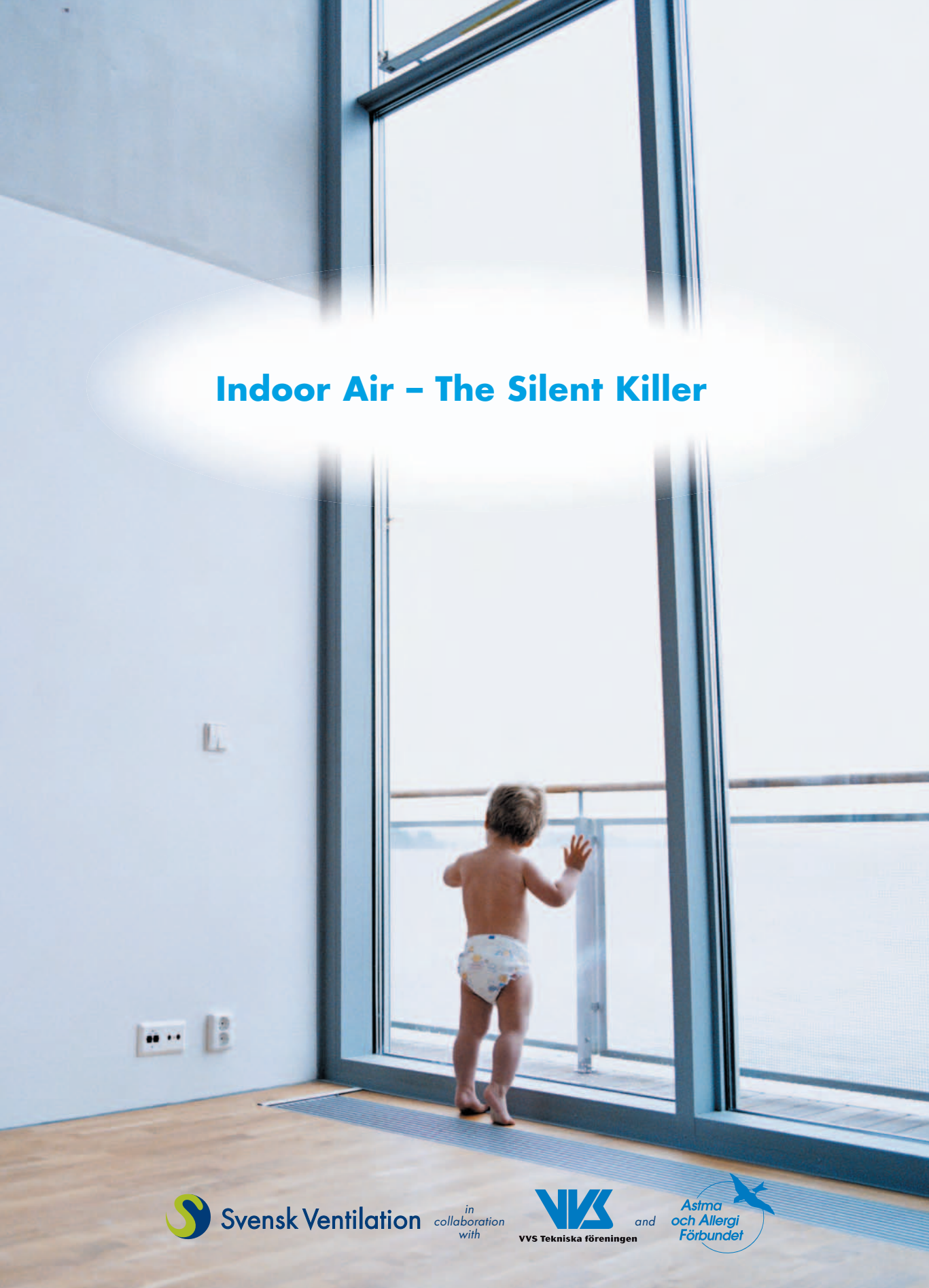
Indoor Air – The Silent Killer



Svensk Ventilation in collaboration with VVS Tekniska föreningen and Astma och Allergi Förbundet

ISBN 91-631-6161-3
LÖWEX Trycksaker AB, Växjö, 2004
Layout: Pegelow Design
Cover picture: Johnér Bildbyrå

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Preface

It's frightening to know just how much we depend on indoor air for survival. People in northern Europe spend 90 percent of their time indoors; this means that the air we breathe comes almost exclusively from indoor sources. We humans consume between 20 and 30 kilograms of air every day. We eat approximately one kilogram of food and drink some three litres of liquid in the same time period. The fact that the air we breathe indoors is important for our health, our well-being and for how well we perform is a given. Still most of us are probably far more aware of the risks we face in the outdoor environment than indoors. Not to mention our fanatical attention to what we eat.

Every year more than 500 people die in Sweden alone from the poor indoor air; most of them poisoned by radon.

There has been very little research conducted in Sweden to date on the indoor environment. Not that there is a lack of competence. On the contrary, some of the world's leading authorities on indoor air are Swedes. The reason for the lack of scholarly work on the subject is that organisations funding research are almost entirely focused on the outdoor environment. This is also true for many other countries, environmental research is almost always about the outdoor environment.

Research on the importance of indoor air is put on the backburner and this has grave consequences. It means, for example, that our attention to climatical problems indoors is diminished and we therefore do not make the necessary investments in good ventilation systems. Our health deteriorates. Fifty years ago, allergy was relatively uncommon. Today there is hardly anyone who is not either allergic themselves or have an allergic person within his/her immediate environment. There are many signs that the indoor air, i.e. the air we breathe 21 out of the 24 hours in a day, has a large impact.

We also know that people do not perform as well in poor air as when they have access to fresh, clean air. Who hasn't stepped into a conference room, a class room or a small office, and immediately walked up to the window to open it saying, "What poor air you have, how are you able to think in here?" If it's wintertime, the window is quickly closed again since the cold needs to be kept out, but hopefully some of the poor air has had time to be replaced.

Good indoor air is a prerequisite for us to feel well. Good indoor air is dependent on good ventilation.

The need for good ventilation seems obvious. Yet why is there such poor ventilation in buildings and homes throughout Europe? One reason is the widely held view that adequate ventilation costs far too much. In reality, however, it can be precisely the opposite, good ventilation saves money. Simplicity, heat recovery and needs-driven systems are three important factors contributing to lower energy costs. Unfortunately, the budgets for both greenfield construction and refurbishment are low, future proprietors do everything to save money, and the demands on energy conservation are given priority to the detriment of the indoor environment. Few realize that the minimum requirements on our air quality are low and fewer still consider doing more than necessary to meet these standards. Such compliance can, under certain circumstances, result in acceptable air quality. But the margins are so small that if a conference room meant for ten people is suddenly used for fifteen (a not so unusual situation) the air quality will decrease substantially. Fifteen people experience discomfort and performance becomes sub-standard.

Another reason that ventilation is not given priority, neither in the construction industry nor in research, is due to the industry itself. We have not been effective in showing the benefits of good ventilation. We have also not been effective in conveying the vast bank of knowledge that is still available within this field. We have been too content with minimum requirements.

With this booklet – that is based on the report Proper Ventilation – we hope to be able to show why it is important to turn our attention to the benefits of good ventilation, in our homes, our offices, our schools, everywhere. Good ventilation is an investment in people's health and their performance. Not an investment cost for a fixture.

Ingvar Ygberg
Managing Director, Svensk Ventilation

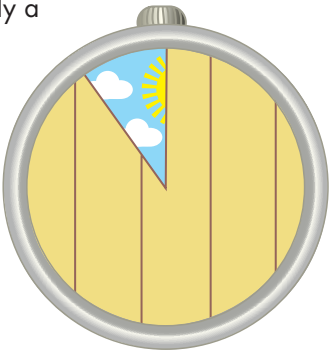
Chapter 1

Why We Need Good Ventilation

Fresh air is one of the most important preconditions for life itself. However, all air contains pollutants, to different degrees, depending on time and place. Much is done to lower the emissions that make our outdoor air poor.

Very little, however, is done to improve indoor air quality. This is in spite of the fact that people in many parts of the world spend almost all of their time inside. In Northern Europe, people spend 90 percent of their time indoors.

Indoor air is, by definition, contaminated air from the outside. Think of it: what we breathe inside is really a mix of outdoor air, and pollutants from construction materials, people, animals, machines and other things that one finds indoors. Compounded with the fact that today's houses are often well insulated, pollutants are quickly trapped indoors if there are not special systems installed to remove them.



Indoor time – outdoor time

People feel better if we have clean air to breathe; we become more effective and perform better, whether it is at work, in school or at home. Also, since the number of sick days taken also go down with increasing air flows, as several studies have shown, it should be a given for everyone to demand good air quality in all of our surroundings.

The number of people with allergies is growing rapidly, and even if science hasn't been able to clarify exactly what it is that causes this increase, the consensus is that the indoor environment is a very important factor. The function of the ventilation system is therefore of crucial importance in order to lower the incidence of allergies.

Today there are really no clear objectives for what indoor air should be like. There are modest requirements to follow, but no one has dared taking the consequences of the development that has happened within research on what air quality really means for us. In a Swedish government report about environment and health (No. SOU 1996:124) there was a proposal for a national

taskforce with the overall objective that "No one should fall ill or suffer negative effects due to deficiencies in the indoor environment." To reach this objective, the report suggested a couple of ancillary goals that show how important ventilation is to reach this objective:

" Sub standard ventilation in homes, schools and pre-schools should be remedied"

" All homes, schools and pre-schools with radon levels in indoor air above the threshold value for private nuisance should be remedied no later than year 2010."

The report also brings up one of the most common arguments against good ventilation. The argument is that good ventilation requires a lot of energy. One of the most important environmental objectives globally, is to lower the energy consumption. Today, there are both simple and effective solutions available for heat recovery as well as for ventilation regulation. With these solutions, a properly constructed ventilation system becomes an effective way to conserve energy. The conflict between good ventilation and low energy consumption simply doesn't exist anymore.

In spite of this, the progress toward improving indoor air quality is very slow. There are several reasons for this:

- *Ventilation is but one consideration in the construction or refurbishment of a building. While it's easy to spot when electricity is incorrectly installed, or that a window sill is crooked, poorly constructed ventilation mechanisms are far more difficult to identify.*
- *Even if air quality is a priority for the architects designing new buildings or spearheading refurbishments, up-to-date information about ventilation systems and alternatives is insufficient among many of the parties involved in the construction process.*
- *The knowledge about how much air quality means to us exists, but it is not widespread. We know that we feel better when we breathe clean air. We also know that we perform better and that there will be fewer sick days. What we don't know is how much better, since there are few surveys about this. As a result, many people are happy with following the minimum standards for air quality. Hopefully that will at least make it "good enough."*
- *It costs money to focus on good ventilation. It is a financial outlay that is often seen only as an expense, not as an investment in better health for everyone spending time in the building. Fortunately, the time to return on investment is short and can be calculated from several sources.*

The ventilation has one principal task. It should remove all the pollutants that are generated in a building and replace the polluted air with clean air. It is as easy as that.

Nothing Happens – Even Though There is Both Knowledge and Money

Today nobody challenges the fact that good ventilation is a prerequisite for fresh indoor air. That goes for homes as well as for workplaces. Still there are many poorly ventilated buildings in most countries. A number of reports and surveys show the same thing – the poor indoor air makes us ill.

The National Institute of Public Health in Sweden wrote the following in a press release in 2001 regarding a report on allergy adaptations to schools:

> **"The awareness on how to create a sound school environment for children with allergy has increased but much remains to be done. Today one quarter of the municipalities in the country have allergy adapted pre-schools and schools."**

The survey had been performed by The National Institute of Public Health together with the Swedish Asthma and Allergy Association. While the authors certainly put a nice spin on the numbers, 75 percent of municipalities have taken no steps to improve their ventilation systems. Since more than 40 percent of all school children have developed allergies, this number is unacceptable.

Radon Decontamination is Stalled

One area within which there is plenty of knowledge available is the impact of radon exposure on humans. (This, and how to deal with it, is discussed in more detail on page 16.) Our way of handling the issue of radon, however, shows that knowledge doesn't always help make things happen. When it comes to radon in particular not even money is enough to make it happen. Today there are somewhere between 280,000 and 500,000 homes eligible for a radon decontamination grant in Sweden.

In 2003, the national program for radon decontamination of single homes set aside MSEK 33 (SEK 15,000 per home) to distribute; in 2004 there is as much again. The number of applications, however, is very low and it's estimated that not more than a third of the money will be used. At this rate, it will be 400 years before all houses and flats in Sweden have been decontaminated (a number that

is obviously absurd). The objective set in 1996 projected that all homes would be decontaminated by the year 2020.

In December 2003, the Swedish Union of Tenants issued a demand that the pace of radon decontamination must increase. They noted in a press release that at least 500 people die every year from radon radiation in their homes.

The chairperson, Barbro Engman, demanded that it be obligatory to measure the radon level in houses and that an official, public register be created posting the results. Engman also wanted to institute a grant for radon decontamination in blocks of flats

The Swedish Union of Tenants is by no means alone in their demands to take radon seriously. So far, very little has happened.

Chapter 2

The Indoor Climate and Health

Breathing indoors can endanger your life.

Indoor air contains many substances that are harmful, if not lethal. Airborne radon particles kill hundreds of people every year in Sweden. Voluntary and involuntary tobacco smoke are also culprits.

Poor ventilation does nothing to alleviate the many troubling environmental hazards we face indoors every day: mould thrives in the humid indoor air, construction and interior decoration materials that have not been tested for prolonged indoor use are just a few of these threats. Half a million people in Sweden are so affected by their indoor environment that they become sick, according to "The Book about the Indoor Environment" that was issued in 1999 by among others The National Board of Health and Welfare.

Adults consume this much air, water and food per day

An adult human breathes approximately 30 kilos of air, corresponding to 25,000 litres, every day. The indoor air contains several hundred foreign substances, the most poisonous of which are ozone, radon and aromatic hydrocarbons.

The indoor air is polluted by a number of different things. Construction materials emit substances that contaminate the air, as do furniture and different types of office machinery, where copying machines and older types of computer screens are among the biggest culprits. Other common sources of pollution of indoor air are tobacco smoke, mould, cleaning agents, people and animals.

People contaminate the air in several ways, from using perfume to cooking. A pollution that we all contribute to, however, is that we all emit carbon dioxide that others have to breathe. If we inhale too much carbon dioxide, we get headaches, feel dizzy and nauseous. The reason that the carbon dioxide level gets too high in a room almost always is that the ventilation has not been accurately calibrated for the number of people in the room or that there is no ventilation at all. The carbon dioxide levels indoors are often used as an indicator of the general level of contamination. If the level of carbon dioxide is high, it is usually assumed that the level of other pollutants is also high.

One consequence of poor indoor climate that is both obscure and hard to deal with is the so-called Sick Building Syndrome (SBS). SBS can manifest itself by a number of different symptoms such as nausea, headaches, itchiness, nasal problems and much more. A person afflicted by SBS often is so in a specific building, with the problems getting worse the more the person stays in that building, and often disappears as soon as he/she stops being there. However, it has also been shown that people who have been affected by SBS over an extended period experience a lowered resistance and their symptoms can become chronic. A survey among 5,000 people in the Northern province of Sweden showed that almost half had at least one SBS symptom every week. One quarter had seen a doctor for their symptoms. The factors that were most commonly found were poor ventilation, dampness/mould, poor cleaning, and and the presence of copying machines and air humidifiers.

To make us feel well, it is important to lower the number of pollutants in the indoor air. We also need to lower the level of the pollutants that are there in total.

Houses and Interior Decoration

A century ago, we built houses weather permitting, preferably when it was warm and dry outside. Construction was also allowed to take time. New construction materials weren't used; you built in wood and stone.

Today, houses are built all year around. New construction materials are invented at a rapid pace. Construction must be fast, not always to keep costs down but as often because the person moving in wants his/her home as quickly as possible. We also have new interior decoration materials and

new interior decoration features and many homes contain both computer screens and laser printers, which are known and serious air contamination sources.

All this puts unexpected demands on ventilation mechanisms.

Experts speak of materials in terms of "high emitting" and "low emitting," i.e. materials that emit larger or smaller amounts of pollutants. Most construction materials emit more pollutants when they are new. The shortened construction times therefore means that, in many cases, new houses pollute themselves more than they used to do.

This, too, puts new requirements on our ventilation sources.

Our Homes

For most of us, our home is the place in which we spend the most time. We sleep, enjoy the company of family and friends; we play, we relax and sometimes we even work there. But few of us consider what the air is like. Is the air good enough to support all this activity? Does the air contribute to the well being in our homes?

The answer usually is a very reluctant, "well?!?"

In a home that is ventilated "well enough" to satisfy minimum requirements, the air exchange should be 0.5 per hour. That does not mean, as is popularly thought, that the air is replaced every other hour. The measurement of 0.5 air changes per hour means that the air is replaced after four hours. That it takes this long is due to the fact that the newly added air is mixed with the old air and therefore diluted. Both old and new air is then continuously replaced. After four hours the amount of old air is so small that it is considered replaced.

It is doubtful if this replacement flow is enough, since too many people become ill from indoor air. People with various kinds of allergies also need significantly higher air flows.

Most homes have a relatively simple type of ventilation. Many only have natural draft ventilation, often with ventilation windows. Natural draft means that the air that is warmed up in the house rises through exhaust air ducts and is then replaced by fresh outdoor air. The outdoor air gets in through ventilation windows, slot valves or simply through cracks and holes in the building.

Natural draft provides a certain level of ventilation. It is important to note that measurements have shown that in houses with natural draft, bedroom air is worse than in the rest of the house.

Many people who think that their home is poorly ventilated are trying to do something about it themselves. They install fans, often in the bathroom and the kitchen. This is a step in the right direction but can, if it is a question of a block of flats with ventilation channels servicing multiple flats, exacerbate the problems in other parts of the building.

For new constructions, there are often minimum requirements on air exchange. These minimum requirements are hopefully enough, given that there aren't more people in a room than there was meant to be – as there of course often is. The minimum requirements also assume that no one in the home is extra-sensitive to pollutants.

In houses built after 1970, the air exchange is often far below the minimum requirements. We then started to build better and better insulated houses, without considering the need to improve ventilation at the same time. The result was houses where the air is practically still.

However, with today's technology and knowledge, a well-insulated house does not have to mean a house with poor air. It could, rather, be the exact opposite.

Pre-schools, Schools and Offices

Our workplaces, too, need better indoor air. The workplace environment legislation is clear and is most often followed. However, here too, the minimum requirements on air flow are set such that there are very small margins. For that reason, schools and pre-schools are two types of places where problems are very common.

Small margins for air quality in an office can mean that a conference room designed for ten people houses fifteen for a couple of hours. The likelihood that the air rapidly becomes poor enough for these fifteen people not to perform well is very high. In offices built for three people, four can usually be found since office rent is a penny that many companies want to pinch.

The day care groups get bigger and bigger, which means that many children have to share space that is too small for them physically; they also have to share the air. Children are often more sensitive than adults and react

more quickly to different problems. In addition, the workplace environment legislation in Sweden is written so that it addresses school children and adults, leaving the pre-school environment unregulated. If the adults in the workplace don't react, it is not possible to point to the children's right to a good working environment.

Our schools, too, have a great need for fresh air.

Today it is not unusual to see classrooms that were initially built and ventilated for 25 pupils and one teacher being used by in excess of 30 pupils, one teacher and an assistant, i.e. by 32 instead of 26 people. Even if the ventilation had been sufficient for the people for which the classroom was designed, it is not at all so with six or seven extra people. The deterioration of the indoor climate is fast. Stale air causes problems with concentration. In a school, where the entire learning process is about concentrating, the results are negative consequences for both pupils and teachers.

Another common problem, especially in schools, is that old buildings with natural draft ventilation were refurbished during and after the energy crisis of the 1970s with the express objective of making them less of an energy drain to heat. The schools were insulated without improving their ventilation. The result was buildings with increased indoor temperature with air that is practically still, making the obvious consequence that the carbon dioxide level in the air goes sky high when the classrooms are filled with pupils. Levels of over 3,000 ppm (parts per million) are common. The Swedish Work Environment Authority directives say that a carbon dioxide level below 1,000 ppm should be sought.

Radon

Almost half a million homes in Sweden are so badly affected by radon that they need to be sanitized. The threshold value for radon in homes is 200 Becquerel per cubic meter. The Swedish Radiation Protection Agency SSI estimates that there are around 150,000 homes with a radon level higher than 400 Becquerel per cubic metre i.e. double what is allowed according to the threshold value. At least as many again lie between 200 and 400 Becquerel per cubic meter, which is also far too high.

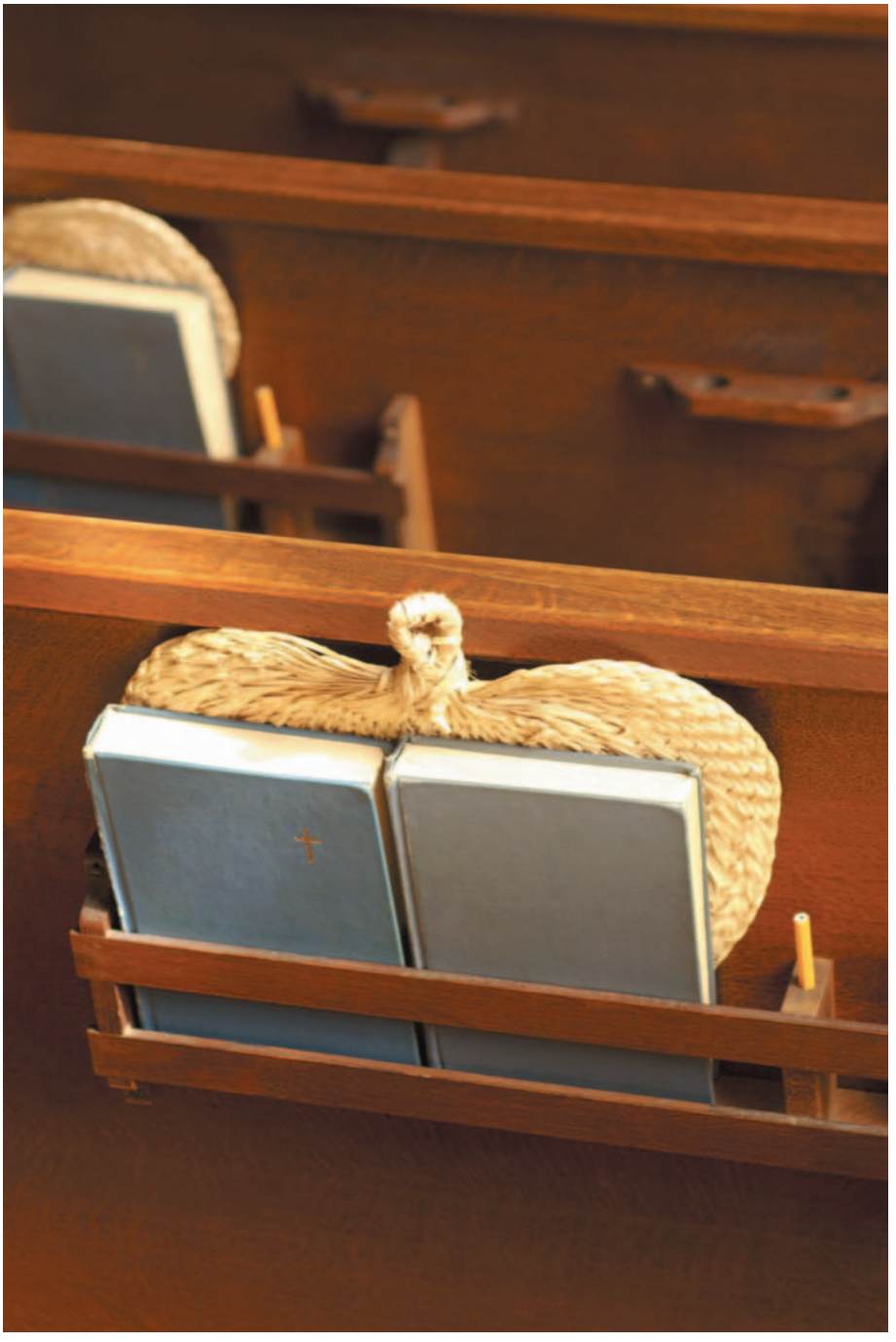
Radon exists in construction materials produced up until 1975, so-called

"Alum Shale Concrete." An even bigger, but maybe less generally known, problem is ground radon, i.e. radon originating directly beneath us underground. Ten percent of the ground in Sweden is considered high radon ground. Water (e.g. from drilled wells) can also contain radon. Almost 3,000 people die every year from lung cancer in Sweden. It is estimated that around 500 of these die as a result of excess levels of radon in homes. The rest is caused by tobacco smoke and other pollution.

The radon issue has been brought up in a number of inquiries and the research into the issues is extensive. There are also funds set aside to do something about the problem. Authorities and researchers agree that this is a major issue. So far, however, the interest among building owners, both considering homes and blocks of flats, is very low. You cannot see radon. You cannot feel radon. It doesn't smell. It simply doesn't show up at all. But radon causes cancer. It can kill.

To measure the radon level is easy. The most common method is to use so called tracking film that you get from a measurement laboratory. The environmental office of every municipality knows where to turn; many municipalities also carry out measurements free of charge. The tracking film is placed in several spots throughout the home and is left there for a couple of months. It is then sent to the measurement laboratory which calculates the result.

If it turns out that there is too high a level of radon in the home there are several options for how to lower it. What should be done depends on from where the radon originates (the ground, water or construction materials) and on how high the values are. Ground radon can be addressed by lowering the air pressure in the house by means of, for example, a radon suction fan. If the house is equipped with an exhaust air system this can be replaced by a combined supply and exhaust air system to lower the radon level. If the high radon level is caused by the construction materials used in building the house, the best thing to do is to replace the affected areas. If this is not possible, ventilation is also effective.



Some Factors Affecting Us

Air Velocity

The indoor air cannot stand still if it is to maintain a high quality. The whole idea with ventilation is to take away the stale air and replace it with fresh air.

When air is moving too fast, however, people experience negative effects. Draft is, for many people, as big a problem as stale air. If you are very sensitive to draft, air velocities as low as 0.15 meters per second at normal room temperature can be very unpleasant. Most of us are uncomfortable if the air velocity is 0.25 meters per second or more. It is therefore important to be able to control the air velocities in well-ventilated rooms.

Humidity

In recent years, "dry air" has become a buzzword and many people ask for air humidifiers. We think that the air is too dry and the solution frequently becomes to add humidity.

Very often, however, the diagnosis of "dry air" is wrong. Instead it is usually a question of too high a temperature (see page 21, Myths about indoor environment and health), or too many pollutants in the air. Complaints about dry air must still be taken seriously – since they almost always point to something, if not the level of humidity, that is wrong with the air.

A lowering of the temperature gives a higher relative humidity. Therefore, the best thing to do when the air feels dry is to lower the temperature.

Temperature

Proper indoor temperature during wintertime is 20-22°C, during summertime it is 22-24°C. There are many surveys that have shown that a temperature differential as little as a couple of degrees too high or too low, significantly decreases our performance. Not only is our effectiveness impacted but also our safety. Simply speaking, we get worse at doing what we do, our ability to think clearly goes down and our work result becomes totally different than if we had done it at better temperature conditions.

A good example of how easily we are affected by low temperatures is that the sensitivity and the finer motor skills of the fingers are hampered at just 20°C. This is due to the fact that when cold, the body concentrates its heat to the vital organs which as a result lowers the temperature in the arms and legs. At 16°C,

Leviticus, 14th Chapter

34. When you come into the land of Ca'naan, which I am giving you as a possession, and I do put the plague of leprosy in a house of the land of your possession,

35. the one to whom the house belongs must then come and tell the priest, saying: »Something like a plague has appeared to me in the house.»

36. And the priest must give orders, and they must clear out the house before the priest may come in to see the plague, that he may not declare unclean everything that is in the house; and after that the priest will come in to see the house.

37. When he has seen the plagur, then if the plague is in the walls of the house, with yellowish-green or reddish depressions, and their appearance is lower than the wall surface,

38. the priest must then go out of the house to the entrance of the house and he must quarantine the house seven days.

39. And the priest must return on the seventh day and must take a look, and if the plague has spread in the walls of the house,

40. the priest must then give orders, and they must tear out the stones in which the plague is, and they must throw them outside the city into an unclean place.

Even the Bible describes the importance of an healthy indoor environment

the temperature of the fingers has sunk so low that it is difficult to write properly.

If the environment is too warm, it is the ability to focus that is most rapidly affected. At 27°C the ability to think clearly is diminished by 30-50 percent.

Air Pollution

The pollution of indoor air is the sum of pollutants from several different sources. Outdoor air that is not cleaned can get in, both through the ventilation system and through other openings in the building. Construction material and interiors can also emit pollutants. Modern ventilation systems have filters cleansing the air from larger particles and pollen. For the filters to work properly it is important that they are properly maintained and replaced as soon as their efficiency starts to deteriorate. The largest health risk probably comes from ultra fine particles; the filters used need to catch these as well. Swedish surveys show that lung cancer is more common among people who have lived in areas with high pollution levels. More people are also hospitalized for asthma and other lung disorders when the air goes bad.

One consequence of this is that ventilation systems, at least in more polluted areas, must be equipped with efficient filters. It is also important to carefully consider where outdoor air inlets are placed. Inlets at street level catch more harmful pollutants than inlets facing backyards or placed on roofs.

Myths about Indoor Environment and Health

The Cleaning Myth

There are many myths about our indoor environment and health. The cleaning myth is just one of them. Many people think that today we clean so effectively that we aren't really exposed to dirty environments anymore – cleanliness in itself would in some way result in us becoming more sensitive to dirt and dust.

This is simply a myth. Most likely, it isn't even correct that we are cleaning better today than before and it definitely is not correct that we become oversensitive to dust if we are not exposed to dust.

However, proper cleaning is an important health-supporting activity for people with allergies and other oversensitivities. It has been shown that people with asthma get worse in rooms where there are dust-collecting interiors that are difficult to clean.

The Air Humidity Myth

"The air is too dry here," a man says and installs an air humidifier.

It is possible that the statement about dry air was correct. But the likelihood that it was not is far greater. It is, in fact, very difficult for us humans to determine, with our senses alone, what the level of air humidity is. The problems that are usually interpreted as signs of dry air, i.e. that the mucous membranes in the eyes, lips and in mouth and nose dry up, depend on other factors such as dust or other pollutants.

It can also be due to the fact that it is too warm. Lowering the temperature on the premises by a few degrees almost always solves the problem at-hand.

To install an air humidifier can often make the problems worse, since high air humidity creates other issues. For instance, the risk of damage from mould and dampness increases dramatically. At an air humidity of 45 percent, which is easily achieved using an air humidifier, house dust mites thrive. House dust mites are small (0.2 mm) creatures that enjoy living in mattresses where it is warm and humid.

In reality, we often have an air humidity of 45 percent and above, without any air humidifier equipment. The reason: inadequate air flow. A sub-myth within the Air Humidity Myth is the recommendation that we, to feel well, need an indoor air humidity of around 40 percent. That, too, is not true. In the northern parts of Sweden the air humidity is significantly lower than that

during large parts of the year – which according to today's research does not give rise to any significant problems. Higher air humidity, on the other hand, does (as has been described above) become problematic. Researchers have proven a strong connection between high air humidity and allergy problems. Air humidity is measured by means of a so-called hygrometer; these are available in many stores and quite cheap (around 20 Euros).

The Ventilation Myth

A widely-believed myth is that it is easy to create a ventilation system by installing a fan in the building. Unfortunately, the solution is not that simple. By installing a fan the conditions can even get worse than without a fan. For the ventilation system to be called a ventilation system at all it should, through its function, improve the air quality indoors. The most important thing is that the ventilation system gives control over how air flows are added and removed. Only then we can guarantee that the air is improved. That is not always the case today. A single fan does not at all give that level of control.

The Furry Animal Myth

Another popular myth is that it is good to have furry animals at home when children are small. This, it is believed, lowers the risk that they become allergic. This myth is built on the following facts that are, in fact, correct:

"People who have furry animals at home are very seldom allergic"

"People who do not have furry animals at home are more often allergic"

So, one concludes that the sheer presence of a furry animal will protect against allergy.

However, that is not a correct conclusion; the explanation is much simpler than that.

People who are allergic, or who know that there are allergies in their family, express self-preservation instincts: they do not keep furry animals in their home. People who are not allergic do not have to think about these things and therefore are more likely to live with a furry animal.

Statistics show, therefore, that people without allergies more often have furry animals than people with allergies. From this you can draw the conclusion that people are sensible. But you cannot accurately draw the conclusion that furry animals protect against allergy.

Chapter 3

Interview

Today's Research and the Demands of Tomorrow

"We really know far too little about the indoor air," says Professor Jan Sundell. "We know that it makes us ill but we do not know why. We know that our ventilation is insufficient but we really don't know how much we need to ventilate to make the air good."

Sundell, Sweden's foremost expert on the connection between indoor air and health, today works at the world's leading research institute for indoor environment, health and comfort: the Technical University of Denmark (DTU), in Lyngby just north of Copenhagen. At the university, students from some 15 countries work side-by-side with their professors to better understand how important the indoor air is for our well being.

Nevertheless Sundell finds that we know far too little, and that the research on indoor air should be at least as much of a priority as the research on outdoor air. We spend a large portion of the day indoors, where the air is often worse than it is outside since a whole host of pollutants are added when the air enters the building.

Professor Jan Sundell

"The air outside plays a relatively small role for the health of the general public globally. While the outdoor air here in the Nordic countries isn't that polluted, the situation is completely different in countries like Mexico where there are tremendous problems. Here, it is the indoor air that is the issue," he says.

Sundell's criticism is focused not only on the research community and their funding (or lack thereof), but also on the ventilation industry. It has, he thinks, sold us all on technology instead of function.

"Ventilation systems, with their ducts and fans, are really quite uninteresting to most people, but everyone is interested in getting fresh air to breathe, both at home and in the workplace," says Sundell.

What, then, is fresh air?

"It is air that we feel healthy breathing, that doesn't make us ill. We should neither get allergies nor headaches nor other things from something as natural as being indoors."

At DTU, there are several climate chambers where mannequins and even live test subjects are exposed to different types of air content. Right now, there is research going on about everything from how ventilation affects the spread of infectious diseases to the impact of the indoor climate in aircraft affect people. The largest research project at DTU can be found in the province of Värmland in Sweden. Sundell and Carl-Gustaf Bornehag are leading the largest survey in the world on how indoor air affects children, with 11,000 children in the area participating in the study (see separate article below).

"Before we started the survey in Värmland few scientists, if any, had directly investigated the connection between the degree of ventilation in homes and our health. I find that extraordinary to say the least," remarks Sundell. "Another important step for researchers is to find out which substances found in indoor air have the greatest impact.".

One example of potential toxins that need more investigation is limonene, a substance that gives everyday household items an imitation lemon scent. Limonene can be found in every home, in commonly found items such as dishwashing liquid and orange peel to perfumes. On its own, limonene is not harmful. But the chemical reacts with ozone (that is not in itself very harmful at the levels found, for example, in homes) to form unstable substances, substances that react quickly on skin and mucous membranes. The reaction is so fast, in fact, that it's nearly impossible to measure or study them – their speed makes them difficult to research.

"Such health-wise interesting pollutants, both gases and particles, are what the leading edge of research is focused on today. What it used to focus on, Volatile Organic Compounds (VOC) and the Total level of such compounds (TVOC), is rather uninteresting," says Jan Sundell.

It may be that the pollutants that the researchers are looking for and at today contribute to the swift increase in allergies we see in large parts of the world. Sweden is somewhere at the middle of this scale, in spite of the fact that in fifty years they have gone from asthma and allergy being something extremely unusual to today when almost half of their children are afflicted by one or the other.

"This increase is not due to us having changed genetically over fifty years. Such an evolutionary change in so short a time span is not possible," says Sundell. "The increase must be due to environmental factors. Indoor air is probably important in this context. Our task now is to find out what it is in the indoor air that affects us this much, so that we then can do something about it." ■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Important Research Projects

Around the world there are a whole host of research projects going on. Following is a brief rundown of some of the larger projects.

The Massachusetts Study

In Massachusetts, U.S.A., Don Milton at Harvard University has led a large field study on how much people were affected by, among other things, varying degrees of ventilation at work. Those who worked in areas where only the minimum requirements on airflow were met had fifty percent higher illness-related absenteeism than those in areas where the airflow was twice as high. The annual loss in productivity for those in the poorer environment was estimated at $400 per person. Most companies claim that they decrease workplace airflow to save energy costs. The research in Massachusetts showed that the financial loss in productivity can be far greater than the savings made on energy.

The Värmland Study

In 2000, Sundell and fellow researcher Carl-Gustav Bornehag contacted all of the families in Värmland, Sweden who had children between the ages of one and six. There were 14,000 such families. Parents of 11,000 children in 8,000 families responded to the survey that thus became, by a significant margin, the biggest study in the world on how the indoor environment affects the health of children.

The study was a combined effort of doctors and engineers, all looking for connections between the indoor air and the health of the children. Four hundred children (200 healthy, 200 with severe allergies or asthma) were selected for an in-depth study regarding the connection between indoor environment and illness:

1. **The children were given an extensive medical check-up**
2. **Their home environments were studied in depth, through on-site surveys and measurements. What pollutants were present? What did the ventilation look like? What had the most impact?**

The study has been going for four years; so far, the researchers have concluded that ventilation has a significant impact on the children's health.

Among other things, the scientists and engineers measured condensation on bedroom windows. They found a correlation between condensation, ventilation and asthma. If there was a lot of window condensation on the bedroom window in the morning it meant that ventilation was poor – and there was a correlative increase in the incidence of asthma among children living in these homes. A double-paned window with more than two inches of condensation seemed to be a clear warning signal.

This important study is likely to continue for several decades and is run by DTU in cooperation with the University of Karlstad together with some 20 other institutions in Denmark, Sweden, Norway, Holland and the United States. Called, "Dampness in Buildings and Health," the study has the overriding objective of understanding why people become ill in houses damaged by dampness.

The Bamse Study

One of the world's largest studies of children with allergy is being carried out in Stockholm, Sweden. More than 4,000 children from Stockholm born between 1994 and 1996 were followed from birth. The purpose was to obtain more knowledge of how different factors, the indoor environment in particular, impact the risk of children getting different forms of allergies. The incidence of allergies is on the rise; whether this is because certain protective factors have been removed, or if harmful factors have been added to the indoor air, is not known. In the Bamse Study the researchers concluded, among other things, the following:

- **A poor indoor climate (mould/dampness/condensation) in the home increases the risk of asthma**
- **Smoking during pregnancy leads to an increased risk that children develop asthma**
- **Breast feeding decreases the risk of children developing asthma**
- **Among children exposed to two of three risk factors (tobacco smoke, poor indoor climate, prematurely interrupted breast feeding), the risk of developing asthma was more than twice that of children exposed to one, or none, of these risks. Similar tendencies existed for allergic rhinitis (hay fever).**

The Bamse Study is a co-operation between The Department of Occupational and Environmental Health, The Astrid Lindgren's Children's Hospital and the

Institute for Environmental Medicine at Karolinska Institutet (one of Europe's largest medical Universities). The children, and their living environment, were checked regularly. At the age of four, 40 percent of the children had some form of allergic problem, i.e. asthma, skin rashes, hay fever or food allergies.

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Since many researchers saw the limitations with the natural draft systems, they moved to combining these with fan-controlled systems. These combined systems, that can work either as a natural draft system or as a fan-controlled system, are called hybrid ventilation systems.

The interest in hybrid ventilation as a potential technical solution jumped in 1998 when a new IEA annex, No. 35 (called HYBVENT) presented a study of a number of pilot projects. The issues that were of particular interest included:

- **Will hybrid ventilation save energy?**
- **Do the users receive adequate air quality?**
- **Is the investment cost increased?**
- **Is the life cycle cost increased?**

A number of field studies have been carried out using different models of calculation. The results unequivocally favoured the benefits of fan-controlled supply and exhaust air. Such systems are significantly more energy-effective than the hybrid ventilation and other systems. Calculations showed that the FTX systems (supply and exhaust air with heat recovery) only had fifty percent of the energy use of the hybrid systems. Their studies also showed that fan driven exhaust air systems and hybrid systems had a relatively similar energy consumption, which is not entirely surprising, since the hybrid systems can be seen as a special case of fan driven systems where the fan is sometimes idle.

In Finland, an analysis has been made of the three alternative systems for hybrid ventilation. In a comparison with traditional FTX systems, their estimate is that more consistent function is found with fan-controlled solutions. The cost of fan-controlled solutions does not have to be higher than for the studied hybrid solutions. Their estimate was also that if the fan-controlled solutions were designed for low SFP values, lower energy consumption was achieved than for other options. SFP means Specific Fan Power and is measured in the unit kW/(m3/s). The number gives an idea of how energy efficient a ventilation plant is.

The NatVent Project

This is a big research project on natural ventilation in offices. The project has been run by nine companies and organisations in seven European countries. The purpose of the project was to reduce energy consumption (and consequently the CO^2 emissions in connection with the energy production) in buildings by:

- **Creating solutions that made it possible to use natural draft ventilation and low energy cooling in countries with cold climates and;**
- **To encourage an increased use of natural draft ventilation and "smart" regulations, so they can become the dominant solutions in new constructions as well as in the refurbishment of office buildings.**

Two NatVent projects have been carried out, one in Malmö, one in Varberg, both in Sweden. In Malmö, the installation included three support fans, one of which is constantly in service and the other two are manually operated. At the office in Varberg there are no fans at all. The system in Malmö should therefore be seen as a hybrid system rather than a natural draft system.

These two projects provided a summary of the actions that are considered necessary to achieve a properly functioning system. The biggest problem is considered to be that it is to warm indoors in the summer. The remedial action recommended is to:

- **Use the chillier night air as a coolant, by running fans in the exhaust air ducts at night.**
- **Improve the sun screens on windows.**
- **Replace lighting with modern low-energy (and low-heat) lighting**
- **Stop the heating system from activating during summertime.**
- **Make sure there are no windows open at night, since this will circumvent the effectiveness of the entire system.**

To improve conditions during wintertime, the recommendations were to:

- **Improve the adjustment of the heating system.**
- **Improve the insulation of the building.**

It is obvious that, in these projects, there are uncontrolled air flows that are due to open windows.

The suggested actions aim only to get the room temperatures down to a more reasonable level.

Chapter 4

The Ventilation Solution

A good ventilation solution brings fresh air indoors. To be truly effective, the ventilation solution must of course be adapted to the building. How was the building constructed? How many people are in it? What are they doing there? What is the environment like around the building? Where in the country is it? For example, the cold winters up north have an impact on what ventilation solutions work there.

A good ventilation solution must also be appropriate, reliable and resource-conserving:

- **Appropriate means that the solution should fit the building in which it is installed, and that the chosen solution should meet the requirements put on it.**
- **Reliable means that the solution chosen works, as intended, for a long time. Normal maintenance is needed for all technical solutions, including ventilation.**
- **Resource-conserving means that the ventilation does not waste energy. It should be cost-effective in every respect.**

To achieve an appropriate and reliable installation, one can, like Albert Einstein once did, say that it should be as simple as possible – but not simpler. This means that there has to be certain quality requirements met in the installation so that a minimum technology level is achieved. If the system solutions are too simple, no one can provide any guarantees of sufficient function.

These three properties - appropriateness, reliability and resource-conserving -- are important prerequisites for a good installation. It is also important that the requirements on our indoor environment are specified in an adequate way. This means that we cannot save on the ventilation air flows. The added air must also be filtered so that we do not introduce outside pollutants. A technically correct ventilation plant enables us to maintain a greater air flow without increasing the energy consumption. Important functions in such an installation are heat recovery and demand-driven control of air flows. More about this can be found in the report “Proper Ventilation.”

Who's Responsibility is it to Improve Ventilation in a Building?

A well-managed construction, whether a new construction or a refurbishment, often makes for a good building. If the work is planned in a good way you always take account of the knowledge available in different areas, and of the latest research findings.

The future proprietor is responsible to make sure that houses that are built or refurbished become healthy houses where people feel well. When procuring contractors and construction materials, it important to make clear to yourself how you want to solve environmental issues, from lighting and sound to ventilation. Therefore, experts in the various fields should be called in early in the project. A good house, where people breathe fresh air and feel well, does not have to be harder or more expensive to build than a not-so-good house. Cost overruns happen when you have to solve problems that surface later in the process.

In Sweden, the Planning and Building Act and the construction regulations from The National Board of Housing, Building and Planning map out what the formal requirements are to ensure that building quality is achieved.

When it comes to existing houses, it is usually the owner who is responsible for air quality. At the individual workplace it is the employer who is responsible. If you feel that the air is stale at your workplace, you should turn to your manager or to the safety officer at your place of business. It is then it is up to the employer to discuss with the building owner about who should pay for the actions needed to improve the indoor air quality.

As a tenant in a block of flats, you should turn to the landlord with any complaints. If you as a tenant don't believe the landlord is doing enough to improve the air, the next step is to contact the Environment and Health Office of the local municipality.

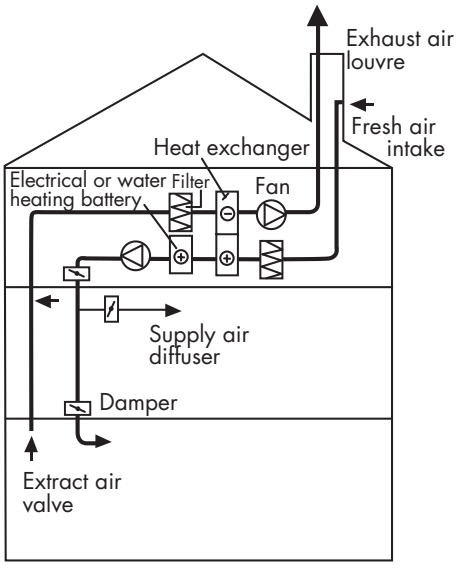
Technical Solutions

Traditionally, there are three different technical system solutions for ventilation. These are: Natural draft systems, fan controlled exhaust air systems and balanced ventilation systems that include supply as well as exhaust air fans. The balanced system can be improved by a heat recovery system.

(The picture is a montage)

"Everything should be made
as simple as possible, but not simpler"
Albert Einstein

Natural draft ventilation means that the air rises through air ducts. Warm air is rising naturally out through vertical air ducts. In this manner, a low-pressure condition is created in the building that forces new air to enter through valves, ventilation windows and other openings throughout the building. Natural draft was common years ago, and worked relatively well since buildings were not so well-insulated and the total volume of the rooms was significantly bigger than today. At that time, one could frequently find a warm chimney shaft that contributed to the natural draft effect. Natural draft in



Example of a ventilation system

new houses is more difficult to find since today's houses are well-insulated in order to lower energy consumption. They also lack the warm chimney shaft.

If you still choose to use natural draft in new construction, it's imperative that you closely study any problems that may occur.

Some established researchers who have realized the deficiencies with natural draft systems have instead chosen to work with solutions where fans ventilate the buildings. In some cases they have combined the natural draft solution with fans that add and remove air during periods of low natural flows, so-called hybrid solutions.

The reason that a number of trial plants have been built with this type of natural draft technology is that the problems have been seen in the traditionally built systems, like with high noise levels and energy consumption. In this type if plants, however, it is not possible to clean the air through filters in an effective and controlled way.

Fan controlled exhaust air means that the air is extracted by means of fans, normally in the kitchen and in bathrooms. The air so extracted is replaced by air from outside that gets in through valves, ventilation windows or other openings in the buildings, i.e. in the same way as natural draft ventilation. Air filtration is not possible in this situation. These systems are common thanks to their low installation cost.

Balanced ventilation systems can be designed in many different ways. Mistakes have been made over the years in designing these systems. Today, research has shown that balanced systems are necessary to achieve a low installation cost, low energy consumption and a good indoor climate.

A good balanced system is simple, stable and flexible. Stability means

that disturbances of different kinds should not affect the function negatively. That someone opens a window, for example, should not make any difference. This is not the case in older systems. Flexibility means that the need for fresh air at any particular moment should regulate the level of ventilation – if there are many people in the room the ventilation is increased automatically. A balanced system combined with heat recovery is often seen as a fourth system.

Effective and energy efficient solutions should provide an opportunity for heat recovery and demand driven air flows. They should also filter the air.

Service and Maintenance

The ventilation system in itself can be a problem for air quality. The issue is almost always due to the fact that the systems are not serviced properly. Some common reasons are:

- **Dirty and/or old filters deliver polluted, not clean, air. Filters must be replaced at least twice a year to be effective.**
- **Filters with low separation can make dirt and micro organisms gather inside supply air ducts and allow them to spread from there.**
- **Dirt gathering in exhaust air ducts can also, in the longer term, decrease the air flow to an unreasonable level.**
- **Shutting fans off during night time can also result in pollutants being spread throughout the duct system.**
- **Problems with dampness can be a result of insufficient poor rain protectors at outdoor air inlets, air humidifiers or be due to condensation in the ducts being poorly insulated.**

The best thing to do is to never let these types of problems occur at all. This is achieved by maintaining the ventilation plant as well and regularly as you maintain the rest of the house. Checking filters regularly is simple and can head off many serious problems.

Homes and workplaces where service and maintenance is properly managed, where the ventilation system is accurately calibrated for the number of people actually there, usually have high air quality. Insufficient maintenance of the systems is a very common explanation to poor air, which the obligatory ventilation control shows.

Noise from Ventilation Plants

A common complaint on fan-controlled ventilation plants is noise pollution. Older plants can be very noisy, which for many people is as serious a problem as draughtiness, stale air or incorrect indoor temperatures.

Modern plants are designed to limit noise levels and are usually very quiet. Older plants can be refitted to muffle, or even get rid of completely, intruding noise. To keep noise levels down it is, among other things, important to maintain a low pressure, i.e. low speed in the ventilation ducts. A large amount of air pushed through narrow ducts can mean high noise levels, while the same amount of air pushed through wider ducts doesn't make much sound at all. To limit the noise levels is of great importance to making sure the plant is perceived as adequate.

Measurement

To truly know the quality of your indoor air, you should turn to a company that is active in measuring air quality. Common warning signs that the air quality is poor include:

- **Headaches, skin problems, unexplained fatigue among people staying in the building.**
- **Many short sick leaves.**

Of course, these symptoms may not have anything to do with air quality. The presence of both conditions, however, can be.

Anyone who identifies these warning signs should begin by going through the existing ventilation plant. Has it been maintained properly? Does it work? Are all filters clean and unbroken? Is the ventilation system being used the right way?

A simple thing to check yourself if you get many complaints is the indoor temperature (see page 19).

Chapter 5

Ventilation and Energy

The energy crisis in the 1970s helped to make us aware of the limited resources of Mother Earth. We started conserving and tried in every way to limit our use of energy.

That was, as most people probably would say, "a good thing."

Yet there were drawbacks. Among other things, houses were insulated to the degree that air stopped leaking in through walls, doors and windows. Since we did not combine these insulation installations with improved ventilation systems, these changes led to a seriously deteriorated indoor environment – an indoor environment that led to health problems for many people. Stale air and dampness became tremendous issues in both new and old houses.

Another drawback to the energy conservation fanaticism of the 1970s was that we often saved on the functions that demanded a certain energy use to work. Our gut reaction nowadays is of course not to unnecessarily use things requiring energy.

But what is unnecessary? Ventilation isn't.

A good ventilation plant does not require a large energy investment. On the contrary, a good ventilation plant lowers energy consumption compared to a natural draft system (in spite of the fact that it actually uses energy to work).

Life Cycle Cost – LCC

When an investment is made today, people almost always take the long view. Years ago, everything was seen as an immediate cost, something costs this or that much and people usually chose the cheapest option.

Today the reasoning is much more complex, but more realistic. One looks at the cost of a product or plant over its entire life cycle. That is what it costs to invest in, to run and maintain and to eventually perhaps take away and destroy. If you calculate LCC, the life cycle cost, you often see that the cost of purchase is a very small portion of the total, often as small as ten per cent. Running and maintenance constitutes the remaining 90 percent.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The cost of heating and ventilation is a considerable part of the running cost for a building. To lower that cost, it is necessary to focus on an effective ventilation system with heat recovery and demand control, which saves energy and thereby lowers energy costs for the building. A somewhat higher investment at the beginning (i.e. when the plant is purchased) pays off quickly when the energy bills go down.

Another advantage is that it is friendly to the environment – the less energy that is needed, the better for the environment.

Natural Draft Wastes Energy

Natural draft, i.e. ventilation that is built on air being extracted through ducts and fresh outdoor air getting in by means of convection forces, doesn't use any additional energy to work like fan controlled systems.

However, natural draft ventilation, or natural ventilation as it is also called, still uses a lot of energy since all heat disappears with the exhaust air. Instead of heating a building, you wind up heating the entire neighbourhood.

The most energy efficient systems are those where fans give you control over both the supply and the exhaust air flows and where there is a heat recovery system installed to make use of the heat content in the exhaust air. In addition, it is important not to add more air than necessary. An important prerequisite for proper function and an energy efficient system, therefore, is demand-driven air flows.

Chapter 6

Everything You REALLY Need to Know

This chapter contains different facts that are important to know for those who want to create a good indoor climate.

1) The research on air hygiene factors have shown that the air flows today used as minimum flows in ventilation plants should be increased. This research points strongly to the need for increased air flows, and for making sure that these can always be maintained.

2) Increasing minimum air flows from e.g. 8 litres/second per person to 16 litres/second per person leads to a dramatic improvement in productivity (e.g. a decrease of people taking sick leave in the workplace), which in itself translates to direct cost-savings.

3) In the majority of the research projects that have addressed natural draft systems in schools a few positive actions have been taken to improve the indoor climate. These actions are:

a) Construction materials were purposefully selected to maintain a low level of emissions.

b) The room volumes have been generously held, which has meant that it has taken longer to reach a steady state, i.e. longer time before you get a constant level of pollutants. That way the average pollution levels have been kept down.

c) Noise levels have been lower than for the corresponding fan-controlled solutions. This has been a well-received benefit by teachers and pupils alike.

d) Teachers and pupils have themselves been able to impact the ventilation air flows by actively opening windows, roof hatches, etc.

These four aspects are not only valid for plants with natural draft ven-

tilation. They must permeate all planning of buildings where there will be people.

4) It could be stated that the problems with indoor climate begins far too late in the construction process. The consequences for the system for the indoor climate must be determined before the form, size and construction principles are decided. In this manner, there is an opportunity to set realistic requirements for the indoor climate and to make sure sufficient space is available for plants and machinery.

5) The overall goal at the planning stage cannot be low energy consumption at all costs. Man and his needs of a sufficiently good air quality must be at the centre of the interest of project management.

6) The chosen technical solution must be able to respond adequately to the expectations that people have on a good indoor climate. A first prerequisite for this is that the ventilation system must be able to stand up to the challenges we place on it. It must be able to extract the pollutants that are created in the building, and replace extracted air (exhaust air) with fresh supply air (outdoor air).

7) The keywords for the technical solutions are appropriateness, reliability and resource-conservation. This means that flexibility must be built into the system, so that flows can be easily altered to follow the needs and rearrangement of the premises can be made, without having to readjust the systems.

8) The air flow requirement, as well as other functional requirements, must be continuously met for the foreseeable future. This puts requirements on, among other things, an effective organisation of operation and maintenance. Because we today strive for a better air quality with ensuing higher air flows, a well-thought plan is required to achieve a resource and energy efficient installation. Ingredients for an energy efficient installation are heat recovery, needs based air flow and low levels of pressure in the ventilation system.

9) Low pressure in the ventilation system is an important factor in eliminating the risk of noise problems.

10) The procurement process for the indoor climate function is important in order to achieve a good end result. The division of responsibility for getting a proper indoor climate must be clear from the beginning, so that it is not shared between several parties. The heating, ventilation and sanitation consultant must take an overriding responsibility to ensure that the function of the installations is according to the wishes of the customer.

Checklist for an Adequate Ventilation System

To construct a proper ventilation system, you should be able to tick all the boxes in the check list below:

- ❑ **Good indoor climate**
  - ***Lack of draft***
  - ***Low noise level***
  - ***Appropriate temperature***
  - ***Good air quality***
- ❑ **Low energy use**
- ❑ **Simple operation and maintenance**
- ❑ **Simple adjustments**
- ❑ **Great flexibility**
- ❑ **Low life cycle cost (total cost)**
- ❑ **Easy to operate and maintain and equipped with detailed instructions**

Chapter 7

Word List and Links

Word List

Air exchange – Gives air flow in cubic metres per hour in relation to the volume of the room, in cubic metres.

Air flow – How much air is flowing per amount of time, this figure tells how fast the air is renewed. The units often used are litres per second or cubic metre per hour.

Air leak – Unintentional air flow

Air quality – The air quality is determined by the amount of pollutants in the air, what kind are present in the building itself, the air flow and the efficiency of the ventilation.

Air supply – Incoming air that is brought in to a room

Balanced ventilation system – Means that both the exhaust air and the supply air is controlled by fans. A development of this system is a balanced ventilation system with heat recovery.

Carbon dioxide (CO^2)– The gas produced when human beings and animals breathe out or when carbon is being burnt. A very common gas. When human beings breathe out, the air consists of approximately 18 percent oxygen and 4 percent carbon dioxide. Carbon dioxide is believed to cause global warming.

Dry air – Air with a relatively low humidity.

Exhaust air – Air that is taken away from a room.

Forgiving ventilation system – A system whose function does not deteriorate by the normal disruptions commonly found in buildings.

Fan controlled exhaust air – Means that the exhaust air is extracted by means of fans.

Heat pump – A very efficient heating system

Heat recovery – To make use of the heat in, for example, the exhaust air.

Hybrid ventilation – A natural draft system enhanced with fans.

Life Cycle Cost – What it costs to invest in, to run and maintain and to eventually perhaps take away and destroy a system/installation.

Natural draft ventilation – Means that the ventilation is controlled by thermal forces

PowerSBS (Sick Building Syndrome) – Caused by bad interior environment. Manifests itself by a number of different symptoms such as nausea, headaches, itchiness, nasal problems and much more.

Ppm – Part per million.

Ventilation – From Latin "Ventilo" or "Ventilare" which means "to air" or "to expose to the wind." Now understood as the transportation and the exchange of air in a building or in a room.

Radon – A gas that is formed when the radioactive element radium falls apart. When we breathe air with radon in it, the radon will harm the cells in our breathing system. Radon is a carcinogen.

Thermal – Air movements caused by differences in temperature.

Links

www.aaaai.org (American Academy of Allergy, Athsma and Immunology)
www.asthma.org.uk (Asthma UK)
www.epa.gov (US Environmental Protection Agency)
www.healthhouse.org (American Lung Association's Health House Program)
www.le.ac.uk/ieh/ukieg/ukieg.html (UK Indoor Environments Group)
www.lunguk.org (British Lung Foundation)
www.lungusa.org (American Lung Association)

Every year more than 500 people die in Sweden alone from the poor indoor air; most of them poisoned by radon. The majority of these 500 people smoke, the combination of tobacco smoke and radon is deadly.

The number of people suffering from asthma and allergies increase fast. Researchers believe that the indoor environment is a major factor for this.

In northern Europe, and in most parts of North America, we spend 90 per cent of our time indoors. Despite that, almost all money going into research, are spent on the outdoor environment. When the indoor environment should be as important – if not more important.

This book is written for everybody who wants healthy indoor air. It provides you with information and facts on how to create a good indoor environment. And why it is so important.

ISBN 91-631-6161-3