G. Dampness in Buildings and Health. Nordic interdisciplinary review of the scientific evidence on associations between exposure to “dampness” and health effects, NORDDAMP. Indoor Air 2001;11:72-86.

Bornehag, CG., Bonini, S., Custovic, A., Malmberg, P., Matricardi, P., Skerfving, S., Sigsgaard, T., Verhoeff, A. and Sundell, J. (2001) Dampness in Buildings as a Risk Factor for Health Effects, EUROEXPO. A multidisciplinary review of the literature (1998-2000) on dampness and mite exposure in buildings and health effects. Submitted.

Cloosterman SG, Schermer TR, Bijl-Hofland ID, Van Der Heide S, Brunekreef B, Van Den Elshout FJ, Van Herwaarden CL, Van Schayck CP. Effects of house dust mite avoidance measures on Der p 1 concentrations and clinical condition of mild adult house dust mite-allergic asthmatic patients, using no inhaled steroids. Clin Exp Allergy. 1999 Oct;29(10):1336-46.

Douwes J, van der Sluis B, Doekes G, van Leusden F, Wijnands L, van Strien R, Verhoeff A, Brunekreef B. Fungal extracellular polysaccharides in house dust as a marker for exposure to fungi: relations with culturable fungi, reported home dampness, and respiratory symptoms. J Allergy Clin Immunol. 1999 Mar;103(3 Pt 1):494-500.

Eggleston PA, Rosenstreich D, Lynn H, Gergen P, Baker D, Kattan M, Mortimer KM, Mitchell H, Ownby D, Slavin R, Malveaux F. Relationship of indoor allergen exposure to skin test sensitivity in inner-city children with asthma. J Allergy Clin Immunol. 1998 Oct;102(4 Pt 1):563-70.

Garrett MH, Rayment PR, Hooper MA, Abramson MJ, Hooper BM. Indoor airborne fungal spores, house dampness and associations with environmental factors and respiratory health in children. Clin Exp Allergy. 1998 Apr;28(4):459-67.

Hirvonen MR, Ruotsalainen M, Roponen M, Hyvarinen A, Husman T, Kosma VM, Komulainen H, Savolainen K, Nevalainen A. Nitric oxide and proinflammatory cytokines in nasal lavage fluid associated with symptoms and exposure to moldy building microbes. Am J Respir Crit Care Med. 1999 Dec;160(6):1943-6.

Holm L, van Hage-Hamsten M, Ohman S, Scheynius A. Sensitization to allergens of house-dust mite in adults with atopic dermatitis in a cold temperature region. Allergy. 1999 Jul;54(7):708-15.

Jalaludin B, Xuan W, Mahmic A, Peat J, Tovey E, Leeder S. Association between Der p 1 concentration and peak expiratory flow rate in children with wheeze: a longitudinal analysis. J Allergy Clin Immunol. 1998 Sep;102(3):382-6.

Julge K, Munir AK, Vasar M, Bjorksten B. Indoor allergen levels and other environmental risk factors for sensitization in Estonian homes. Allergy. 1998 Apr;53(4):388-93.

Koskinen OM, Husman TM, Meklin TM, Nevalainen AI. The relationship between moisture or mould observations in houses and the state of health of their occupants. Eur Respir J. 1999 Dec;14(6):1363-7.

Lindfors A, van Hage-Hamsten M, Rietz H, Wickman M, Nordvall SL. Influence of interaction of environmental risk factors and sensitization in young asthmatic children. J Allergy Clin Immunol. 1999 Oct;104(4 Pt 1):755-62.

Moon JS, Choi SO. Environmental controls in reducing house dust mites and nasal symptoms in patients with allergic rhinitis. Yonsei Med J. 1999 Jun;40(3):238-43.
Nahm DH, Park HS, Kim CW, Park JW, Hong CS. Seasonal variation of IgG subclass antibodies to house dust mite in sera from mite-sensitive asthmatic patients. Ann Allergy Asthma Immunol. 1998 May;80(5):411-5.
Nicolai T, Illi S, von Mutius E. Effect of dampness at home in childhood on bronchial hyperreactivity in adolescence. Thorax. 1998 Dec;53(12):1035-40.
Nishioka K, Yasueda H, Saito H. Preventive effect of bedding encasement with microfine fibers on mite sensitization. J Allergy Clin Immunol. 1998 Jan;101(1 Pt 1):28-32.
Norback D, Bjornsson E, Janson C, Palmgren U, Boman G. Current asthma and biochemical signs of inflammation in relation to building dampness in dwellings. Int J Tuberc Lung Dis. 1999 May;3(5):368-76.
Oie L. Nafstad P. Botten G. Magnus P. Jaakkola JK. Ventilation in homes and bronchial obstruction in young children. Epidemiology. 10(3):294-9, 1999 May.
Ponsonby AL, Couper D, Dwyer T, Carmichael A, Kemp A, Cochrane J. The relation between infant indoor environment and subsequent asthma. Epidemiology 2000 March Vol. 11 No. 2.
Ricci G, Patrizi A, Specchia F, Menna L, Bottau P, D'Angelo V, Masi M. Mite allergen (Der p 1) levels in houses of children with atopic dermatitis: the relationship with allergometric tests. Br J Dermatol. 1999 Apr;140(4):651-5.
Ronnmark E, Jonsson E, Platts-Mills T, Lundback B. Different pattern of risk factors for atopic and nonatopic asthma among children--report from the Obstructive Lung Disease in Northern Sweden Study. Allergy. 1999 Sep;54(9):926-35.
Schafer T, Kramer U, Dockery D, Vieluf D, Behrendt H, Ring J. What makes a child allergic? Analysis of risk factors for allergic sensitization in preschool children from East and West Germany. Allergy Asthma Proc. 1999A Jan-Feb;20(1):23-7.
Shapiro GG, Wighton TG, Chinn T, Zuckrman J, Eliassen AH, Picciano JF, Platts-Mills TA. House dust mite avoidance for children with asthma in homes of low-income families. J Allergy Clin Immunol. 1999 Jun;103(6):1069-74.
Sporik R, Squillace SP, Ingram JM, Rakes G, Honsinger RW, Platts-Mills TA. Mite, cat, and cockroach exposure, allergen sensitisation, and asthma in children: a case-control study of three schools. Thorax. 1999 Aug;54(8):675-80.
Tunnicliffe WS, Fletcher TJ, Hammond K, Roberts K, Custovic A, Simpson A, Woodcock A, Ayres JG. Sensitivity and exposure to indoor allergens in adults with differing asthma severity. Eur Respir J. 1999 Mar;13(3):654-9.
Wan GH, Li CS. Dampness and airway inflammation and systemic symptoms in office building workers. Arch Environ Health. 1999A Jan-Feb;54(1):58-63.
Warner A, Bostrom S, Moller C, Kjellman NI. Mite fauna in the home and sensitivity to house-dust and storage mites. Allergy. 1999 Jul;54(7):681-90.
Warner A, Bostrom S, Munir AK, Moller C, Schou C, Kjellman NI. Environmental assessment of Dermatophagoides mite-allergen levels in Sweden should include Der m 1. Allergy. 1998 Jul;53(7):698-704.
Warner JA, Frederick JM, Bryant TN, Weich C, Raw GJ, Hunter C, Stephen FR, McIntyre DA, Warner JO. Mechanical ventilation and high-efficiency vacuum cleaning: A combined strategy of mite and mite allergen reduction in the control of mite-sensitive asthma. J Allergy Clin Immunol. 2000 Jan;105(1 Pt 1):75-82.
Weiss ST, O'Connor GT, DeMolles D, Platts-Mills T, Sparrow D. Indoor allergens and longitudinal FEV1 decline in older adults: the Normative Aging Study. J Allergy Clin Immunol. 1998 Jun;101(6 Pt 1):720-5.
Wever-Hess J, Kouwenberg JM, Duiverman EJ, Hemans J, Wever AMJ. Risk factors for exacerbations and hospital admissions in asthma of early childhood. Pediatric Pumonology 2000 29:250-256.
Wickens K, Pearce N, Siebers R, Ellis I, Patchett K, Sawyer G, Stone L, Tohill S, Kennedy J, Slater T, Lewis S, Fitzharris P, Crane J. Indoor environment, atopy and the risk of the asthma in children in New Zealand. Pediatr Allergy Immunol. 1999 Aug;10(3):199-208.