

## Odour problems in buildings – result of 682 cases

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### ABSTRACT

Various odours can cause a negative perception of the indoor air quality. The intensity of the odour can fluctuate for example due to weather conditions, ventilation, and use of the building. In addition, the degree of odour perception among individuals, is highly variable. Absence of an adequate measuring method makes it difficult to get a systematic and uniform description of the odour and where in the building the odour is most noticeable. This leads to challenges in clarifying the causes and relevant measures are often difficult to submit. Examination of 682 cases with odour in dwellings and commercial buildings have shown that causes and remedial actions can be revealed by a systematic procedure. Complainers are asked to characterize the smell in few, standardised words and describe where and when they experience the odour. This information is often crucial for the surveyor when performing the following building examination.

### INTRODUCTION

In buildings, there are several various volatile compounds that make up the specific odour in the indoor air. These molecules can have an origin from outside or from various sources inside buildings. Indoor sources that affect the odour can be building materials, use and residence of people as well as various consequences due to exposure to water leaks, fire, or other damages (SINTEF Community 2012, Ryan & Beaucham 2013, Bøe & Mattsson 2018). There is no certain evidence that common levels of volatile substances in Norwegian indoor environments pose any health risk (Norwegian Institute of Public Health 2015). On the other hand, studies of some of the normal occurring substances, such as from mould damages has shown that living in home with mould problems may increase the risk of respiratory infections, and symptoms (Pirhonen et al 1996). In some work environments, there may be connections and levels that are unacceptable and thus constitute a clear health risk (Swedish Work Environment Authority 2015).

The specific odour the human olfactory organ can sense, consist of a complex combination of many molecules and chemical compounds released to the air. Small changes in the molecular composition can change the perception of the smell. This complexity makes it extremely difficult to develop or use adequate measuring methods (Sensorisk studiegruppe 2015). Nevertheless, with a trained sense of smell and experience from several odour cases, our survey has

shown that methods can be described to remove the undesirable odours, even though the exact source or definition of the odour is not always revealed.

Some of these substances, but not all, can be perceived as an odour. The perception of smell varies between different people, so there is no unambiguous definition or level of what is acceptable (Norwegian Institute of Public Health 2015). Under normal conditions, the concentration of odour from normal sources is so low that it does not lead to a problem with indoor air quality (Norwegian Building Authority 2017). Avoidance of odour sources indoors and a good air exchange leads to a removal or at least dilution of pollutants and odorants. This will ensure good indoor air quality (SINTEF Community 2017). However, due to air pressure differences that can occur under different ventilation conditions, ventilation can cause local negative pressure that led to odours from adjacent areas and structures being drawn into zone where it is perceived as troublesome (Mahooti-Brooks et al. 2004).

Odours are perceived differently by different people. Abnormal odours indoors can be perceived as annoying to some people, while other does not experience any undesired smell (Hägerhed-Engman et al. 2016). It is shown that odour assessment can be performed both by the users of the buildings and by experts in the field (inspector). However, it is noticeable that it can be significant variations in the assessments even between experienced inspectors because they have individual sense of smell and knowledge (Hägerhed-Engmann et al 2009).

Age, gender, smoking and state of health are examples of factors that affect the sense of smell. Permanent lack of sense of smell (and taste) has also recently been shown to be a consequence of certain infections, such as acovid 19 infection (Dæhlen 2021). Absence of odour can therefore be due to both actual absence of an odour and the individual variation of the sense of smell.

It has been revealed that even absence of physical occurrence of odour, can be experienced as an unpleasant smell by some people. This is described as “distortion on olfactory perception” or “phantom odour perception” (“phantosmia”). The reason for such condition is explained by several reasons, for instance after experiencing a shock or an unpleasant incident, such as a house fire or mould damages (Nordin 2009). Treatment is reported to be active therapy, medications, and surgery (Leopold 2002). Bainbridge et al (2018) reported that 6,5% of people over 40 years old experience phantom odour problems. Two out of three of those who experienced phantom odour were

women. Reporting odours even when there is no real source may be one of the reasons why it is not always possible to clarify an odour source. However, this cannot be known in the first place and one should therefore always take as a starting point that the odour has a real source that can be found.

Measuring odour is difficult and complicated for various reasons: the human olfactory organ is extremely sensitive and even small particles or molecules can be detected by the human nose. The results of for instance chemical measures such as VOC (volatile organic compounds), normally give a low result despite a distinct smell at the location. Chemical measures on a molecular level can be carried out, but the result is in most cases hard to interpret and rarely lead to the actual cause of the odour (Norwegian Institute of Public Health (2015).

Intensity of odours tends to decrease as time passes by natural decomposition, although this depends on the source and other factors (Norwegian Institute of Public Health 2015). In cases where this process is time-consuming, active measures are needed. Which measures depend on the source of the odour, type of materials and building physics. The optimal solution is removal of the odour source. Where this is not possible, a thorough cleaning can have a satisfactory effect. Use of ozone or products with odours to mask the problem usually have limited lasting effect. In some cases, sealing of the odour can have an effect, but this is rarely recommended as the only action (Bøe & Mattsson 2018).

In many cases, mould damages have a characteristic odour, but not all mould damages have a special or significant smell (Koskinen et al 1999). However, if it is a sense of mould odour, house owners often have a clear perception of the problem and source since specific odours often are reported in cases due to water damages (Hägerhed-Engmann 2009). Despite this, our experience is that even simple causes can be difficult to solve for those who do not have a sufficient understanding of building physics and experience of such issues. In cases with more complicated causes, it has been shown that even professionals with a potentially good knowledge of buildings and building physics may have difficulty finding out the causes of odour problems. A reason for this might be that professional building surveyors in Norway have not standardised established methods for investigating odour problems in buildings in general (Bøe & Mattsson 2019) and especially not in the survey documents that is made in connection with property transfers (Ministry of Justice and Public Security 2020). The consequence of this is often that not even simple issues are clarified in a satisfactory manner. Furthermore, it is rare that odour problems have insurance coverage. This may be because the cause of the damage is not eligible for coverage, but also

because the original reason for the odour which may be covered by the insurance has not been determined.

In a building there are many potential odour sources and clarification of odour sources can be difficult. However, odour problems are due to a source combined with air movements or diffusion into the residence zone. A systematic examination of air movements often provides a good basis for clarifying even diffuse odour problems.

We have through 35 years assessed many cases regarding odour problems indoors in various buildings. 682 cases of odour-problems of various types and severity have been studied to gain knowledge about this complex issue. The main objective of the study has been to investigate whether the odour-problems can be classified into specific groups and based on this find a procedure that can be helpful in solving odour problems in general. This part of the study has resulted in a list of 15 categories that often, occasionally, or rarely is the probable cause of the unpleasant odour. The idea is that categorising the odour-sources will make it easier to solve the problems. In table 3, a listing of the most common sources of odours reported in our 682 cases is listed and described briefly. The dataset is also studied to see if there is a coherence between building age, building type, location in the building and odour-problems. Another main issue of this study has been to develop a protocol and procedure that can be followed by building inspectors working with odour problems. This procedure will facilitate the work to solve difficult odour problems. Such procedure, which is based on the survey of 682 cases as well as experience from daily work on solving a large spectre of building problems, is described in figure 1 and table 1, 2, including a suggestion of useful tools and preparations and a general description on how the survey can be carried out.

## **MATERIAL AND METHODS**

### **General**

Review of 682 surveys where the odour problem was the main reason for the assignment, have been carried out by Mycoteam in the period 2007 - 2020. Information from the reports and other relevant information of the main problem has been assessed in this paper. In cases where there were minor odour problems in addition to the main problem, this has not been included in this study.

The work on examining odour problems, is based on a three-stage procedure; 1.) Collection of information before inspection. This includes information from the residents regarding odour-variation, construction details, previous reports, and other relevant information. 2.) Visual and odour examination at the site with a survey of building physics, which normally

includes a. Constructions, b. Ventilation conditions, and c. Sampling. 3). Assessment and report (figure 1).

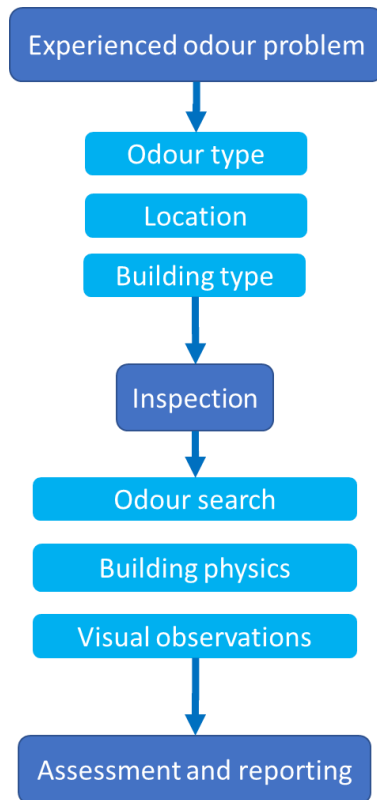


Figure 1. Flowchart of the procedure for odour examination.

**Collection of information**

Prior to an assignment, we ask residents or users of the building for general building information and location of the smell. Questions such as when the smell is observed, if there is any variation in the intensity and what kind of smell it is, are being asked. It is also of interest to find out how many of the people who normally stay in the premises experience the smell. The following issues should be clarified prior to the inspection (table 1).

Table 1. Relevant information the users are asked to clarify before the inspection.

1	Is the odour persistent or does it fluctuate? Variation in the odour pattern should be clarified prior to the inspection.
2	Has there been a recent change in building physics or use of the building that can influence the occurrence of odour? Does this change cohere with the time the smell was first noticed?
3	If odour is fluctuating: what time of day / week is it most likely to experience the smell? Is there a seasonal fluctuation or does the weather affect the odour perception?

4	Can the inspection be arranged on short notice? Inspection should ideally be done when the odour is present.
5	Does the building ventilation affect the odour? Information about settings and operating hours is needed.
6	A detailed or as detailed description of the building construction should be described prior to the inspection.

To ensure an optimal examination, precautions are given to the residents, users, or caretakers of the building prior to an inspection (table 2).

Table 2. Relevant information before the inspection.

1	Odour producing activities prior to the inspection must be limited, such as brewing coffee, cooking, smoking etc.
2	People attending the inspection cannot use strong perfumes or similar products that can conceal or reduce the chance of smelling the odour in question.
3	Specific types of food, scented candles, incense, and similar products with strong scent that can affect the indoor air, must be removed before the inspection.
4	The ventilation can affect to odour. In some cases, air-vents should be considered closed prior to the inspection or at least tested by the residents whether this affects the odour perception.
5	Make sure the temperature is high enough. Temperature is an important factor in the perception of smell.

**Visual inspection and odour examination**

Based on given information - visual examination of available surfaces and constructions for any deviations in relation to building conditions, moisture problems and other conditions that may be relevant to the specific odour problem are being performed. In addition, we carry out a general odour control by using the nose in the various premises trying to locate deviations and patterns of the odour. An important task in this phase is to try to locate differences and to locate where the odour seems to be strongest. This can be time consuming and regularly pauses must be taken outside the area of suspected odour.

**Building survey**

Ventilation and air flow inside the building is important to reveal. Measurements involving air exchange rate, where fresh air enters and where the

exhaust air exits can be carried out. In addition, we examine pressure differences within the building. We also consider how this can vary with use of the building and seasons. Dräger air flow test tubes are used for clarifying air leaks and air currents. In some cases, it is also necessary to carry out more detailed pressure-differences using adequate equipment to measure the pressure differences between separated areas on a more permanent basis (logging).

### Sampling and analyses

In cases where it is suspected that the odour is due to special building materials or microbiological damage, material samples can be taken for odour examination in odour-neutral laboratory environments and/or microscopic analyses.

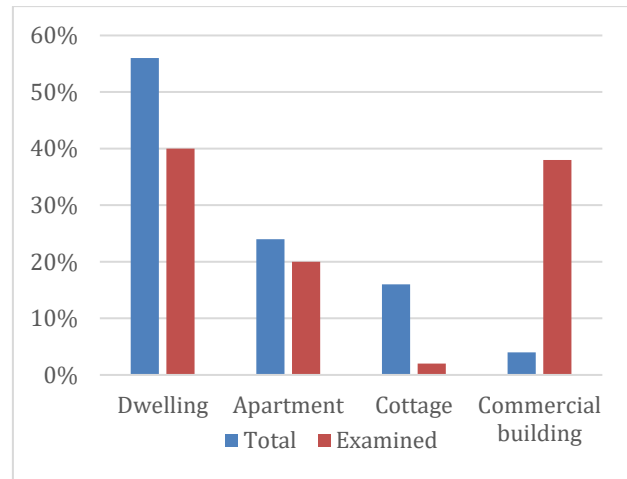
Material samples are taken with a suitable tool and kept in an air-tight bag or wrapping. It is important to ensure that the container does not affect the odour of the sample. Several layers of aluminium foil are a suitable material for keeping the odour sample tight and unexposed. Surface growth of mould is sampled with a tapelift from the surface. In special cases a few other methods can or are being used. For instance, measuring volatile organic compounds (VOC) can be performed if the source of the odour is related to petroleum products.

## RESULTS

### Type of building

Of the 682 surveys we have examined in period between 2007 and 2020, the building type was clearly stated in 537 cases. The remaining assignments had a vague or inadequate description. In addition, several cases do not include buildings at all, but cars, buses, trains, boats, and various other objects.

The distribution of the various building types is shown in Figure 2. Red columns show the total percentage of various building types in Norway. The first column shows that of all Norwegian buildings, 40 % are dwellings. The blue columns show the percentage of the odour assignments that have been present in the various building types. Approximately 58% of the odour problems in this study, are listed in a dwelling. Numbers from the distribution of all buildings in Norway, are gathered from Statistics Norway (2021). We point out that the total number of buildings in Norway obviously (blue columns) is much greater than the buildings that have been examined by Mycoteam (red columns). In this case, we compare the numbers in percentage, thus being able to compare the numbers. The results show that the distribution between houses and apartments correspond well with the total number of dwellings, while assignments in cabins and commercial buildings deviate.



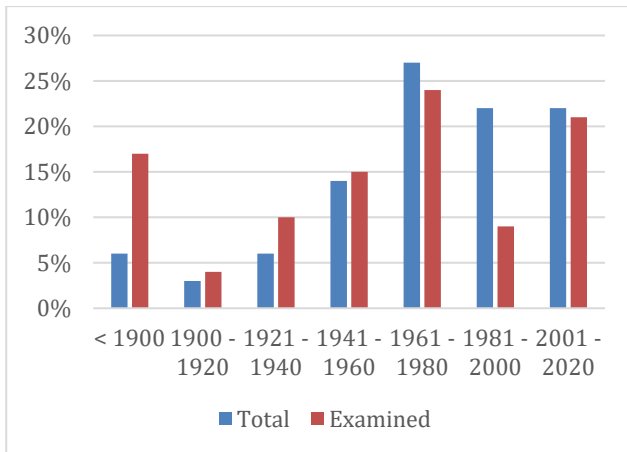
**Figure 2. Type of building with reported odour problems (n = 537) examined by Mycoteam 2007-2020 compared with total amount of Norwegian buildings (n = approx. 2.6 million).**

The distribution of the surveyed building types agrees well with the general distribution of different building types in Norway (Statistics Norway, 2021). The discrepancy on a larger proportion of commercial properties in our survey may be because there are many commercial buildings (offices, schools, shops) located in South-Eastern Norway where the population density is higher than other areas in Norway. In addition, many of them are on the ground floor in apartment buildings and apartment blocks.

### Building age

Figure 3 shows the distribution of buildings with odour problems in relation to year of construction. We see that the distribution of odour problems agrees well with the general distribution of the age of the building stock in Norway (Statistics Norway 2021). The discrepancy in the number of buildings examined from <1900 is probably since Mycoteam is based in Oslo, where there are many brick buildings from the 19<sup>th</sup> century.

The problem with assessing the age of buildings is that old buildings are refurbished, modernized, and rebuilt. For this reason, therefore, both newer materials and constructions are found in old buildings, which means that even old buildings can have "modern" problems.



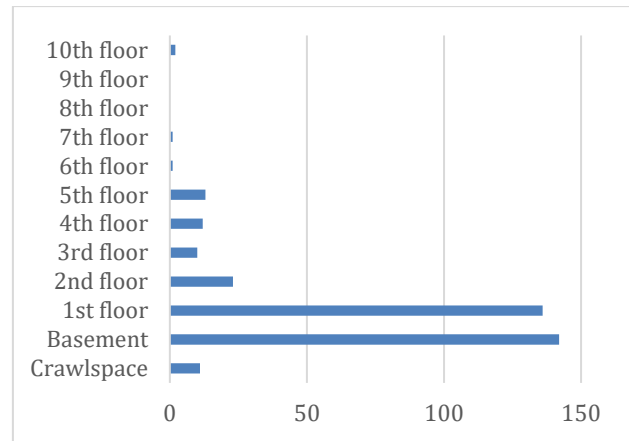
**Figure 3. Building with known age with reported odour problems (n = 274) examined by Mycoteam 2007-2020 compared with total amount of Norwegian buildings (n = 1,5 million).**

The distribution of the age of buildings shows that odour problems occur in buildings regardless of how old they are.

**Location of odour problems in the building**

The review of the reports shows that the largest number of odour assignments have been associated with basement floors and the first floor (Fig. 4), which is as expected since most buildings have a residential floor on the first floor and often a basement. In addition, it is especially the basement that has moisture problems that can cause odour problems in these areas. In a several stories building, there is normally an air flow from the basement to the upper stories, thus explaining why odours in the basement affects especially the first floor.

The exception is odour problems in apartment buildings that normally have a boundary to a separate floor. Within the individual apartments, it has turned out that there are odour problems that are mainly unrelated to which floor it is. The declining trend with the number of odour cases upwards on the floors is because there are few tall buildings in Norway and the fact that all buildings have a 1<sup>st</sup> floor, but the number of stories decrease in a building after first floor. The sudden drop from 5<sup>th</sup> floor to 6<sup>th</sup> floor is probably due to our location in Oslo where there is an old regulation not allowing buildings higher than 5 stories in a great area of the city.

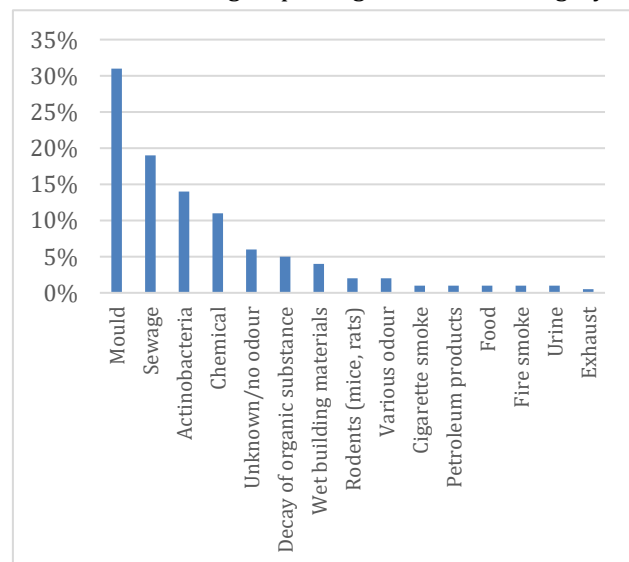


**Figure 4. Location of examined odour problem compared (n = 342) in surveys performed by Mycoteam 2007-2020.**

**Sources to and characterization of odour types**

Experience of various odours is individual, both in terms of type of smell and intensity. Our experience is thus that there may be different descriptions of the same smell. Since we have requested the smell to be described with key words instead of a fuller description, it is easier to see a pattern in the type of smell in question.

We have listed a summary of current odour categories where both odour type and presumed origin (such as external source, building-related, use-related, or damage-related) from the 545 cases where a characterization of odour has been reported (figure 5). Based on a description made by the inspectors in the specific assignments, we have made a list of the most common odours we have experienced. In some cases, similar odours are grouped together in one category.



**Figure 5. Description of observed smell in examined cases of odour problems (n= 545).**

This is not a complete overview of assignments with odour problems we have examined. The reason for this is that when the main cause of the assignment is not odour but, for example, a clear and extensive problem

with water, fire, sewage, mould or wood-decaying fungi attack, the assignment is normally not defined as an odour damage.

All odours have an origin either inside the building or from the outside. The odour compounds can theoretically be dispersed with air movements and diffusion from areas with high concentration in the air to areas with low concentration and quite far from the actual source. Our investigations have shown that the source of odour is hidden in constructions or in many cases is place somewhere other than where it is being smelled. This can be explained by the fact that in cases where the odour sources are clearly visible and obvious, they are naturally more easily detected and thus removed without the need for external expert assistance.

The most common spread of odour, such as mould odour from leaky basement walls as well as food and cigarette smoke odour via air leaks from adjacent neighbouring apartments, occurs with air movements (figure 6). One consequence of this is that many odour problems are experienced more during the heating season than during the hot season. The reason for this is that the transport of odorants from hidden sources increases when there is a negative pressure in the building. This understanding is important both when it comes to identifying an odour problem and assessing the effect on the indoor climate. On the other hand, temperature of building materials and the indoor environment also affects the risk and strength of specific odours. Higher temperatures usually cause increased release of molecules and odour, thus causing stronger perception of certain odours.



**Figure 6.** Air leakages transport odour from the source to other areas.

Typical examples of common odour problems are sewage odour from air leaks in drainpipes (figure 7). Odour might also come from objects in the rooms (figure 8-9).



**Figure 7.** Various air leaks from drainpipes is a common cause for odour problems.



**Figure 8.** Objects in the rooms can be the source of odour.



**Figure 9.** Not even a dead mouse behind a refrigerator is not necessarily an easy problem to detect without a systematic approach.

## DISCUSSION

### Defining and solving odour problems

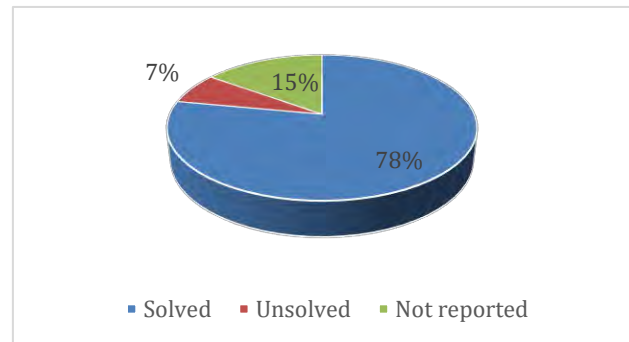
The possibility of solving a difficult odour problem, increases when a thorough and systematic procedure is followed. This work often starts with a detailed description by the residents experiencing the odour. It is often useful getting information regarding the presence and variation in the presence of the odour and construction details. This is due to the difficulty and variable description of individual perception of various odours. Prior to the odour inspection, we ask the client to give information regarding what kind of smell they experience. Furthermore, information about any variations in space, time and intensity is of crucial importance.

Odours can, based on origin, be divided into two main groups: biological origin and non-biological origin (table 3).

**Table 3. Types of odours that can be found in buildings.**

Origin	Type of smell
<b>Biological origin</b>	
Mould	Various odours are placed in this category since mould species can create different odours. Some specific mould species generate characteristic odours that can easily be recognized by a trained nose, such as <i>Chaetomium globosum</i> and <i>Stachybotrys chartarum</i>
Actinobacteria	A characteristic odour that is related to the smell of mould, but easy to recognize and separate from mould by a trained nose.
Deterioration	Dead animals and other biological products being decayed.
Faeces	Faeces from mammals cause a distinct and characteristic smell.
Sewage	Air leakages from the sewage pipes give a distinct smell.
Urine	Urine from mammals cause a distinct smell. Specific types of chemicals, mould species and bacteria can also cause an odour that resembles the smell of urine.
Food/cooking	Smell from cooking.
<b>Non-biological origin</b>	
Petroleum products	Diesel fuel, fuel oil, gasoline and kerosene all give distinct odours that can be distinguished by the human nose.
Tobacco	Smoke from cigarettes and other tobacco products.
Fire smoke and fire related smell	Odour from burned materials, smoke from fire, soot.
Chemical	Products and materials such as paints, chemicals, glue, floor coverings, new building material.
Aromatic	Fruity odour from ethereal oils, scented candles, incense, and similar sources.
New building materials	New materials used within a building has variable odours.
Wet building materials	Wet building materials has variable odours.
Other sources	Various smell, such as inadequate ventilation.

Through a high number of various odour problems, we have gathered experience that in most cases lead to solving the problems (figure 10).



**Figure 10. Result of examined odour problems (n= 682).**

Internal discussions are carried out in complicated cases, thus using the knowledge and competence within the organization to find a solution to the problem. It is important to prepare for the job already before the inspection takes place. Prior to the building examination, the inspector needs to gather as much relevant information as possible. In this phase, it is important to establish knowledge about the technical aspects of the building, such as construction details, ventilation, use of the building, construction changes that have been made recently and so on. It is also important to find out how long the odour has been present and how many people in the household (and among visitors) that experience the specific odour. Because odour problems tend to fluctuate in strength and presence, a preliminary study by the residents is often helpful to make sure the odour is present when the building inspection is taking place. Prior to inspection, the residents are asked to give feedback on the odour strength at the day of the inspection. If the odour is absent at the time the inspection is scheduled, the inspection should be postponed. In addition, residents are told to minimize or remove other odour/sources prior to the inspection. This includes removing scented candles and similar products, avoid using perfume and other distinct fragrances, avoid cooking food with distinct smell and so on.

Many of our inquiries come from people who recently have moved into a new house or bought a new property. These cases are usually difficult to solve because the new owner lack information about both the odour history and the building history. In addition, former owners are usually hesitant to give out information on possible former odour problems.

When performing the actual odour inspection, this must be done in shorter periods at a time and must include frequent breaks in fresh air. The search for the odour must both be based on information from the residents but also based on a thorough building inspection. It is often necessary to crawl on the floor and use a stepladder to examine odour variety in the building. Odours occur when gases / molecules are

being spread by air currents to the air. Hence, creating a change in the air currents and a change in the pressure in the building is often necessary to reveal the odour we are searching for. This can be done by using fans in the house and close windows, doors, and air hatches. In some cases, it is also helpful to use portable fans to create a pressure change in the specific areas. The use of plastic to close openings and create a zone with reduced size can be a relevant procedure for instance in bigger rooms and open areas. The portable fan will suck air from one side of the provisional zone to the other side of the zone. This can help generate a stronger precipitation of the odour within the zone. In buildings with a balanced ventilation system, the settings and use of the ventilation system is important when searching for the undesirable smell. When searching for odours, it is often a search for air flow between constructions or areas. An air flow test tube or other smoke-producing devices are helpful tools in this process.

### Use of odour panels as a helpful tool

Due to the lack of adequate and helpful measuring methods, a trained odour panel can be used to evaluate and assess odour samples. The people who attend an odour panel, should have experience in considering odour problems in buildings. The odours that cause problems in buildings deviate from those odours that are relevant in for instance in distinguishing differences in the food and nourishment industry. Therefore, there is little adequate education or suitable tests that can be transferred from this large industry. As far as we know, there is no systematic procedure or established list of relevant odours that can facilitate the task of revealing an odour problem in an indoor environment. Nevertheless, by establishing an odour panel with experience from field studies, we can perform a neutral assessment that can decide whether certain building materials have a distinct smell or not. For instance, we use odour panels to consider whether building materials still have traces of odour after renovating a building from a fire damages. The odour panel have certain odour-groups to choose from in their evaluation. In addition, the panel is stating the level of odour strength based on a four levelled scale (no odour, limited odour, moderate odour, strong /substantial odour. All tests are being performed in an odour neutral environment. The participants of the odour panel have experience from field work regarding odour problems but have no knowledge of what kind of problem or issue they are facing in the specific case. When carried out like this, the use of an odour panel is a helpful tool in addition to an inspection at site (Sensorisk studiegruppe 2015).

### CONCLUSIONS

Odour problems occur for various reasons and in all types of buildings, regardless of the age of the building.

With a systematic approach, it is possible to clarify and solve even complex odour problems. Our experience in working on odour cases for several years, has shown that the source of an unpleasant and unwanted odour can be due to both new and old causes of damage.

Since there is possibly a large gap between simple and comprehensive solutions, a thorough investigation can be necessary to solve the case and simultaneously save unnecessary costs. This study, that are based on 682 odour cases performed the last 13 years, have shown that there is a high solving rate (78 %) of solving the problem, despite often being a complex problem. The high rate of solving the problems is due to trained inspectors with years of experience in combination with a systematic and thorough approach to the problems. The starts with gathering important and often vast and detailed information from those experiencing the odour. The next step consists of a thorough and often time-consuming inspection to try to find the source of the smell. To solve a difficult odour problem, understanding the building physics and construction is essential. Changing the air movements and pressure within certain areas can generate the odour if absent at the time of the inspection. It is not essential to have a particularly good sense of smell to clarify odour problems, but it is obviously a helpful tool. It is often a collaboration between the trained and experienced expert and information from the users or residents that lead to solving the case.

### ACKNOWLEDGMENTS

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