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Mould and dampness in European homes and their impact on health

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Content

Abbreviations

CFU	Colony forming units
COPD	Chronic obstructive pulmonary disease
ICD	International Statistical Classification of Diseases and Related Health Problems
LRI	Lower respiratory illness
OR	Odds Ratio
RR	Risk Ratio
URI	Upper respiratory illness
WHO	World Health Organization

1 Aim and scope of this report

This report aims at showing the impact of mould and dampness on living in a healthy home. An unhealthy home is supposed to promote illnesses, more or less severe, and leads in consequence to (direct health) costs for medication or even hospital admission and on the other hand to (more indirect) economic costs when employees are sick and could not do their work. In this study report, the scientific foundation for the relationship between mould and dampness and respiratory illnesses of building occupants is shown. To achieve a magnitude about the effect of mould in homes on respiratory diseases, a meta-analytic synthesis is done in order to summarize the available statistical data. In a further step, a projection about the potential of modernizing the building stock and reducing mould sources on lowering the impact on the occupants' health has been made and measures for improvement are outlined.

1.1 Importance of the indoor environment for health and wellbeing

Humans are not isolated from their environment as they breathe the surrounding air and inhale particles and substances that are part of the atmosphere. Hence, especially the entire respiratory system is vulnerable to a bad air quality which can promote the development of different illnesses. As most of people - at least in industrialized countries - spend about 90 % of their time indoors, the built environment is a crucial factor for the influence of indoor air on the respiratory health of building occupants.

For adults, the home and the work place are equally important for health as they spend much time at both places. Concerning the home, a lot of time is spent asleep. Sleep, in turn, is important for a good regeneration of physical and mental resources to be able to perform well on the next day. The air quality in the bedroom should include a healthy air without signs of chemical or microbial hazards. The same is important for children and infants with classroom air quality instead of work places. Additionally, they spend more time in the home like adults and their respiratory system is much susceptible to hazards than those from adults.

Actually, over 80 millions of people in Europe live in a home where at least dampness is present [1]. This means that the potential for saving health cost could be huge if the relationship between the presence of mould or dampness and the development or prevalence of certain diseases (mainly respiratory diseases) would be clear in its direction and magnitude. Improving the building quality, i.e. avoiding mould and dampness in buildings, could be compared with the health costs that might be saved.

The situation in schools is similar. Many schools as well as day-care centres are affected by a bad indoor air quality or even mould problems. 95 million pupils visit a school in Europe every day and mould problems are suspected to cause at least unspecified symptoms like wheeze, cough and common colds and in more severe cases, absenteeism due to illness. This, in turn, may lead to a de-

crease in learning ability and therefore on the long-term perspective a lower socioeconomic status due to a lower academic achievement. Improving the learning conditions in schools by reducing mould and dampness would not only beneficial for health costs but also for the productivity potential of future (knowledge) workers.

1.2 Prevalence of asthma and other respiratory diseases in Europe

The prevalences for certain diseases are very different concerning the geographical distribution but as well in their magnitudes.

Asthma is one of the most common lower respiratory diseases. Some countries are more affected than others. Especially the Scandinavian countries, UK, Benelux and France have high prevalence rates that may exceed the value of 10%. The southern and central regions of Europe range between 3 and 9% [210].

For COPD, prevalence data are difficult to gather, as robust estimates are lacking for most European countries. Estimations from large-scale studies range from 5 – 10% but these studies differ in various aspects what makes it difficult to take these values as trustworthy [3].

For acute lower respiratory disease like bronchitis, it is estimated that between 30 and 50 per 1000 people are affected by a bronchitis each year. This means that about 16,500,000 people each year have a need for primary care [4].

For more unspecific diseases like cough, nocturnal cough or common colds, it is difficult to gather consistent data of incidences or prevalences across Europe.

1.3 Costs of asthma and other respiratory diseases

To judge the economic impact of respiratory diseases, the possible costs are typically divided into three categories: direct costs for medical treatment (medication, physician, hospitalization,…), indirect costs for loss of productivity for the work force and the monetarized value for the time lost due to the illness in disability-adjusted life years (DALYs). The first two aspects are summarized and researched in so called cost-of-illness studies where patients are asked about their expenditures for physicians and medication and their total amount of working time loss due to asthma attacks.

The study from the European Lung White Book with a large population sample investigates the costs from lower respiratory diseases thereunder as well asthma and additionally pneumonia, obstructive sleep apnoea syndrome and as a summary index chronic obstructive pulmonary diseases (COPD) [6]. The calculations are displayed in Table 1.

The costs for respiratory illnesses are obviously high and if it would be possible to eliminate some sources and reasons why people develop respiratory illnesses, the reduction of these costs would also be possible.

Table 1:
Overview about direct and indirect costs for different respiratory diseases, adapted from [6].

Illness	Direct costs [billions €]	Indirect costs [billions €]	Monetized value of DALYs lost [billions €]	Total costs [billions €]
COPD	23.3	25.1	93.0	141.4
Asthma	19.5	14.4	38.3	72.2
Pneumonia / Acute lower respiratory infections	2.5	NA	43.5	46.0

2 Study method

For epidemiological research, several possibilities for summarizing results from several studies are available [7], each of them has its own advantages and disadvantages.

The first one is the "traditional" narrative review, a qualitative assessment method. A carefully done review can give a good orientation about the actual state of knowledge and an overview about future research needs. On the other side, selection of studies and conclusions may be influenced by the subjective view of the author. At the moment, only punctual efforts for a standardized procedure how to perform a review and draw conclusions to assure a good quality are available, e.g. [8], [9].

The second possibility is to perform a meta-analytic synthesis. In epidemiological research, two types of meta-analyses are used, depending on the available data sources. The one which is methodologically more reliable is a meta-analysis based on individual data, e.g. if number of events and non-events in each group are available. Statistical calculations can be done for the meta-analysis and the appropriate effect size could be chosen. Further, it could be assumed that all data that are included in meta-analysis are unadjusted and no pooling of data has been done.

The other possibility for a meta-analysis is summarizing data out of published studies, in which sometimes only aggregated values like Odds Ratios, unadjusted or adjusted, are indicated. This method is assumed to have some disadvantages compared to the aforementioned one. One reason for this is that the publication and therefore the availability of data is very different. In some studies the results are adjusted for several confounders like age, socioeconomic status and others, the unadjusted values are not presented. In other studies, only unadjusted values are given. Pooling these data together may lead to an increase in heterogeneity and an resulting point estimate that could not be inter-

preted due to the huge amount of possible bias variable that are responsible for heterogeneity. Despite these disadvantages, this is a common way to do a meta-analytic synthesis as in most publications, individual data are not available.

To summarize the available knowledge and to derive an estimation about the magnitude of the influence of mould and dampness on health, the meta-analytic synthesis based on publication data has been chosen for this study. In advance, there is a need about an introduction to the methodology how data about the relationship between mould, dampness and health are collected.

2.1 Meta-analytic methodology

In this section, the meta-analytic approach will be presented. The general procedure to perform a meta-analysis is illustrated and the possibilities and limitations in general and compared to a narrative review are explained.

2.1.1 Procedure

The main goal of a meta-analytic synthesis is the aggregation of all existing studies about a certain hypothesis to derive conclusions based on a larger amount of participants. Instead of summarizing individual studies with e.g. 100 participants, a meta-analysis aims at summarizing all available and qualified studies and has then a foundation of e.g. 10.000 participants from all studies. To highlight the relationship between mould at home and health of the occupants, several meta-analyses have already been conducted [10], [11], [12], [13], [14]. But as the latest extensive analyses, i.e. analyses that cover all fields of relevant health outcomes, are already five and nine years old, a new analysis is needed to cover all published research up to today. A newer analysis is focused solely on the development of asthma due to mould at home [11] or to the risk of rhinitis [10] and covers not all respiratory illnesses and another analysis summarizes only certain studies without making a claim of completeness [14].

The procedures of a meta-analysis are determined according to ensure a good scientific quality of the resulting work (for more detailed information see for example [18], [15], [30], [16]. The first step is usually the formulation of the specific research question. For this work we are interested in the relationship between the occurrence of mould and / or dampness in dwellings and the prevalence and incidence of all kinds of respiratory diseases. The next part is an extensive literature search to gather all available knowledge about the specific research question. During or after this search, inclusion criteria have to be defined to assure that only studies that met both the research question and fulfill sufficient methodological issues are included in the analysis. Inclusion criteria for this work are defined in section 2.5. Parameters of the experimental research have to be coded in the next step and all important variables have to be included in the coding scheme.

After completing the coding, statistical calculations can be done to investigate the supposed relationship between the variables of interest. To do this, effect sizes are calculated which give an indication about the relationship between two variables in general and as well on the magnitude of the association. Dependent on the data structures that are found in the original studies, different effect metrics are used. For epidemiological studies, either odds ratios (OR) or risk ratios (RR) are preferred effect sizes. They can be calculated directly from ratios of the original studies or from prevalence or incidence tables that might be found in the studies. If given, adjusted OR or RR were preferred for inclusion in the analysis, if they were not given, crude OR or RR were used. Both metrics are interchangeable if occurrence probability for the diseases is low. As threshold for a low probability, all values below 10% are accepted [17], [18].

2.1.2 Possibilities and limitations

A meta-analytic approach implies some important advantages when compared with a more traditional narrative review. On the other hand, there are some methodological issues to be considered to ensure the quality of the meta-analysis.

One main advantage of a meta-analysis is that it is more objective than a narrative review. Although there are some guidelines and standards for conducting a review (e.g. [8]) and to ensure a certain transparency or traceability on which information the derived conclusions are based on, a review does not touch the original data in a statistical way. A meta-analysis can do this as it calculates a summarized effect based on all available studies that fulfill certain methodological criteria.

A special issue of this work is to do the meta-analysis with epidemiological data. This differs partly from common meta-analyses as the effect estimates are expressed either in Odds Ratios (OR), Risk Ratios (RR) or other combined metrics based on binary data. Combining these data into a single effect estimate is much more difficult than combining continuous data from different studies. First, OR and RR and other measures (e.g. Prevalence ratios, Hazard Ratios) cannot simply be summarized into one effect size. Normally, OR are preferred for meta-analyses as logistic regressions have OR as output, but RR are normally more easier to interpret. A common way to solve this was calculating ORs as effect sizes and then interpret them as RRs. But technically speaking, this only correct when the probability for having a certain outcome is very low, typically below 0.1.

2.2 Classification of illnesses

All illnesses or health outcomes were categorized according to the International Statistical Classification of Diseases and Related Health Problems (ICD-Classification). This is the standard classification tool for physicians and published by the World Health Organization (WHO). The focus of this report is on respiratory diseases which are covered by the categories J00-J99 (Diseases of the respiratory system). Table 2 gives an overview about the categorization of respiratory illnesses.

Table 2:
Classification of respiratory diseases according to the WHO ICD-system.

Code	Title	Illnesses (examples)
J00-J06	Acute upper respiratory infections	Acute sinusitis, pharyngitis, tonsilitis, laryngitis, rhinitis, common cold
J09-J18	Influenza and Pneumonia	Different forms of influenza and pneumonia
J20-J22	Other acute lower respiratory infections	Bronchitis, unspecified acute lower respiratory infection
J30-J39	Other diseases of upper respiratory tract	Chronic rhinitis, allergic rhinitis, chronic sinusitis and tonsilitis, chronic laryngitis
J40-J47	Chronic lower respiratory diseases	Chronic bronchitis, Asthma, COPD
J60-J70	Lung diseases due to external agents	Coalworker's pneumoconiosis, farmer's lung
J80-J84	Other respiratory diseases principally affecting the interstitium	Adult respiratory distress symptom, pulmonary oedema
J85-J86	Suppurative and necrotic conditions of lower respiratory tract	Abcess of lung
J09-J94	Other diseases of pleura	Pneumothorax
J95-J99	Other diseases of the respiratory system	Respiratory failure, not elsewhere classified

Almost all respiratory outcomes could be covered with this section, with the exception of some rather unspecified symptoms like wheeze, dyspnea or cough. Those are categorized in the section R00-R09 (Symptoms and signs involving the circulatory and respiratory systems).

2.3 Literature search

The first step for the meta-analytic procedure was an extensive literature search. To include all publicly available knowledge, the following databases were searched: ISI Web of Science, Sciencedirect, PubMed, ERIC and additionally Google Scholar and the WorldCat catalogue. Additionally, the proceedings of the most important conferences like Indoor Air, Healthy Buildings, CLIMA, IAQ and Roomvent were searched by hand as well as the following journals: Indoor Air, Building and Environment, Energy and Buildings, Environmental Health Perspectives and Allergy. In a next step, references from identified studies, reviews [19], [20], [21], [22], [23], [24], [25], [26] and meta-analyses [10], [11], [12], [13], [14] were checked for additional material.

To capture the physical part of the studies, the following keywords were used: (visible) mo(u)ld, damp(ness), mo(u)ldy odo(u)r, mo(u)ld spots, (window) condensation, moisture, water damage. For the health outcome, we used asthma, allergy, allergies, atopy, health, hospitalisation, hospitalization, medication, mucous membrane symptoms, pulmonary disease(s), respiratory disease(s), well-being.

In total, this literature search yielded over 200 publications dated from 1986 to 2015. The publications found are not all relevant and suitable for inclusion in a meta-analysis. Inclusion criteria have to be defined and studies have to be checked whether they fulfil these criteria and could be included in the synthesis or not and have to be excluded from further analysis. Criteria are defined based on methodological issues or with regard to the focus of the study. The criteria are presented and explained in section 2.5. The methodological differences that may influence the inclusion or exclusion of a study are discussed in the next section.

2.4 Introduction to epidemiological studies

To evaluate if a certain risk factor influences the development of a defined illness or disease and to identify risk factors that may promote or hinder this outcome, researchers have to conduct epidemiological studies. Dependent on the focus of the research, different types of studies exist - each with its own advantages and limitations. The studies which were used to evaluate the influence of mould and dampness on health are observational in its character, experimental studies like clinical trials were not used in this context.

Three main types were identified from the literature search (see section 2.3): cohort studies, case-control studies and cross-sectional studies, the main principles and limitations are explained in more detail in the next sections.

Table 3 gives a general overview about the different types of studies and their distinctive features. In some cases, special designs were used, like nested case-control studies, this method is explained in section 0 as it is an modification of a normal case-control study.

For more detailed information, see [27], [28], [30]. All following elaborations in the chapters 2.4.1 to 2.4.3 are based on these publications.

Table 3:
Overview about specific characteristics of epidemiological studies [27], [28].

	Cohort study	Case-control study	Cross-sectional study
Type of study	Analytical	Analytical	Descriptive
Type of data	Longitudinal	Longitudinal	Transversal
Timing	Normally prospective	Normally retrospective	Point in time
Directionality	Forward	Backward	Non-directional
Type of disease measurement	Incidence	Incidence or Prevalence	Prevalence

2.4.1 Longitudinal Cohort studies

A cohort study is a forward-oriented, mostly prospective study with a large sample size. A certain population is observed over a certain time period, normally several years, sometimes even decades if they develop a certain disease.

The most important advantage of a cohort study is the good quality of the gathered data. During the study process, participants were continuously observed and confounding factors can be eliminated more easily than in any other study design. Further, risk estimations could be derived due to the prospective character of this method where incidence cases are identified and were set in relation with different supposed risk factors.

The main disadvantages are that this type of study is very expensive and time consuming as it is conducted over a long time period and for diseases with a very small number of incidences, a huge number of participants is needed. One further problem is the loss of participants over the time-period of the study due to migration or deaths.

In this report, the focus is on studies with completely healthy subjects at the beginning of the study.

2.4.2 Case-control studies

Case-control studies compare persons that have a certain illness or disease ("cases") with persons without this disease ("controls"). Case-control studies have always a backward-orientation, i.e. potential risk factors for the development of the outcome are evaluated either with questionnaires about exposures to risk factors or with medical documents from doctors or hospitals. Most case-control studies are also retrospective, i.e. the disease has already occurred for the case-group.

The advantage of case-control studies compared to cohort studies is mainly that the sample size can be much smaller and this method is therefore cheaper and less time consuming than a cohort study. The total time of a case-control study is also smaller as the participants have already the disease and don't need to be observed over several years.

A problem of case-control studies is the choice of controls. They have to be as similar as possible to the cases except that they don't have the disease which is the focus of the study. Possible confounding factors like age or socioeconomic status have to be equal in the case and the control group. A widely used procedure for the choice of controls is population-based, i.e. random selection of the total population or matching of each case with a control that has similar characteristics in the supposed confounding factors (e.g. matching each child with asthma with another healthy child that has the same age).

Another problem of case-control studies is that the risk ratio could not be calculated due to the backward-oriented character of the study. Instead, odds ratios are calculated which are nearly equal to risk ratios if the incidence for the disease is very small.

2.4.3 Cross-sectional studies

Cross-sectional studies are non-directional, i.e. neither backward nor forward-oriented, studies. On a single point of time or a very short period of time, participants are asked about their past and current exposures, actual health or disease status and other variables depending on the context of the study. Compared to the other two methodologies, it is a quick and inexpensive way to get an overview about possible relationship for a disease that is relatively common and has a longer duration. This can be the basis for hypotheses that may be tested later in case-control or cohort studies.

Disadvantages of cross-sectional studies are that they can only identify prevalent cases, no incident cases due to the short period of evaluation. This leads to a rather strong limitation of the methodology namely that no causal relationships could be derived out of a cross-sectional study as no data whether the exposure preceded the disease or vice versa. Additionally, only participants that survived over certain time to be available for the study are included in the sample. This may bias the results and conclusions that are drawn from the data.

2.5 Inclusion criteria

The literature search identified in total seven questionnaire indicators of mould in homes and schools which were used in the studies. These were the following: visible mould or mould spots, dampness, mould and dampness (not separated), mouldy odour, condensation on windows or other surroundings, water damage and signs of moisture. Additionally, some studies measure fungal spore concentration in colony forming units [CFU]. For the health outcomes, the illnesses were specialized in a very detailed way, e.g. differentiation into sinusitis, bronchitis, otitis, tonsillitis. All these criteria were coded separately, but as not every study has this degree of differentiation, all outcomes are summarized either into upper respiratory diseases or lower respiratory diseases. The distinction of the outcomes has been done according to the definition of upper and lower respiratory tracts in the ICD-system. The categories J00-J06 and J30-39 (see Table 1 for explanations) were categorized as upper respiratory illnesses (URI), the categories J09-J18, J20-J22 and J40-J47 were summarized as lower respiratory illnesses (LRI).

To be included in the meta-analysis, studies had to fulfil the following criteria:

- At least one health outcome is measured in the studies, either a subjectively evaluated illness or a doctor-diagnosed disease. Studies that display only the physical conditions are excluded

- Buildings with mould damage due to flooding or natural catastrophes are excluded from further analysis, the focus is set on normal use of buildings and the resulting mould signs.

- It is known that mould in buildings interacts with other possible health hazards like pet allergens, house dust mites or dust [40], [55], [94], [111]. The focus of this work is the mere influence of mould on health, i.e. studies that combine mould with these other possible variables are excluded from further analysis.

- Studies have to report original data and every set of participants is included only once in each separate analysis. This point is related to the fact that sometimes case-control studies are derived out of cohort or longitudinal studies and the participants in the case-control study have already participated in the cohort study. Additionally, for huge cohort studies more than one publication is typically available, but the underlying data are from the same participants.

- Sufficient statistical data had to be provided in the study to calculate an effect size, e.g. odds ratios, risk ratios or contingency tables. Ideally, the provided data are adjusted for confounding variables or at least some explanations must be given in the text.

2.6 Moderators

There are several possible moderators that may influence the effect estimate. In this following section they are divided into moderators for the physical part (measurement of mould) and the health part (measurement of health outcomes).

For the physical part, it is mainly interesting if the way of measurement of mould and dampness has an influence on the calculated outcome. Hence, studies are divided into studies that measure the presence of mould via questionnaires, which is a visual inspection of the respective buildings. This part is further subdivided into questionnaires filled out by the building habitants or by trained inspectors that visit every building in a survey. On the other hand, some studies measured the presence of moulds with physical measurements (normally fungal spore concentration in colony forming units (CFU)) and compared these outcomes with the health of the occupants.

To evaluate mould or dampness in building by questionnaires, different indicators have been defined (e.g. visible mould spots or mouldy odour). A separate calculation of effect size will be done for every indicator to see if one is more detrimental than others.

On the other hand, health outcomes can be very different as well and the influence of mould may also differ. The outcomes are therefore divided in several subcategories. The first one considers the way of measurement. Like the physical measurements, the health outcomes can be measured by questionnaires that are filled out by the occupants or the guardians or parents when children or infants are the target population. Another way to include health outcomes is to rely only on diagnosed diseases by a physician. One focus of this work is to investigate if the effect estimate is different when diagnosed diseases are compared with symptoms from questionnaires.

With regard to the different types of diseases, an effect size for every possible health outcome will be calculated (i.e. when a sufficient number studies with this disease is available). In an additional step, all diseases will be summarized into upper and lower respiratory diseases.

Additionally, effect sizes will calculated separately for different population-based characteristics, e.g. age of the participants (infants, children and adults) or duration of exposure time (exposure in childhood or adulthood).

3 Results of the meta-analytic procedure

In this section, the results of the literature search will be displayed briefly, before the results of the different types of epidemiological studies are evaluated in the sections 3.2 to 3.4.

3.1 Results of the literature search

In total, the literature search identified 170 studies, of these were 99 conducted as a cross-sectional design, 31 were case-control studies and 40 were longitudinal studies. Not all of these were eligible for meta-analysis for different reasons which will be explained in the respective section. The results will be shown for each type of study separately as the outcome is sometimes different (e.g. prevalence vs. incidence). In total, about 1,250 effect sizes were calculated and summarized.

3.2 Cross-sectional studies

In total, from the 99 cross-sectional studies that were identified from the literature search 66 met the defined inclusion criteria. The studies included different age groups, beginning with children up to older adults. Most of the studies measured the exposure to any mould indicator with questionnaires that were either filled out by the occupants or by trained inspectors who visited the buildings. In some few studies, physical measurements had been taken and putted into relation with health outcomes. For the health outcomes asthma, wheeze, cough, rhinitis, bronchitis, allergic rhinitis, nasal symptoms, eye symptoms, throat symptoms, skin symptoms and common cold, enough studies were available to show results for each mould indicator separately. These results are shown in section 3.2.1 whereas in section 3.2.2 summarized effect sizes are calculated (either for all mould indicators or for summarized health outcomes. In section 3.2.3 the influence of several moderators like the method of diagnosing a health outcome.

3.2.1 Results for each mould indicator

Asthma

The most studies were available for asthma. In total, 40 cross-sectional studies had been included in the analysis. Figure 1 shows the results for the prevalence of asthma compared to the presence of one mould indicator.

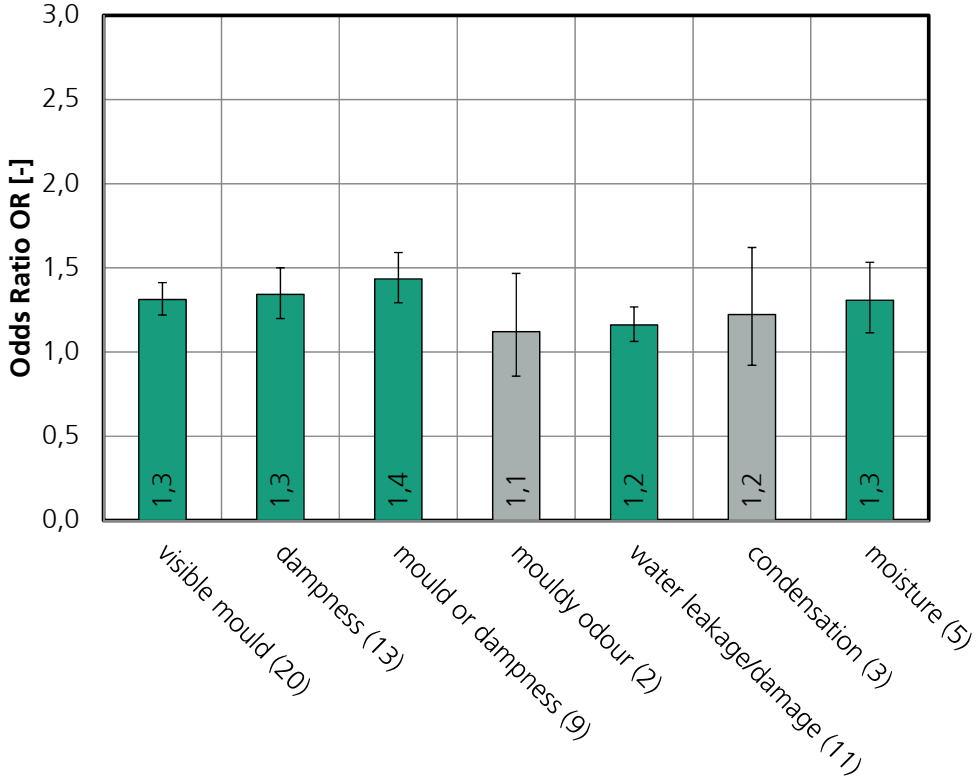

Figure 1:
Relationship between the prevalence of asthma and the presence of one of seven mould indicators. The number following each indicator is the amount of underlying studies. Error bars are 95%-confidence limits. Statistically not significant values ($p > 0,05$) are displayed in grey.

For further interpretation the average value of the indicators mould or dampness and dampness has been considered. With this value it can be concluded that the chance of having asthma vs. not having asthma is 40 % higher in damp or mouldy dwellings compared to non-damp or mouldy homes.

Wheeze

Wheeze is often accompanying asthma as an unspecific symptom. This symptom is supposed to be influence by mould as well. Figure 2 shows the results for wheeze and every mould indicator.

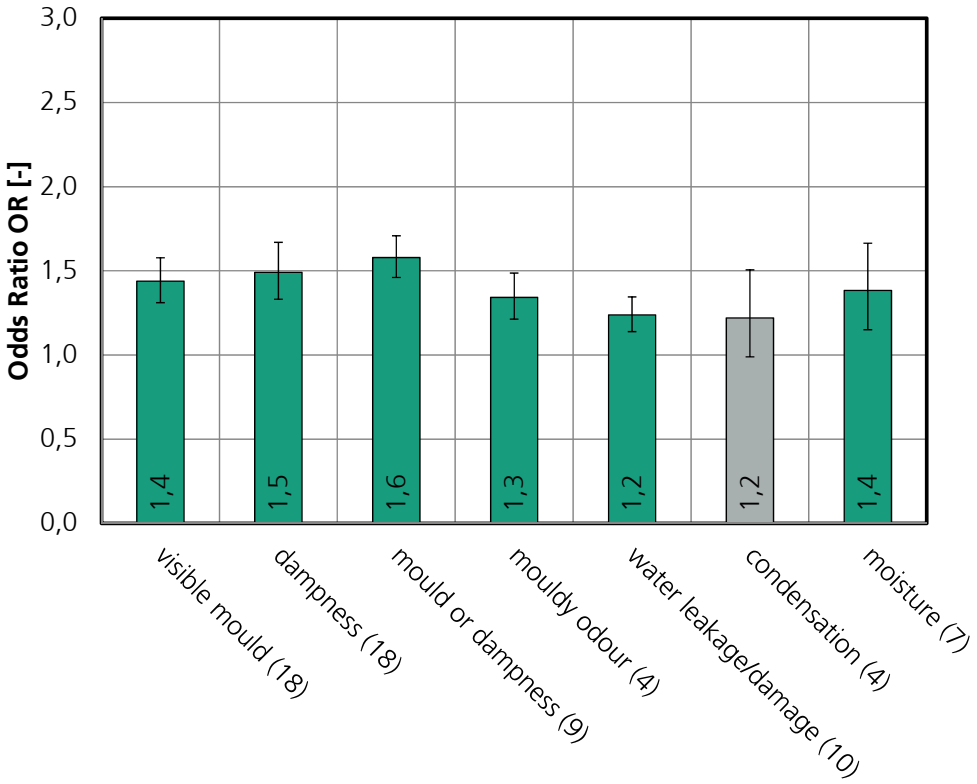

Figure 2:
Relationship between the prevalence of wheeze and the presence of one of seven mould indicators, notations as in Figure 1.

Here, all values, except condensation, are significant and slightly higher compared with the asthma outcomes. If at least mould or dampness is present, the chance for having wheeze is between 40 % and 60 % higher than without this indicator.

Cough

Cough is another unspecific symptom that comes often together with asthma or is a warning signal for the development of asthma. The results for this health outcome are displayed in Figure 3. All values, except for mouldy odour are significant. The highest (significant) values, and therefore the highest influence, are obtained for dampness and window condensation and reach an odds ratio about 1.8. The other values are in the same range as asthma and wheeze results.

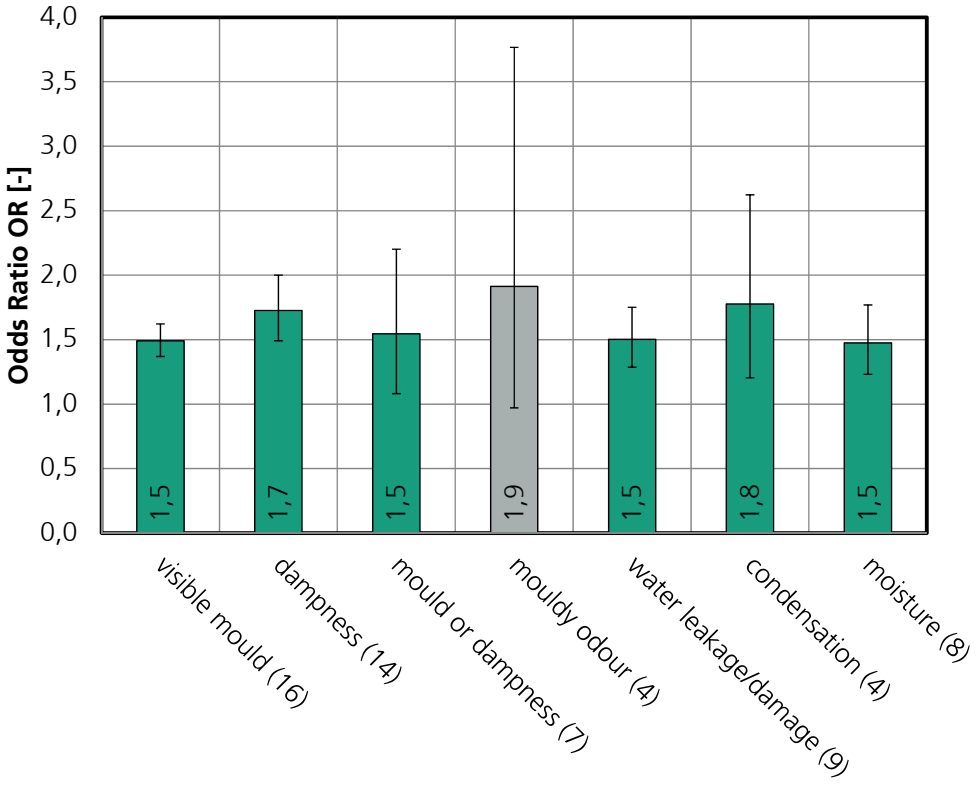

Figure 3:
Relationship between the prevalence of cough and the presence of one of seven mould indicators, notations as in Figure 1.

Rhinitis

Rhinitis is a very common upper respiratory illness. Results are displayed in Figure 4. For this health outcome, the number of studies is rather low, e.g. for mouldy odour, only one study is available. Although almost all values are significant (except for moisture), the interpretation is uncertain due to this small number.

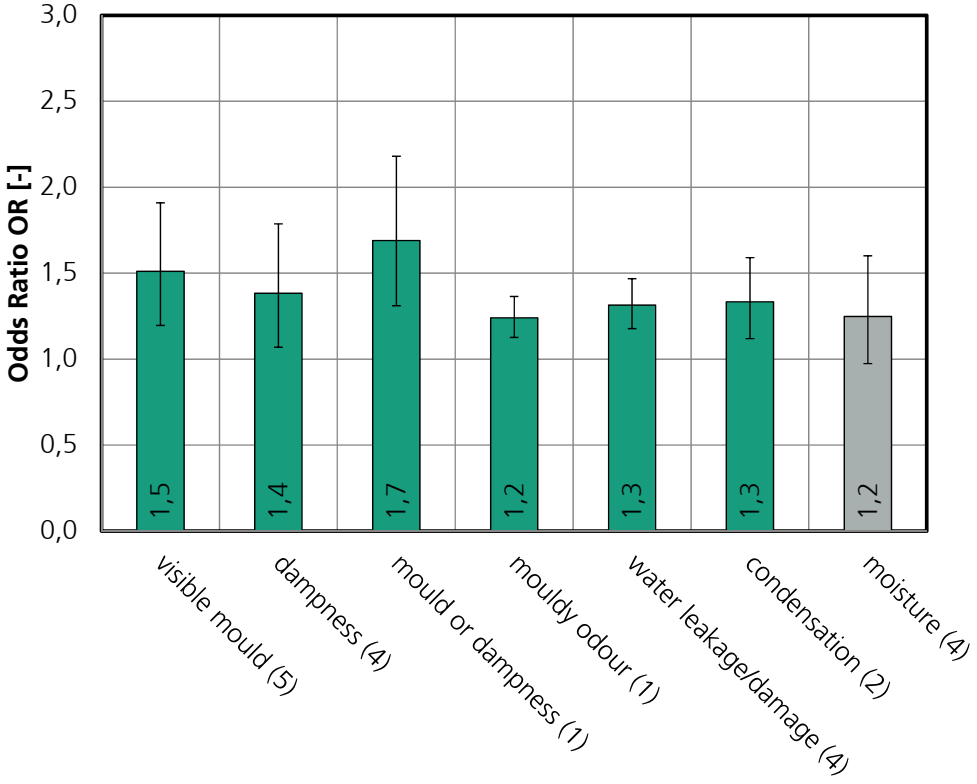

Figure 4:
Relationship between the prevalence of rhinitis and the presence of one of seven mould indicators, notations as in Figure 1.

For mould and dampness, the ORs are about 1.4 to 1.5, for the other indicators they are lower and located between 1.2 and 1.4. Compared to asthma, wheeze and cough, the influence seems to be smaller in its magnitude and in its clarity.

Bronchitis

Bronchitis is a severe illness of the lower respiratory tract system. Figure 5 shows the relationship between the presence of different mould indicators and the prevalence of bronchitis.

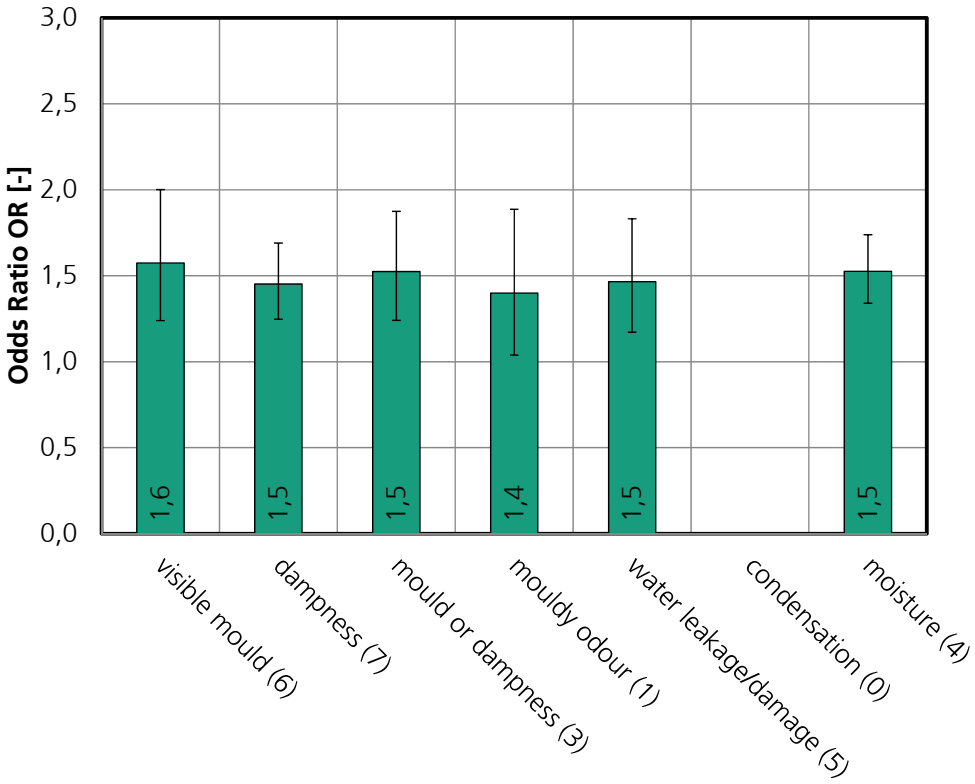

Figure 5:
Relationship between the prevalence of bronchitis and the presence of one of seven mould indicators, notations as in Figure 1.

All odds ratios are significant and are located in the range between 1.4 and 1.6, the same range as asthma and wheeze. No values could be obtained for condensation.

Allergic rhinitis / hay fever

Allergic rhinitis or hay fever is a rather common illness of the upper respiratory tract. Its prevalence ranges from about 14% in Germany [208] up to over 20% in the United Kingdom and France [209].

The number of studies is quite small. Every interpretation is therefore limited. Figure 6 shows the meta-analytic results. The values for mould, dampness, mould or dampness and moisture are significant, the others are not.

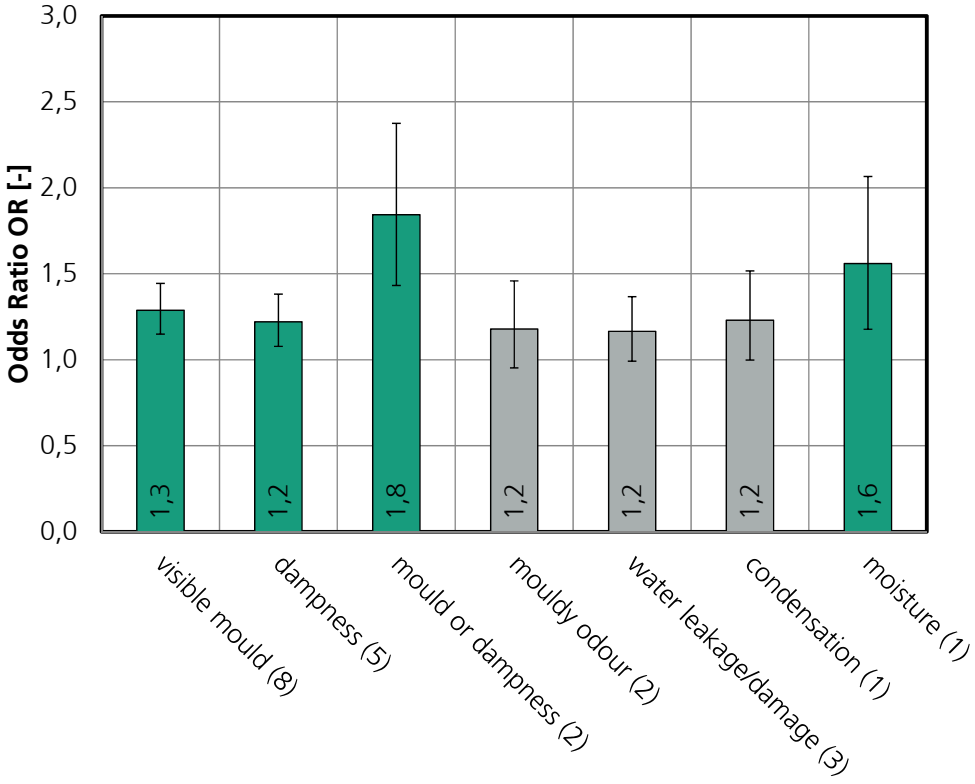

Figure 6:
Relationship between the prevalence of allergic rhinitis or hay fever and the presence of one of seven mould indicators, notations as in Figure 1.

As the results for rhinitis (see Figure 4), the ORs for allergic rhinitis and hay fever as upper respiratory illnesses or infections seem to be lower than the values for lower respiratory diseases like asthma and bronchitis.

Nasal symptoms

Under these symptoms, unspecific phenomena like a running nose or blocked or itching or dry nose are summarized. Normally, they are not classified as illness according to the ICD-system, but reduce comfort and perceived health of people that suffer from these symptoms. Figure 7 shows the results for every mould indicator.

Like for most of the health outcomes the number of studies is quite small. For visible mould, mouldy odour and condensation, the values are significant. For the latter one, the ORs is about 2.0. Additionally, the confidence interval is very small indicating that condensation may constitute an important factor when nasal symptoms are present. Contrarily, for mouldy odour, the OR is above 2.0 but the confidence range is very large indicating that there are probably many confounding variables in the data that do not allow to derive a clear relationship.

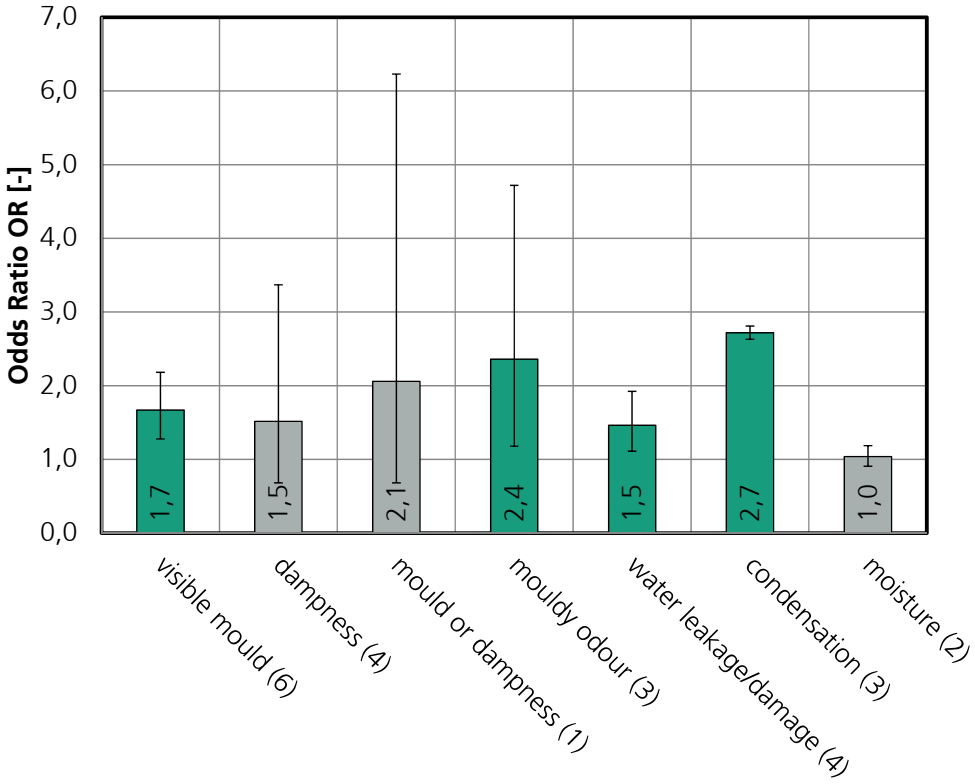

Figure 7:
Relationship between the prevalence of nasal symptoms and the presence of one of seven mould indicators, notations as in Figure 1.

Eye symptoms

Under this category, symptoms like dry, itching or irritated eyes are summarized. Like nasal symptoms, this category defines unspecific symptoms that affect primarily human well-being or may serve as a primary sign for developing a certain disease. Figure 8 shows the results.

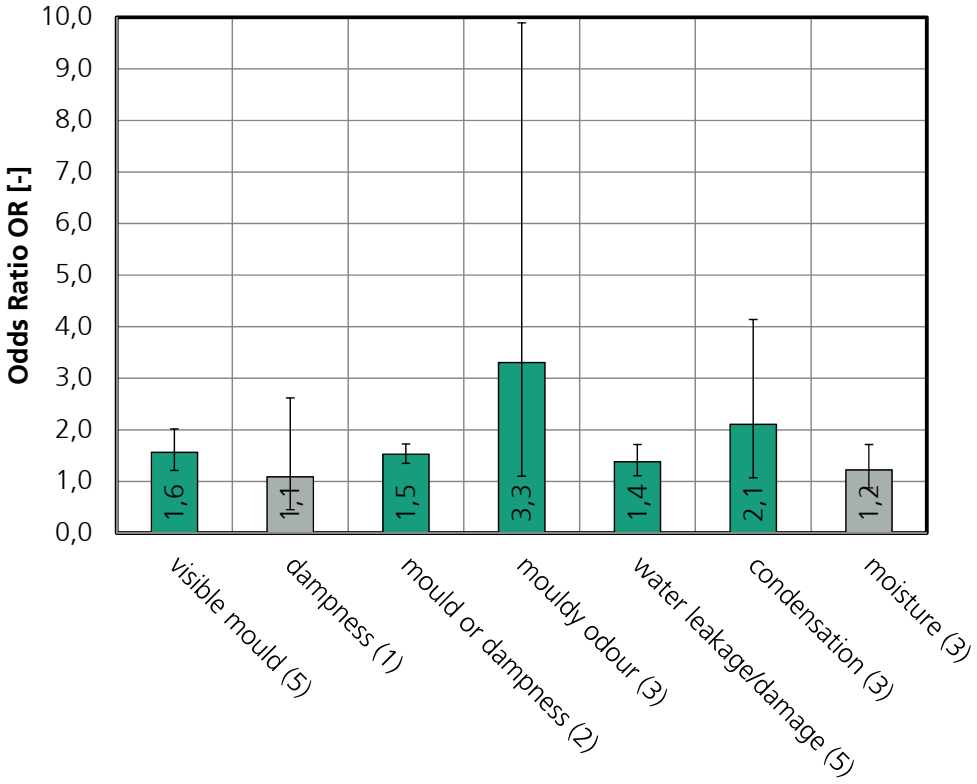

Figure 8:
Relationship between the prevalence of eye symptoms and the presence of one of seven mould indicators, notations as in Figure 1.

For visible mould, mould or dampness, mouldy odour, water damage and condensation, the values are significant. Especially for mouldy odour, the relationship is very high as the OR is almost 3.5, but confidence interval is very broad. But, like the nasal symptoms, mouldy odour seems to interact mostly with unspecific eye symptoms. This needs to be investigated in more detail in future research as many confounding variables may be still included in this relationship and the number of studies is quite small. Similar to the nasal symptoms, the value for condensation is quite high (OR above 2.0), but here in contrast, the confidence range is very broad.

Throat symptoms

Under this term, symptoms like dry cough, itching, irritated or sore throat are summarized. Like nasal and eye symptoms, this health outcome is rather unspecific but in contrast to the aforementioned ones it concerns the lower respiratory tract which may be more susceptible to mould. Figure 9 shows the results.

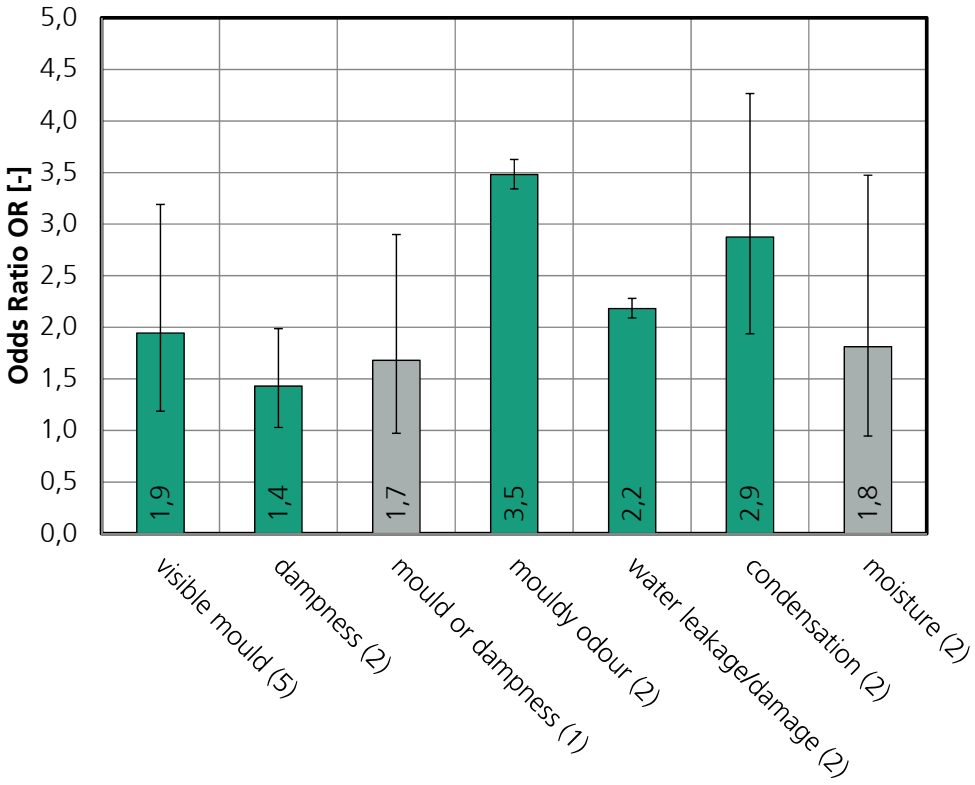

Figure 9:
Relationship between the prevalence of throat symptoms and the presence of one of seven mould indicators, notations as in Figure 1.

Except mould or dampness and moisture, all values are significant and mouldy odour and condensation show a strong relationship. Like in the two health outcome before (nasal and eye symptoms) mouldy odour and condensation have the highest magnitude of relationship to this health outcome. But here, the confidence intervals are more narrow than at the other two. Especially for mouldy odour, the range is small, but there are only two studies available for this calculation. The OR for mouldy odour is about 3.5, the same range as for the eye symptoms (see Figure 8).

Skin symptoms

Under this definition, symptoms like itching, irritated or dry skin are summarized. This health outcome refers not directly to the respiratory system, but is nevertheless important for human wellbeing. Figure 10 shows the results.

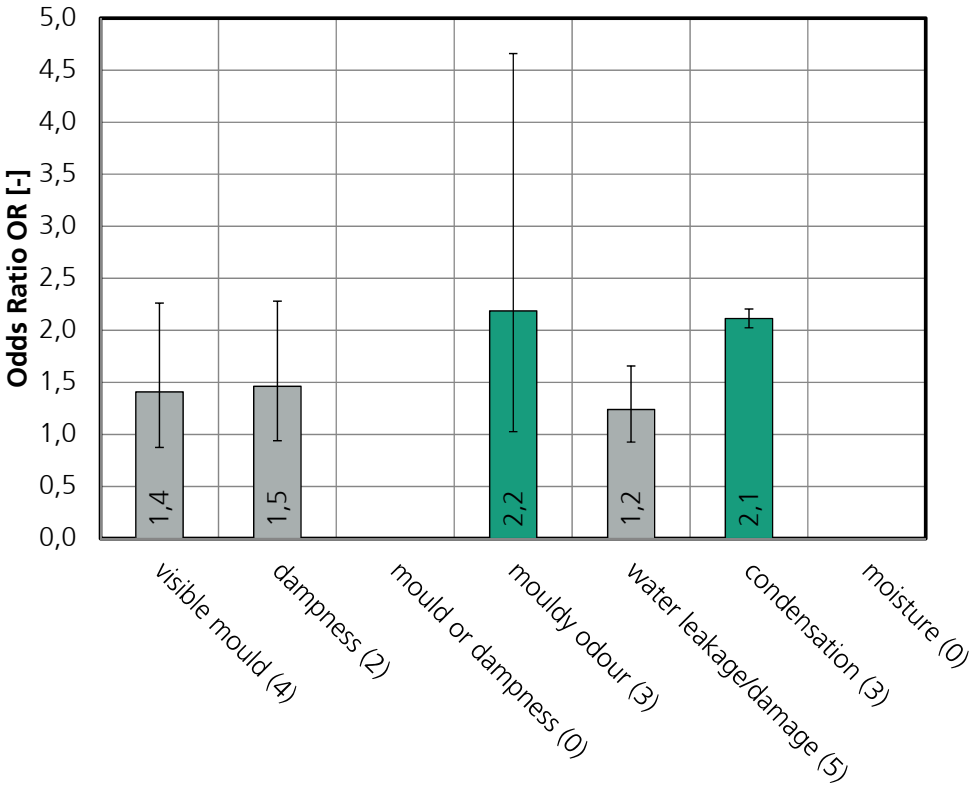

Figure 10:
Relationship between the prevalence of skin symptoms and the presence of one of seven mould indicators, notations as in Figure 1.

Like the other unspecific health outcomes, the values are highest for mouldy odour and condensation, and also only those values are significant. Due to the small number of studies, interpretation is very limited. Nevertheless, the influence for condensation seems to be quite high with an OR of 2.0 with a very small confidence interval. Mouldy odour seem to have an influence as well but needs to be investigated more in detail. The other indicators seem to be less important as they reveal no significant relationship and the magnitudes of ORs are small.

Common cold

Common cold is similar to rhinitis and a very common illness. For example, almost every child in Germany has at least one common cold per year [207]. Figure 11 shows the results for every mould indicator.

The values for mould and dampness are significant and in a similar magnitude (1.5 to 1.7). These values are higher than those for the lower respiratory diseases asthma and bronchitis. This may be an important finding as common cold has a considerably higher prevalence than asthma. For the other indicators the number of studies is too small and for mouldy odour and condensation, no studies are available.

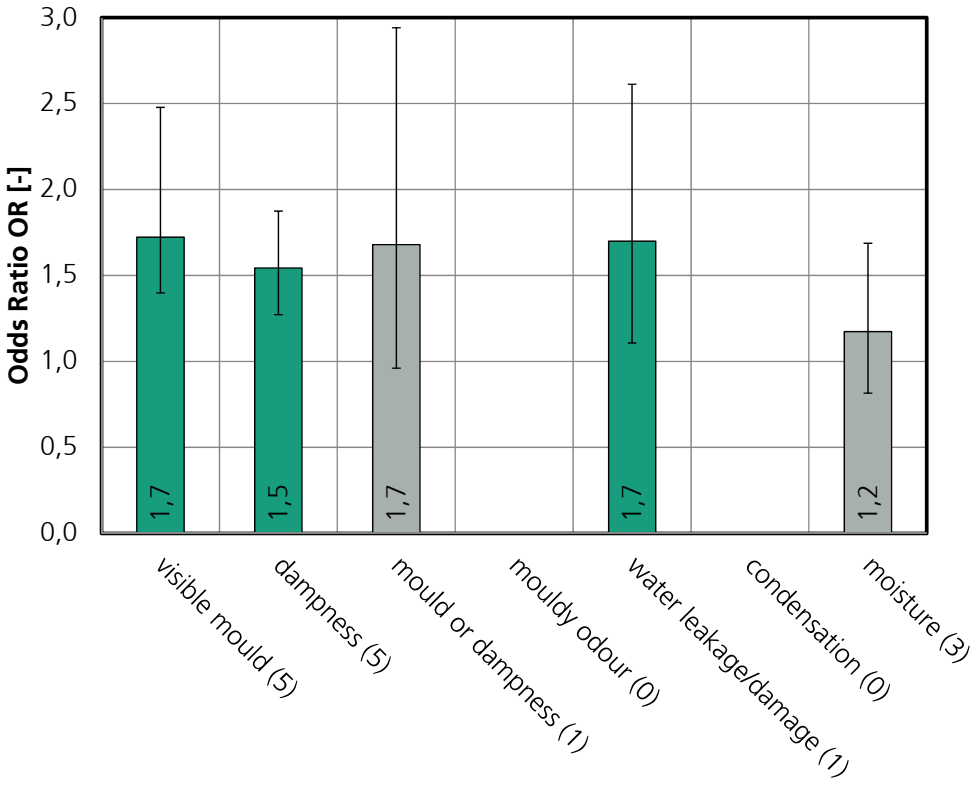

Figure 11:
Relationship between the prevalence of common colds and the presence of one of seven mould indicators, notations as in Figure 1.

3.2.2 Summarized health outcomes

In this section, the different outcomes are summarized together to get an overview about principal tendencies and relationships. Firstly, all respiratory diseases and all mould indicators are combined into one single value, i.e. the prevalence of diseases if at least one of the aforementioned mould indicators is present, is shown in the diagrams. Additionally, some potentially interesting moderator variables like the way of diagnosing asthma (i.e. doctor diagnosed or self- or parent-diagnosed asthma) are investigated. Another important variable is the age of the participants and finally, a differentiation into upper and lower respiratory diseases has been made to see if one of these is more vulnerable to the presence of mould and dampness.

Figure 12 shows the comparison between asthma and all other summarized respiratory illnesses. The values for both are nearly in the same range (around 1.5) and both are highly significant suggesting that the relationship between mould indicators and the prevalence of either asthma or other respiratory illnesses is given.

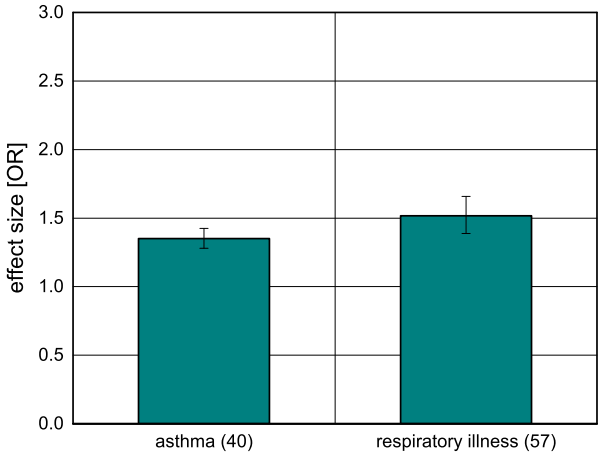

Figure 12:
Relationship between the prevalence of asthma and respiratory illness in general when at least one of seven mould indicators is present, notations as in Figure 1.

Figure 13 shows the comparison between asthma and common cold, an illness that occurs very often especially in the winter season when at least dampness or mould are present (the indicators are not included in this graph). The OR for common cold is highly significant as well and even higher in its magnitude than asthma, suggesting that a mouldy dwelling may promote this illness.

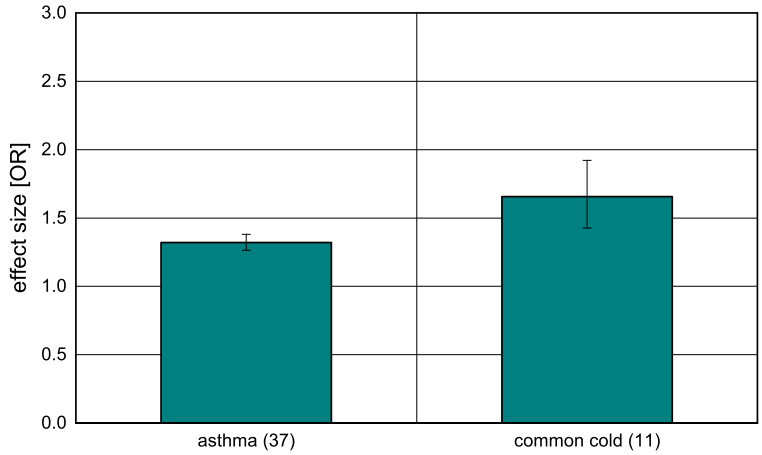

Figure 13:
Relationship between prevalence of asthma and common cold when at least one indicator of visible mould and/or dampness is present, notations as in Figure 1.

A further question is how the way of evaluating mould or dampness influences the outcome. Most of the studies ask occupants if visible mould spots or mouldy odour is present. Alternatively trained inspectors are sent to the homes to indicate if mould indicators are present. These two possibilities are summarized under subjectively evaluated mould indicators. The most objective way is to measure the presence of mould spores. This measure is classified as objectively evaluated mould indicators. Figure 14 shows the results for asthma.

Most of the studies used the subjective method, i.e. asked participants or trained inspectors if mould is present. Only five studies used objective measurements. Both values (subjective and objective) are significant, it seems that the way how mould is evaluated did not affect the result as ORs are in a similar range, the OR for objective measurement is only slightly higher but has a very broad confidence interval. It could not be concluded from this data if there is a difference both ways of measurement.

All other studies with an outcome on respiratory illness are summarized together and the influence how mould is detected was investigated as well. Figure 15 shows the results. Like asthma, most of the studies evaluate mould with questionnaires, only ten studies have measured fungal spore concentrations. The values of ORs are similar to those from asthma except the tendency that objectively evaluated mould indicators showed a lower OR than subjective mould indicators. Given the fact that the confidence range are rather broad, no conclusions about the influence of how mould is detected on the magnitude of the health-mould relationship could be derived.

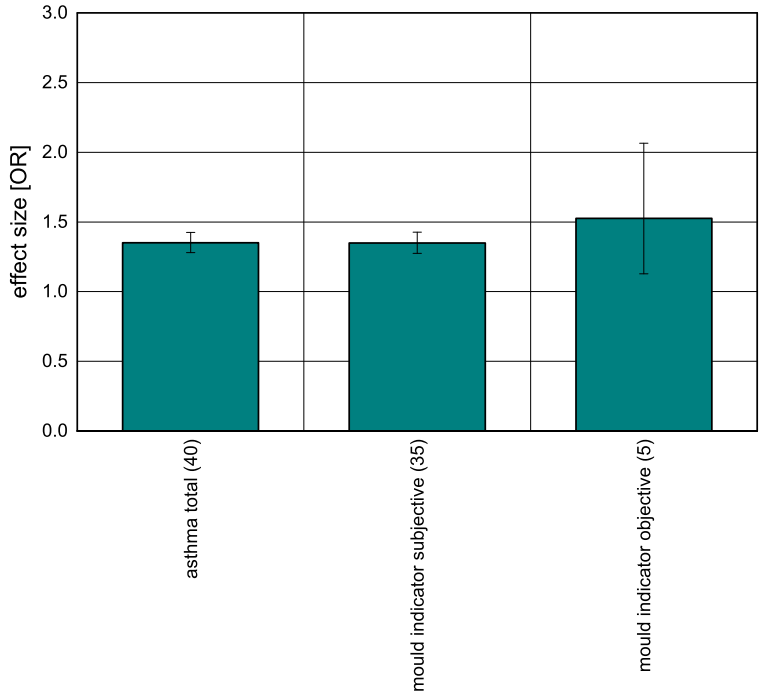

Figure 14:
Relationship between the prevalence of asthma and the presence of at least one of seven mould indicators, separated by the way how mould and dampness are evaluated, notations as in Figure 1.

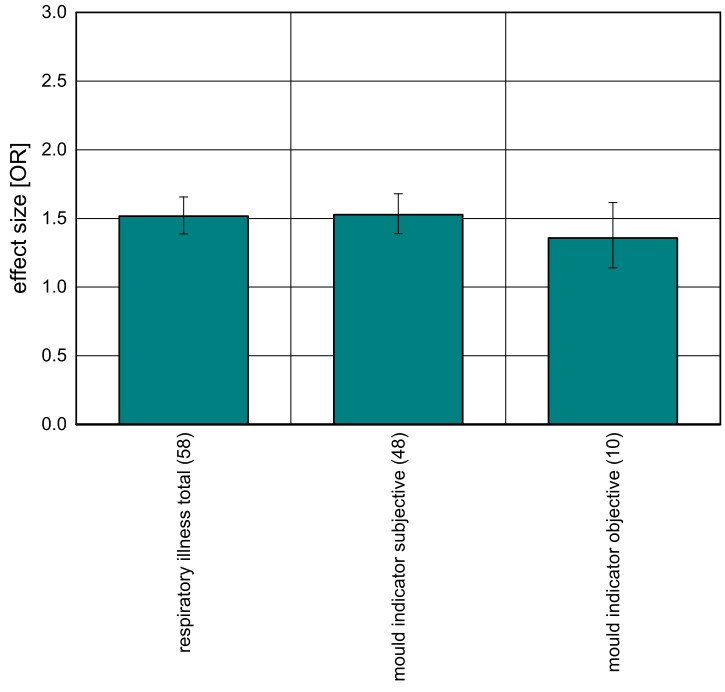

Figure 15:
Relationship between the prevalence of respiratory illness and the presence of at least one of seven mould indicators, separated by the way how mould and dampness are evaluated, notations as in Figure 1.

The way how an variable is measured could be extended to the health outcome. Both subjective measurements, i.e. asking the participants if they have a certain illness, or objective measurements, i.e. relying on doctor-diagnosed illnesses are present in the studies. Figure 16 shows the results of these analyses.

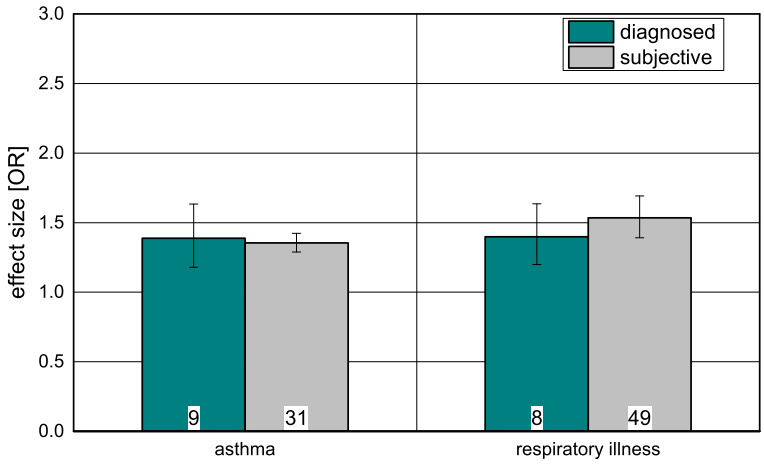

Figure 16:
Relationship between the prevalence of asthma or respiratory illness when at least one mould indicator is present separated by the way how the health outcome is evaluated, notations as in Figure 1.

Another question is if the relationship is stronger or weaker when separating into different age groups. Normally, infants, children and older people are more vulnerable to their environment and the presence of mould may be more detrimental for these groups than for middle-aged adults. For this analysis, the studies were subdivided into four groups: infants (age < 13 months), children, adults and studies with all age groups where no differentiation has been made. It was not possible to separate the group of elderly people (see Figure 17).

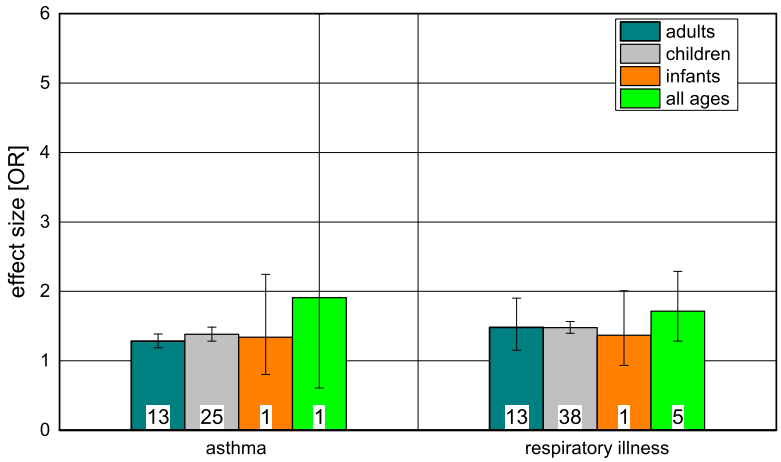

Figure 17:
Relationship between asthma, respiratory illness and presence of at least one mould indicator separated into different age groups, notations as in Figure 1.

Most studies are available for adults and children. The analysis lead to similar values for the ORs for adults and children. The group of infants has nearly the same OR, but only one study is included both for asthma as for respiratory illnesses. The group that mixes all ages together has the highest OR, but as well only one study included. Keeping these results in mind, no conclusion about the influence of age could be derived. Maybe this is caused by the cross-sectional design of all studies in this chapter. As they focus only on one single time point, many possibilities for bias may occur (see section 2.4.3).

Finally, all illnesses concerning the respiratory system are divided into upper (URI) and lower respiratory illnesses (LRI) according to the ICD-classification system from the WHO. Outcomes that may have their origins both in the upper and lower respiratory tract (e.g. wheeze or cough or shortness of breath) are summarized under the term "general symptoms". All outcomes that could not explicitly assigned to a ICD-classification (e.g. throat symptoms or mucosal symptoms). Figure 18 shows the results for this differentiation for the cross-sectional studies.

The results showed that the OR for both categories are in the same range. Conclusions about a different relationship between mould and upper or lower respiratory illnesses could not be confirmed.

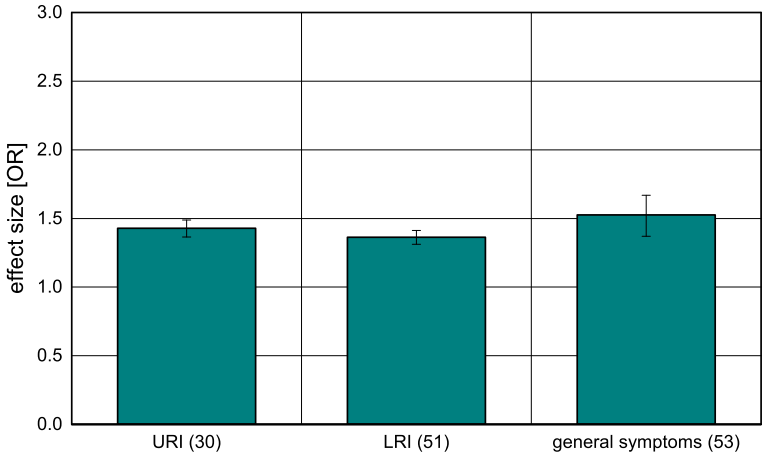

Figure 18:
Results for the differentiation into upper and lower illnesses and general respiratory symptoms, notations as in Figure 1.

3.3 Case-control studies

Although case-control studies normally report prevalences like the cross-sectional studies, the meta-analytic results are reported separately. This is due to the different methodology and time span (retrospective orientation in contrast to one single point in time for cross-sectional studies, see Table 3).

The number of case-control studies is much smaller than the cross-sectional studies and fewer differentiation in different illnesses is possible. In the following section, the results for asthma, wheeze and cough are shown for different mould indicators. Detailed information on other illnesses could not be derived out of the studies as the focus lies on asthma. Additionally, a global value for asthma and one for respiratory diseases in total (asthma excluded) is given.

Figure 19 shows the results for asthma and the different mould indicators and all indicators combined. The global effect size for asthma is OR = 1.8, this value is significant (p = 0.000).

As depicted in the picture, the values for OR are very similar for every mould indicator. No studies were available for signs of moisture in the building. The global effect size for asthma is clearly higher than that in cross-sectional studies. The mean ORs are slightly higher compared with those from the cross-sectional studies, but confidence ranges are rather broad.

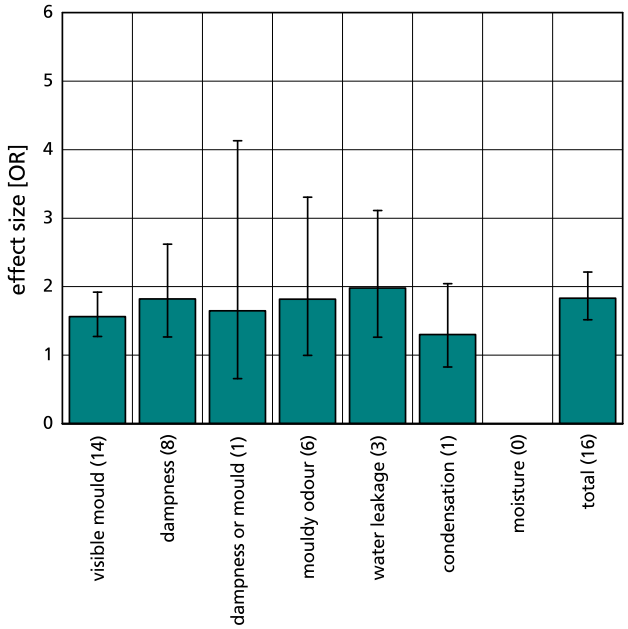

Figure 19:
ORs for asthma and several mould indicators and as global value, notations as in Figure 1.

In the next part, wheeze and cough are compared, Figure 20 shows the results. More studies are available for wheeze, for cough only three indicators are displayed. The OR are in the same dimension except for the category "dampness or mould", where the OR for cough is clearly higher than for wheeze. Indeed, there is only one study for each health outcome, a meaningful interpretation of these results is therefore barely possible.

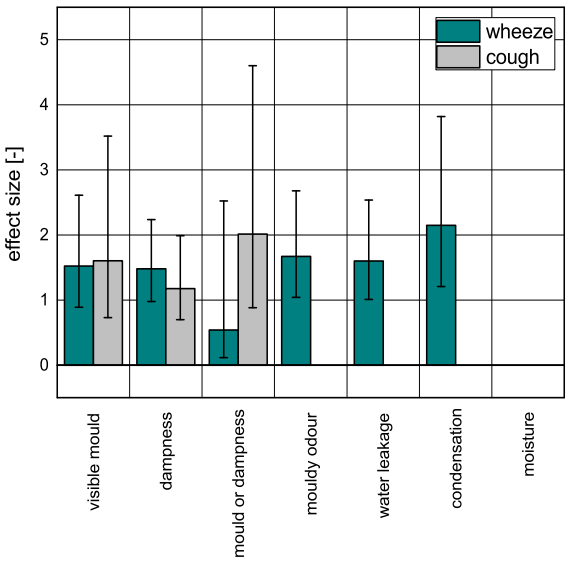

Figure 20:
ORs for wheeze and cough for every mould indicator, notations as in Figure 1.

Combining asthma and all mould indicators together and for wheeze and cough respectively (the two health outcomes are then combined to "other respiratory diseases") leads to the results in Figure 21.

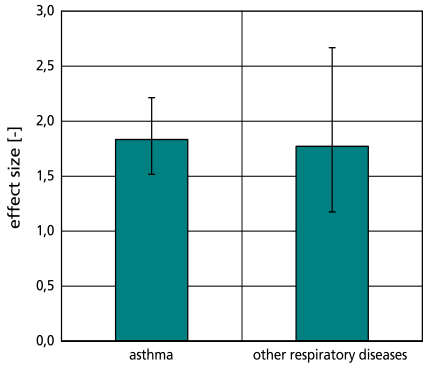

Figure 21:
ORs for asthma and all other respiratory diseases for all mould indicators, notations as in Figure 1.

The value for asthma is higher than in the cross-sectional studies (see Figure 12) and reaches almost 2.0. This may indicate that the study design is important for the result. As case-control studies have a retrospective character and not just one single point of time, the possible bias may be smaller as they observe people over a certain time period.

The next analysis focuses on the sort of respiratory illness, i.e. if the upper or lower respiratory tract is affected. The differentiation was made in the same way as for the cross-sectional studies. Wheeze and cough were classified into "general symptoms".

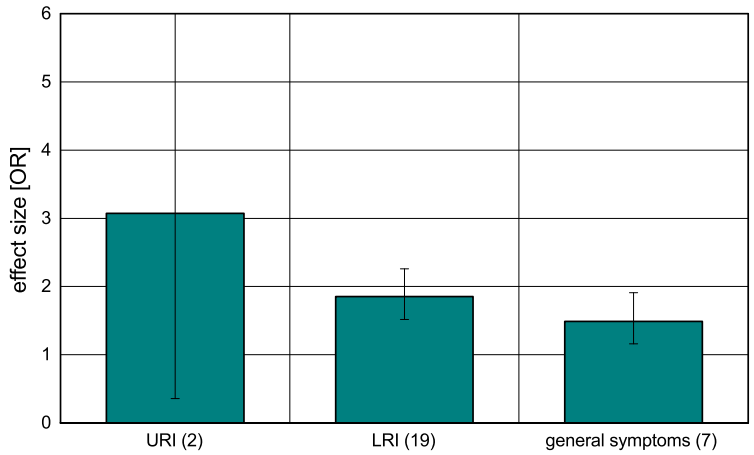

Figure 22:
Results for the differentiation into upper and lower respiratory illness and general symptoms, notations as in Figure 1.

The values for LRI and general symptoms are significant. The value for URI is high, but the confidence interval is nearly not displayable due to its size. As only two studies are included there, interpretations are not possible. The general symptoms seem to less affected by mould as LRI (which includes mainly asthma studies).

3.4 Longitudinal / cohort studies

For the longitudinal studies, it was important that subjects were healthy at the beginning of the study and only the new cases of the disease of interest were counted. This very strong requirement leads to the exclusion of a rather big part of the longitudinal studies and mainly birth cohort studies were eligible. The second reason for this drop-out was the fact that several publications for the same cohort study exist and all these publications refer to the same data which leads to a biased effect sizes if all the publications were included in the calculations.

The third reason is the indication of effect size. Mostly, incidence data were indicated and both ORs and RRs could be calculated. But sometimes, studies indicated only OR or RR without the underlying data and these values could not be converted into each other and are comparable. For the reason of easier interpretation and due to the fact that more studies indicate the Risk Ratio, this measure was chosen as effect size for the longitudinal studies.

The results in this section are divided into asthma development and the development of respiratory diseases. Figure 23 shows the effect sizes.

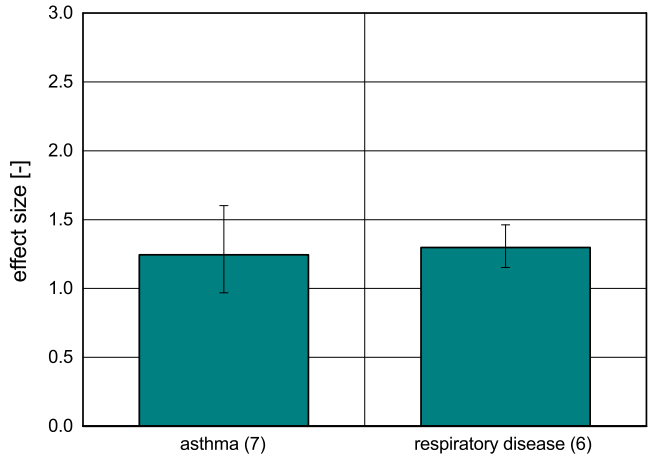

Figure 23:
RRs for asthma and respiratory diseases when at least one mould indicator is present, notations as in Figure 1.

This figure shows that the risk to develop asthma in a mouldy home is about 1.25 as high as in a non-mouldy home, and about 1.3 as high for respiratory diseases respectively.

Like in the cross-sectional and the case-control studies, a differentiation was made into upper and lower respiratory diseases and general symptoms like wheeze or cough. Figure 24 shows the results.

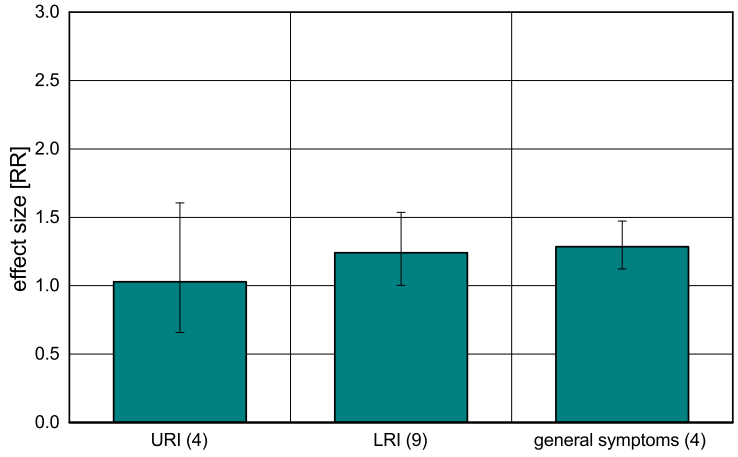

Figure 24:
Results of the differentiation between upper and lower respiratory illnesses and general symptoms, notations as in Figure 1.

4 Estimating the population affected by damp or mouldy dwellings for the case of asthma

The main outcome of the meta-analysis is a single OR-value as a summary index of all included studies. The question in this section is how to estimate the magnitude of persons that suffer from respiratory illness due to the presence of mould in their homes. As dampness is a prerequisite for mould growth and mould growth will occur, if dampness is not eliminated the figure for the share of the population living in wet or damp dwellings has been assumed for being affected by mould growth. In a next step it is projected what happens with this number of persons when the percentage of damp or mouldy homes could be reduced.

The first approach focuses on the prevalences, i.e. deals with the OR-values from the cross-sectional studies. An OR is computed as follows equation 1:

$$OR = \frac{a_d / na_d}{a_{nd} / na_{nd}} \qquad [-] \qquad (1)$$

The parameters in this equation can be defined according to Table 4. In this work, the interesting target value is the difference between a_d and a_{nd}. The parameter a_{nd} covers all persons who have asthma due to other risk factors (e.g. atopic parents or other) but not due to mould as they are not living in a damp or mouldy home. This "baseline" is subtracted from the number of persons who suffer from asthma and live in a damp or mouldy home, which is covered by the parameter a_d. The challenge for this approach is that each of these four parameters must be known which is only possible with several assumptions as no general statistical data exist about all of these values.

Table 4:
Example of a hypothetical epidemiological study where the relationship between damp or mouldy homes and the prevalence of asthma is analysed.

	damp or mouldy dwelling	No damp or mouldy dwelling
Asthma	a_d	a_{nd}
No asthma	na_d	na_{nd}

For this purpose the RR is more suitable as less assumptions are necessary for an estimation. The RR is calculated according to equation 2.

$$RR = \frac{a_d / (a_d + na_d)}{a_{nd} / (a_{nd} + na_{nd})} \qquad [-] \qquad (2)$$

The advantage of using the Risk Ratio is that it is not necessary to know each parameter of the formula. It is sufficient to know the summary values (a_d+na_d) and (a_{nd}+na_{nd}). The first one is obtainable by European statistics about how many people living in mouldy homes. This value is known with about 80.3 million people (see [1] for further information). The second one is the population which is not living in damp or mouldy homes. This value could be obtained by subtracting those people who live in damp or mouldy homes from the total population.

Prevalence rate of having asthma

Additionally, the value of persons who suffer from asthma but live in a non-damp or mouldy home is needed. This is the only value which is more difficult to obtain, as no large statistical database is available for this special question. In this work, the prevalence rate for asthma is estimated using the data of the WHO world health survey [210], which has been analysed with special focus on asthma also in [211].

In order to pool the available prevalence rates onto the region considered in this study the following method has been applied in order to adjust for the different sampling in the countries *i*:

$$PR = \frac{\sum pr_i \frac{s_i}{w_i}}{\sum \frac{s_i}{w_i}} \qquad [-] \qquad (3)$$

With pr_i the prevalence rate in each country *i*, s_i the sample size and w_i is the sampling weight. The sampling weight has been selected as post stratification weight if indicated, else the probability weights have been used or, if not available, the sampling fraction has been computed as population size by sample size (data taken from [210]).

Using this method the prevalence rate of having asthma in the considered European countries can be estimated using the formula (3) and the data summarised in Table 5 at being 7%. This is equivalent to approximately 36.3 million affected people. In the further calculation this proportion has been taken as total prevalence rate for dwellings, regardless of whether they are damp and wet or not.

The value a_d is the target value which can be calculated by transposing equation 2 to a_d and the value a_{nd} can be determined by solving the parallel condition that the total prevalence rate of having asthma (a_d + a_{nd}) is 7%.

Table 5:
Selected prevalence rates of clinical asthma from the WHO world health survey [210] for the available countries considered in this study. Population and sample size are listed as indicated in the survey reports of each country. The sampling weight selected as post stratification weight (*), probability weight (") or sampling fraction (°) according to the available data from the survey.

Country	Prevalence Rate of Clinical Asthma	Population	Sample Size	Sampling Weight
Austria	7,63%	8.111.000	1.055	7.688,2 °
Belgium	10,00%	10.296.000	1.012	10.173,9 °
Croatia	4,57%	4.439.000	993	3.341,2 "
Czech Republic	4,71%	10.246.000	1.918	8.956,2 *
Denmark	10,19%	5.351.000	1.003	5.335,0 °
Estonia	1,99%	1.338.000	1.021	995,1 *
Finland	10,24%	5.197.000	1.013	5.258,2 *
France	10,59%	59.850.000	1.008	62.913,8 *
Germany	7,55%	82.414.000	1.259	65.459,9 °
Greece	6,84%	10.970.000	1.000	10.970,0 °
Hungary	7,66%	9.923.000	1.419	6.953,8 *
Ireland	9,19%	3.911.000	1.014	4.579,3 *
Italy	6,26%	57.842.000	1.000	57.842,0 °
Latvia	2,70%	2.329.000	929	2.150,5 *
Luxembourg	9,44%	447.000	700	619,5 *
Netherlands	15,32%	16.067.000	1.091	14.726,9 °
Norway	12,32%	4.514.000	1.936	3.579,7 *
Portugal	7,83%	10.049.000	1.030	8.096,9 *
Slovakia	4,10%	5.398.000	2.539	2.164,1 *
Slovenia	8,66%	1.986.000	1.322	1.502,3 °
Spain	7,12%	40.977.000	12.023	7.121,4 *
Sweden	20,18%	8.867.000	1.000	10.896,6 *
UK	18,15%	59.068.000	1.200	49.223,3 °

Risk Ratio of having asthma in mouldy dwellings

The one value remaining is the RR stemming from the meta-analysis. In prevalence studies, RR is not computable as these studies do not cover a time span but only a single time point. As explained in section 2.1.1, OR and RR are interchangeable if the probability of occurrence is low, i.e. under 10 %. In the case of asthma there is a prevalence rate of 7% in the considered countries. Thus RR has been set equal to the obtained OR for further analysis and equation 2 is used for further calculations.

This implies certain assumptions for all further steps, which are in detail as follows:

- Prevalence rate of asthma of people living in non-mouldy homes is not changed over time (i.e. the only factors that is changed is the decrease of the number of mouldy homes).

- Prevalence rate of asthma does not change over time (i.e. new cases and deaths are equal in their amount)

- Independence of risk factors is assumed (i.e. when a child has atopic parents and lives in a mouldy home, the risk of having asthma is higher as if the child has non-atopic parents).

These assumptions are partly quite restrictive and sometimes very "artificial" but nevertheless a first attempt to derive an absolute number of persons that suffer from asthma due to mould and to show the dimensions of efforts to reduce mould in homes.

Prevalence rate of having asthma in damp or mouldy dwellings

Together with the figures outlined above, that 16.1 % of the European population live in wet or damp dwellings (approx. 83.5 million people), 7% is the prevalence rate of having asthma in Europe and the risk ratio of having asthma in a mouldy dwelling is 1.4 (cross sectional data) the fraction of the population, who lives in damp or mouldy dwellings and has asthma can be solved.

$$a_d = RR \frac{a_{nd}(a_d + na_d)}{(a_{nd} + na_{nd})} \quad [-] \quad (4)$$

This yields approximately 7.7 Million people do live in a damp or mouldy dwelling and have asthma, which is a prevalence rate of 9.2% of the population living in damp or mouldy dwellings.

Table 6: Resulting population in millions living in damp or mouldy vs. not damp or mouldy dwellings and having asthma vs. not having asthma when solving for 7% prevalence rate of having asthma, 16.1% living in wet or damp dwellings and a risk ratio of 1.4 for having asthma and living in a damp or mouldy dwelling.

	damp or mouldy	**not damp or mouldy**	**total**
asthma	7.7	28.6	36.3
no asthma	75.8	406.5	482.3
total	83.5	435.1	518.6

As the fraction of the population not living in damp or mouldy dwellings is 6.6%, there are 2.6 % more people having asthma in damp or mouldy dwellings than if they would live in non-damp or mouldy dwellings Thus it can be concluded, that this share of a higher prevalence of having asthma is due to the circumstance of living in damp or mouldy dwellings. Related to the absolute number of people living in wet dwellings, there are thus approximately 2.2 million people across Europe having asthma because of living in damp or mouldy dwellings.

5 Trend analysis on the modernisation of wet or damp dwellings

With the societal challenge to encounter climate change there are various ambitions to accelerate the modernisation of the existing buildings, which contributes significantly to energy consumption. With the objective to reach carbon neutral building stock until 2050 e.g. the German federal government has set out the aim to achieve a modernisation rate of approximately 2% [213]. This ambition is a great opportunity to address inappropriate indoor environmental conditions properly and to improve the existing buildings accordingly.

Based on this figure a simple trend analysis has been performed considering the situation of an average share of population living in wet or damp dwellings of ca. 16% [212]. Different scenarios have been elaborated assuming that this number remains stable for non-modernised buildings and that modernised buildings are in a better condition after retrofit than they were before, i.e. that after modernisation there would be a smaller share of population living in wet or damp dwellings than before. This has been calculated as follows:

Assumed modernisation rate

$$\dot{m} = 0{,}02 \qquad [-] \qquad (5)$$

Share of non-modernised dwellings d_{nm} and modernised dwellings d_m in year y compared to today

$$d_{nm} = (1-\dot{m})^y \quad \text{and} \quad d_m = 1-(1-\dot{m})^y \qquad [-] \qquad (6)$$

With the assumed share of affected population in non-modernised dwellings a_{nm} and modernised dwellings a_m the share of population living in damp or wet dwellings p becomes

$$p = d_{nm}a_{nm} + d_m a_m \qquad [-] \qquad (7)$$

The following scenarios have been outlined in Figure 25:

- **Ideal situation**: 0% of the population are affected by wet or damp dwellings in the modernised buildings
- **75%-improved situation**: 4% of the population are affected by wet or damp dwellings in the modernised buildings
- **50%-improved situation**: 8% of the population are affected by wet or damp dwellings in the modernised buildings

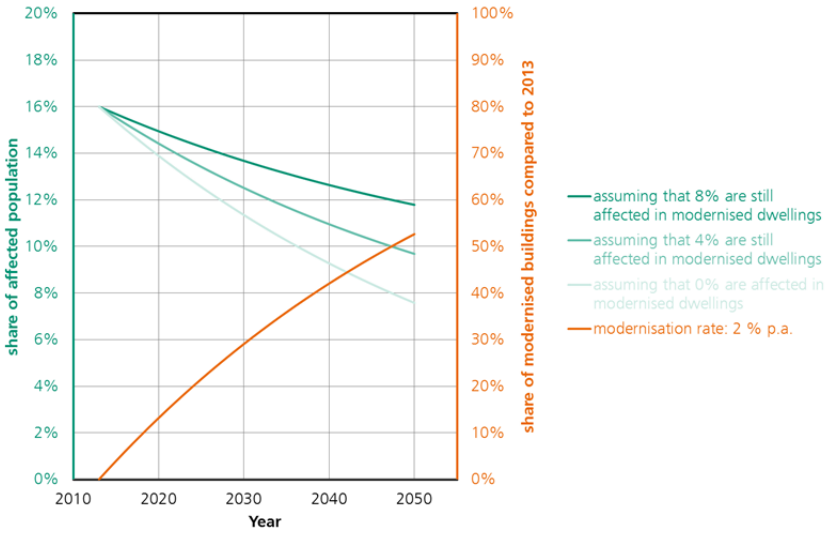

Figure 25:
Projection of the share of the population affected by wet or damp dwellings with a modernisation rate of 2% p.a. and different qualitative levels of modernised dwellings.

This leads to the following figures:

- Share of modernised buildings in 2050 compared to 2013: ca. 47%
- Share of population living in wet or damp dwellings in 2013: ca. 16.1%
- Share of population living in wet or damp dwellings in 2050: ca. 11.9%

Thus if we would achieve an improved building stock, which halves the number of affected people due to damp and wet dwellings from approximately 16% to 8%, with a modernisation rate of 2% p.a. the adverse living conditions of wet or damp dwellings and the share of affected population would reduce by approximately 25% until 2050. Consequently the associated respiratory illnesses can be expected to reduce accordingly, accompanied by a decrease in the related public health costs.

Assuming, that prevalence rates do not change over time and that risk factors are independent this projection of a reduction by 25% would mean a reduction of approximately 550.000 affected persons in 2050 for the case of asthma.

6 Discussion and Conclusion

This study report describes an extensive meta-analysis about the relationship between mould and dampness in the indoor environment and the prevalence and incidence of respiratory diseases, especially asthma. This analysis revealed that despite of the huge amount of studies that have been made in this field, the derivation of significant relationships is not trivial. This is on the one hand a consequence from the different types of studies that have been conducted, most of them are cross-sectional in their design and do not allow to derive dose-response relationships. Fewer studies are based on a case-control and an even smaller number is based on a cohort design which is technically speaking the only epidemiological design that allows to derive risk estimates.

The values for the results and therefore quite different. The cross-sectional studies revealed an OR of 1.4, the case-control studies an OR of about 1.8 and the cohort studies estimated a risk to develop asthma of about 1.25 in damp or mouldy homes compared to non-mouldy homes. All these three values have in common that they are statistically significant, i.e. the general relationship between the prevalence of asthma and the presence of mould could be confirmed.

An additional moderator analysis has been done to highlight if certain parameters are responsible for the relationship, i.e. if some illnesses are more susceptible to mould than others or if the way how mould and health outcomes are investigated has an influence about the magnitude of the relationship. However, the moderator analysis revealed no special characteristics about these moderators. ORs are mostly in the same range for every moderator. Most of these analyses were only possible for cross-sectional studies, only superficial calculations could be made for case-control- and cohort studies due to the small number of publications.

Finally, an estimation of the share of population having asthma because of living in damp or mouldy dwellings has been outlined. A trend analysis with a projection accounting for the modernisation of the building stock has been performed, which shows the potential of decreasing the number of affected persons and thus for saving health costs when damp or mouldy homes are renovated. This method has strict assumptions, but is a first step to gain a magnitude of impact on the occupants' health.

A general relationship between the presence of mould and dampness and the prevalence of respiratory diseases could be established. As magnitudes depend strongly on study design, more systematic research with epidemiogical case-control- and cohort studies are necessary to derive dose-response relationships. Then, moderator analyses could be more promising then currently as this is

mostly possible only for cross-sectional studies which have the weakest epidemiological strength. The calculation method for estimating health impacts could be refined to precise the prediction.

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