A new school - could we do better?

(1) Report on a quest for knowledge

"The school is a central arena for creation of future societal health, function knowledge, productivity and well-being for our children today and the working force of tomorrow".

Maybe it sounds a bit high-flown, this quote from Bakke 1999. But it presented me with the starting point for a quest for ways of improving the indoor environment in schools. Are there improvements to be made, and if so what are the problems and how can they be alleviated? Is there a sufficient budget available for school building, or are the improvements doomed by the strictures of a standard budget?
The construction of a new school in the Dutch town of Voorschoten[1] gave me a welcome opportunity to look into these questions. I will present the results of this investigation in a three-part form. This, the first part, is about the background, about the general points of departure and the experiences of others, world-wide. The second part is a report on the design phase and the choices made in this phase. The third part, which describes the construction phase and the first experiences with the school in practice, will be published after the school is taken into use in the spring of 2002.
A good building and an optimal indoor environment do not, of course, guarantee a good school. That is something we must credit to a committed teaching staff who interact inspiringly with their pupils, an exciting syllabus and the facilities needed to implement it, and a home front of involved parents. The building and its indoor climate can interfere with these circumstances, but they can also have a positive effect. And the latter is the goal of this mini-series.

INTRODUCTION

When I recall my school days, there are many incidents that come to mind. But the backdrop is that of the classrooms which were always too hot, too cold, too stuffy or too draughty. When my own children first went to school, these pictures came back to me. Not much had improved. On the contrary, the windows were bigger than they used to be, but there were no effective sun blinds so it was often very hot in the classroom. The radiators were not turned on or off until school began, because there was no adequate control mechanism. A window could be opened to provide ventilation, but then some pupils sat in a draught, particularly in the row next to the windows. In other words, there was little freedom of choice apart from too hot or too cold, or fresh air with a draught or a stuffy atmosphere.
Now that my grandchildren are at school, I get the impression that there has been a certain amount of improvement, but new problems have also arisen. Take air pollution, for example, at levels we scarcely knew in the past and the soaring rates of asthma, particularly among children and young adults. Consider the demand for ICT facilities, which are often not there, and for computer education, which is often at best makeshift, in most schools. Is our society incapable of building good schools? Are the budgets too low? Do we need to put more thought into the buildings themselves? Is there too little know-how available? Or is it a combination of factors?
Well, thinking does not cost anything, so it makes sense to start with that.

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THE SEARCH FOR KNOW-HOW

Learning from someone else's experience is an excellent way of acquiring knowledge. In the area of the indoor environment, the Indoor Air and Healthy Buildings conferences are excellent venues for this purpose, and I have attended them in an eager search for know-how. The 1999 and 2000 conferences yielded a total of 65 papers about schools - a kaleidoscope of varied research into problem schools, causes and effects - results of varying degrees of usability whose essence I present below and in (Bronsema 2001).
Sadly, it must be said that the gulf between the sphere of research and that of practice is still very wide.
Researchers are often incapable of supplying usable information to the practice world, with which they are barely acquainted. Perhaps, too, it is not in their interests to solve the problems, for there has to be something left to research doesn't there?

2.1 Indoor Air 99[2] *(Bronsema, 1999, 2000)*

The majority of the papers relate to what is termed 'intervention studies' in problem schools. Apparently there are indoor environment problems in schools all over the world.
Heavy additional investments must often be made in new school buildings in order to get rid of the worst complaints. Sometimes even these fail to help, as in the case of a Swedish school where serious fungal and bacterial contamination had arisen due to water damage Both pupils and staff started getting health problems some months after inauguration of the new building. After several attempts at rehabilitation, the building was demolished!
A second striking aspect is the considerable importance of good ventilation. This is something we recognize as a common theme to practically every conference topic.

2.2. Healthy Buildings 2000[3]

This conference also heard many reports of intervention studies. Although the Healthy Building conferences are meant as a meeting place of science and practice, few usable results emerged in relation to schools. Ones understanding of the subject is, of course, deepened by acquaintance with all the problems that people encounter globally. The provisional 'Guidelines for indoor air quality in schools' (ISIAQ 2000), prepared by the ISIAQ Task Force 7, which were presented are a typical product of scientists. They contain extremely little practical information for designers but a large number of subjects on which 'more research' is needed. The guidelines also include a checklist for indoor environment studies in existing schools.

2.3 Publications

There is an abundance of publications available, especially from Scandinavia (ISSO/SBR 1999, <Summary by Schaaf and Scheure 1999>, National Institute of Public Health Sweden 1996, Swedish Board of Housing and Planning 1999, Bakke 1999, Umwelt Bundes Amt 2000 etc.). These publications, which are aimed at the stakeholders of schools - governors, teaching staff, pupils and parents - provide helpful recommendations for the use of existing school buildings. Designers can of course profit from these, but they will find little in the way of concrete data for the design of new schools.
Regarding the Dutch situation, contacts within ISIAQ.nl[4] and the NvvA[5] have yielded interesting discussions.

ASTHMA AND ALLERGIES: DISEASES OF WELFARE?

The number of papers about asthma and allergies presented at Indoor Air 99 and Healthy Buildings 2000 was surprisingly large. Another striking point is that the number of sufferers from these complaints are highest in those countries with the best reputation in the area of hygiene. According to one speaker, the average number of inhabitants who suffer from an allergic complaint is 35% for the EU as a whole; but in Sweden the figure is 40%, while under young adults it reaches 50% (Sävenstrand e.a. 1999). It this due to air pollution, or are children raised in such 'sterile' conditions that they become hypersensitive to less than pure air? Can asthma and allergy be regarded as diseases of welfare? There were several speakers who, although not claiming this directly, hinted strongly that this question must be answered affirmatively.
The indoor environment plays a considerable part in the triggering of

allergies, particularly among children whose immune systems are still developing. Passive smoking, humidity and moulds, dust mites, pets, soft furnishings, poor hygiene and inadequate cleaning all aggravate these complaints.

A GOOD INDOOR ENVIRONMENT FOR YOUNG AND OLD!

In the field of HVAC engineering, attention focuses chiefly on the indoor conditions of offices and other buildings for 'grown-ups'. Shouldn't we start paying much closer attention to houses and schools, the places where our little ones spend so much of their time? In my view, the question answers itself.
Caring about the nippers at school does not mean treating the adults who work there as unimportant. On the contrary. Children may perhaps be more sensitive to the physical interior conditions, but for adults psychosocial factors such as work quality, management, work stress, social atmosphere and job satisfaction also play a part in how the interior environment is experienced. Many of these factors are recognizable in the teaching profession. On the one hand, teachers are expected to meet high standards while dealing with a continual stream of changes in their educational tasks. On the other, the teaching profession is subject to a range of problems such as increasing staff shortages, high rates of sick leave, temporary replacement staff, changing job descriptions and changing classes. Female teachers form a majority in primary education, and women are generally more sensitive to external conditions than men (Bullinger, 1999). Many female teachers moreover combine their jobs with a heavy workload in the family home, and that is a job that also is expected to meet higher and higher standards. This all aggravates the risk of SBS[6] and health problems, and that is why it is important to provide a healthy, comfortable and productive indoor environment. Good interior conditions are thus important not only to the pupils but also the teaching staff.

INDOOR ENVIRONMENT AND HEALTH: THE SCANDINAVIAN CONNECTION

The Scandinavians have a high reputation in the area of hygiene, the indoor environment and health. It will therefore do no harm to start by listening to what they can tell us.
J.V. Bakke from the Norwegian labour inspectorate gave a good summary of the relevant factors in the interior environment of schools in his contribution to Indoor Air 99 (Bakke, 1999).

- Poor indoor air quality increases the occurrence of respiratory disorders and causes and/or aggravates allergies and over-sensitivity.
- Poor routine cleaning, dust, moisture and high temperatures irritate the mucous membranes, aggravate respiratory problems, cause head-aches and tiredness, and impair the ability to concentrate.
- Excessive temperatures impair concentration in children and cause restlessness among girls. The interior temperature in a classroom should not exceed 22^0 C in the winter and should preferably be less.
- Ventilation is necessary to control air contamination and humidity, but a maximum CO_2 concentration of 1000 ppm is not a sufficient guarantee for health and productivity.
- Acoustic and visual aspects (illumination) are highly relevant.

Let's go into these aspects one for one.

INDOOR AIR QUALITY

The quality of the indoor air is impaired by various pollutants. The most common ones are as follows.

Volatile organic compounds (VOCs)
Paint, glue (e.g. floor covering adhesive), cladding materials etc. are the main examples, but concrete (form oil) and furniture are also potential sources of VOCs. Among VOCs, formaldehyde is one of the most notorious.
VOCs irritate the mucous membranes and skin, so that those who are sensitive to them suffer burning eyes, sore throats, runny noses and dry skin. Symptoms like these are often ascribed to excessively 'dry air'. The humidity generally has nothing to with the complaints, although a relatively low humidity may sometimes aggravate them.
Preventive measures are essential to prevent these problems. So select materials with the lowest possible VOC

emissions and do in any case make an issue of this in the assessment. Floor coverings, walls and ceiling finishes merit special attention here because of the large surface areas involved.
As to the corrective measures available, the primary one is good ventilation, both before occupation of the school and once it is in use. Even if it is a new school, there's no need for it to smell new! (Arashidani, K. et al. 1999)

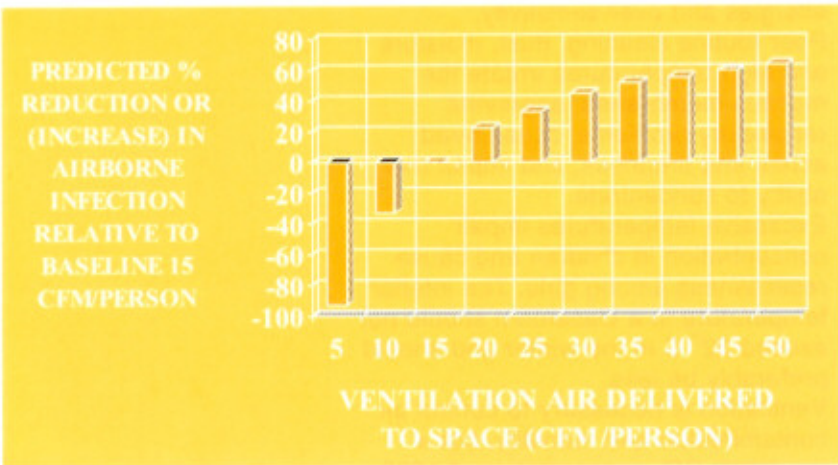

Figure 1 – Airborne infection risk and ventilation rate according to Nardell. Keegan et all

Bio-aerosols
Bio-aerosols enter the air from coughs and sneezes, and can transmit diseases. This hazard is invariably increased when many people occupy the same room as in a classroom (Bartlett, Kennedy et al. 1999). A child with measles or mumps can quickly decimate a class of thirty. The link between ventilation flow rate and infection risk has also been studied scientifically (see figure 1; Nardell, Keegan et al. 1991). Efficient ventilation, particularly in winter when many people have colds, is a good means of suppressing the concentration of bio-aerosols.
Some bacteria can cause infections in people; the Gram-negative bacteria are primarily responsible for this. (The Gram test divides the bacteria into two groups: Gram positive and Gram negative). Gram-negative bacteria contain endotoxins, biologically active lipopolysaccharide molecules that can cause various inflammatory responses in the lungs and airways (Slob 1996). Since people are themselves the major source of bacteria, a high density of people in a space will clearly result in a higher concentration of bacteria and endotoxins in the air. This is born out by research into air quality inside aircraft, the spaces with by far the highest occupation density (1.2 m^3 air space per person, compared to 4.7 m^3 in a school classroom, 25 m^3 in an office or 50 m^3 in an average living room). Endotoxin concentrations
measured in passenger aircraft cabins were six times those of a typical office. On fairly long flights, CO_2 concentrations around 1,500 ppm were also measured (ASHRAE Annual Meeting 2001, Cincinatti, OH, Seminar 2, Aircraft Cabin Air Quality. No papers available).

Pet animal allergens
Allergens from animals can cause reactions in sensitized people. Many children (50%?) have a cat, dog, hamster or guinea-pig at home and unwittingly carry allergens to school with them on their clothing. Pet allergens have been shown to be present in practically every classroom, including those where no animal has ever been present (Godish and Russell, 1999). The rampant growth of allergies, especially among children and young adults, means that this problem merits serious attention.
The best preventive measure is not to allow animals into the classroom. Good ventilation and adequate routine cleaning can help limit the concentration of allergens.

Fungal allergens
Fungal allergens can occur in the air when mould grow on damp building materials and in a humid atmosphere (Würz e.a. 1999). A dry building, a dry interior environment and the use of mould-resistant materials (Adan 2000) are the best prevention. It is difficult to eradicate a fungal infestation once it has occurred.

Pollen allergens
Pollen grains are brought indoors by ventilation air and on children's clothes, and cause problems only in specific periods. Pollen allergies give most problems in schools in park-like surroundings.
It has been shown that the concentration in the indoor air is usually lower than outdoors, even when natural ventilation

is used. This is probably due to the grains adhering to surfaces in the interior. When the classroom windows are opened, the indoor concentration of pollen can rise to equal that outside. These allergens have generally vanished from the indoor environment by a few months after the high season.
Mechanical ventilation with high-quality air filters could in principle present a solution for this problem. An intrinsically better solution is to opt for pollen-free or low-pollen trees, shrubs and plants when laying out the gardens (Ogren 2000). Not all horticulturalists are knowledgeable about this kind of data, however.
Keeping the windows closed during the pollen season is another simple and reasonably effective measure, but it is of course detrimental to the quality of the indoor air.
On the whole, flowering plants do not belong in the classroom.

Dust
Dust particles, particularly small ones (PM_{10} and $PM_{2.5}$)[7] are always present in indoor air; sometimes they are visible in sunlight entering through the windows. Research has shown that the concentration of dust in schools is often higher than in offices. The blackboard, the furnishings and open bookcases are the chief sources of dust (Ligman, Casey et al. 1999). The use of dust-free chalk and cleaning the blackboard with a wet sponge or cloth are excellent preventive measures (ISO/SBR 1999).
Inorganic dust is not harmful in its own right, but since allergens, micro-organisms and VOCs can attach themselves to floating dust particles, and these may be inhaled, it is necessary to prevent high concentrations arising. It has been shown that more mucous membrane irritations and breathing problems occur in a dusty environment. Small dust particles form a deposit on furniture, floors and walls, and must be removed using a good vacuum cleaner.

Routine cleaning (ISSO/SBR 1999)
To maintain the quality of indoor air, it is essential for the classrooms to be well cleaned, so that allergens, dust and micro-organisms removed. Good routine cleaning, not only of floors, but also of furniture and curtains, is important (Kildesö, Bach Nielsen et al. 1999). Here are some recommendations:

- Use hard floor coverings rather than soft ones.
- Reduce walk-in contamination by providing clean-off mat zones of 4 to 6 metres in length inside and outside each entrance.
- Ensure that the playground is thoroughly swept clean several times annually.
- Use non-harmful cleaning agents with a minimum content of VOCs (see before).

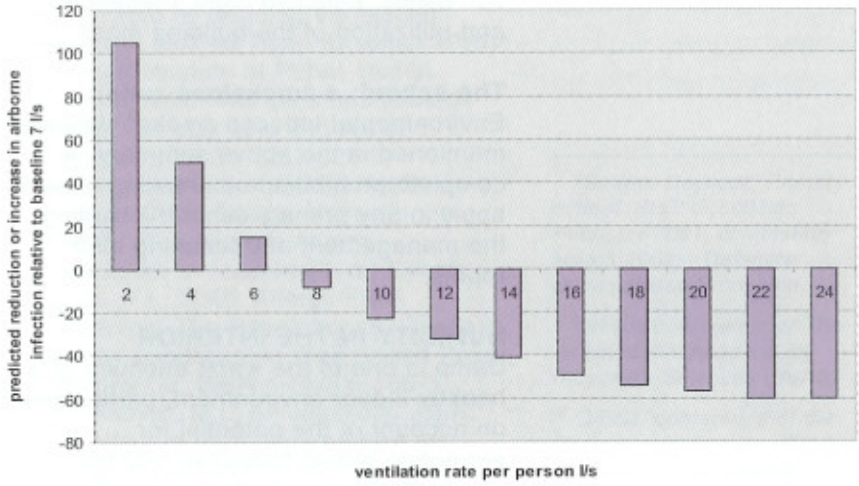

Figure 2 – Airborne infection risk and ventilation rate according to Nardell. Keegan et all

- Clean classrooms after the last lesson of the day, so that all VOCs will have evaporated by the following morning.
- Use vacuum cleaners with filters that offer the highest possible level of filtration (HEPA).

Classroom temperature in winter
The winter classroom temperature should ideally be no more than 20^0 C. Research has shown that many SBS symptoms disappear like snow before the sun when this rule of thumb is obeyed (Wyon 1993, Reinikainen & Jaakkola 1993, Jaakkola & Reinikainen 1990). The lower the room temperature, the better the air quality, owing to lower emissions from the interior materials. At a lower air temperature people moreover feel the air to be fresher (Bronsema 1994). At a lower temperature, the relative humidity is also lower, and this is good for the mucous membranes in the occupants' airways and eyes.
Finally, maintaining a lower air temperature saves energy. There is thus no good reason at all to opt for a temperature above 20^0 C. Teachers and

pupils who find this too cold can simply put on some extra clothing.

Classroom temperature in summer
The summer temperature in the classroom should preferably not rise above 25° C, particularly in the spring or autumn when it is cool outside. Quite apart from mechanical cooling, there are various technological means for keeping the temperature down, including suitable sun-blinds, effective night ventilation and utilization of the building mass.

The school: a smokeless zone!
Environmental tobacco smoke[8] was not mentioned in the above summary. A complete prohibition on smoking should apply in any primary school, including the management and teaching staff rooms.

HUMIDITY IN THE INTERIOR

Damp is one of the worst enemies of a healthy indoor environment, particularly on account of the potential for promoting mould formation and the resulting release of allergens and micro-organisms into the air. The above-mentioned example of the Swedish school that was past rehabilitation is germane. New school buildings should be handed over in a dry condition, and must be kept dry when in use. Here are a few points for attention:

- Reduce the amount of building moisture by using dry building methods and/or prefabricated construction.
- Prevent thermal bridges where condensation could occur in winter.
- Design thermal structures in such a way that any internal condensation accumulated can gradually evaporate during the summer.
- Provide adequate ventilation during fitting out of the building; if the fitting out takes place in winter, put the central heating installation into operation.
- In areas with a high water table, ensure that the ground floor is sufficiently raised.
- Create a dry crawl space with effective drainage. Take care not to leave organic materials behind in the crawl space[9]. If necessary, provide a layer of seashells to keep the crawl space dry.
- Consider restricting the crawl space to wet areas and general spaces (Geldof 1991)
- Ensure that the building is weatherproof as early as possible to prevent rainwater penetration. Apply roofing in good time.
- Pressure-test the water pipes in order to reveal hidden leakages as early as possible[10]. Repeat pressure-testing just before delivery.
- Check the sewers and rainwater pipes for freedom from blockages and leaks.
- Allow sufficient time in the completion schedule for the above-mentioned checks. Avoid a hectic period leading up to delivery. Ensure 'peace and quite' on the site.
- Preferentially use dry cleaning methods and use vacuum cleaners with HEPA[11] filters.
- Make sure pupils are not forced to bring wet raincoats into the classroom by providing well ventilated corridors or cloakrooms where they can hang them.
- VENTILATE! VENTILATE! VENTILATE!

VENTILATION

The preventive measures described above constitute a first, necessary step towards good indoor air quality. The second, equally essential step towards a healthy interior environment is effective ventilation. The VOCs emitted by the interior finish (not wholly avoidable), human aerosols, dust and allergens of various types must be diluted by ventilation to the least harmful possible concentrations. The requirements that every ventilation system has to meet are as follows:

- A sufficient flow rate
- Sufficient ventilation efficiency
- Draught-free air distribution (both summer and winter!)
- Minimum energy consumption.

TO BE CONTINUED...

Part 2 of this mini-series, "The design: from theory to practice" goes into further detail about the envisaged preventive measures and the technical aspects of the ventilation system.
Part 3, "The devil is in the detail", comprises a report of the realisation and the first-year experiences with the new school.
Both parts will be published in the next issues of the REHVA Journal.

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[4] The Dutch branch of ISIAQ - www.isiaq.nl

[5] Nederlandse Vereniging voor Arbeidshygiëne (Dutch Association of Industrial Hygiene)- www.nvva.nl

[6] Sick Building Syndrome

[7] PM stands for particulate matter, and the numerals 10 and 2.5 indicate particle sizes in microns.

[8] ETS: Environmental Tobacco Smoke

[9] I removed a number of pieces of wood bearing impressive fungal colonies from the crawl space of my last home. I was just in time, for the mycelium was on the point of infiltrating the wall cavity.

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[11] HEPA filters have a filtration efficiency of 99.97% for dust particles of 0.3 micron and larger.

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[9] *I removed a number of pieces of wood bearing impressive fungal colonies from the crawl space of my last home. I was just in time, for the mycelium was on the point of infiltrating the wall cavity.*

[10] *In my present apartment, a concealed leakage in a water pipe resulted in complete saturation of the floor screed and parquet floor. It took about 3 months to dry out using mechanical air dryers and the damage amounted to about • 45,000.*

[11] *HEPA filters have a filtration efficiency of 99.97% for dust particles of 0.3 micron and larger.*