Indoor Air Quality and Healthy Housing

In industrialized countries, most people spend over 90% of their lives inside buildings. During this time the health, quality of life, and productivity of the occupants are directly affected by the nature of the enclosed environment.

Modern buildings clearly have a problem providing a healthy or even appropriate indoor environment. The US EPA concedes that about 30% of new or renovated buildings have serious indoor air quality problems (IAQ), and ranks IAQ as our most prominent environmental problem.

Extensive measurements by numerous agencies have shown that the typical modern home contains a chemical soup of volatile organic compounds (VOC's) like formaldehyde, xylene, isobutylaldehyde, vinyl chloride monomer, and other organochlorides, aldehydes and phenols from all kinds of manufactured wood products, paints, carpets, and synthetic textiles including furniture and carpets, PVC, foam insulation, tile and carpet glue, etc.

Radon from the soil, ozone from some electrical appliances, and micron-sized particles from many sources add to the health risk. Some biological sources can also degrade the indoor air quality of a home. Although previously under-emphasized, it is now widely accepted that fungal growth is a serious health risk.

There are several strategies that can be employed to dramatically reduce the presence or concentrations of these pollutants.

The first line of attack should always be the avoidance of products that contain solvents, glues and plastics. There is an increasing number of commercial sources of natural paints, glues and materials that can substitute for the more dangerous building materials (e.g. particle board, waferboard, foam insulation, paint). The use of natural (and unpainted) lime-cement or mud plasters and solid wood as wall finishes, and concrete, linoleum, solid wood, and ceramic tiles for floor finishes can reduce total VOC concentrations by an order of magnitude.

The second step in improving IAQ is to design a house that removes pollutants, at least to levels of the outdoor air, if not lower. This involves increased volumes, and more controllable, ventilation, porous adsorbers, and plants. Hygroscopic materials moderate RH and can permanently adsorb some VOC's. Any falling or running water will act as a powerful particulate filter. Plants such as Devil's Claw and spider plants measurably improve IAQ by filtering and humidifying the air while consuming CO_2.

Radon control requires an airtight and/or ventilated floor and basement system. Exclusion and removal of radon must be a serious design consideration: approximately 5000 deaths per year are attributed to radon gas in the US, where it is the second leading cause of lung cancer. Ventilation of the living area does aid radon control, but it is imperative to first design and build the ground floor as airtight as possible to avoid penetration.

Maintaining a high, and uniform, wall temperature and moderating swings in indoor relative humidity through the liberal use of hygroscopic "breathable" materials can virtually eliminate the potential for fungal growth. Avoiding materials which act as substrates for fungal growth is a complementary approach.

Airborne particulates, especially those less than about one micron in diameter, can seriously damage the lung. Studies have shown that 75% of all damaging airborne particulates originate in the exterior air. In healthy homes, which produce few particulates, the percentage is likely higher.

High quality filtration of the outdoor ventilation air, by mechanical or natural means, combined with a reasonably airtight building enclosure can be used to greatly reduce the number of particulates present within the home.

Durisol and Healthy Housing

The Durisol family of cement-bonded wood fibre building products have been used for years because of their beneficial impact on a healthy indoor climate. For example, the Norwegian firm Cobolt Architects uses cement-bonded wood fibre for entire wall and roof constructions, often cladding the inside and out with ventilated wood boards.

There are many reasons why Durisol results in healthy housing. Some of the most important and directly quantifiable reasons are discussed below.

Mould/Fungus Control

A major concern in many cold-climate countries is the growing number of studies that link allergies, immuno-depression, and illness to the amount and type of fungal and mould growth in a home. The paper facing of drywall is an ideal mould growing substrate, and even ceramic tiles will allow mould growth if soap and skin residue are allowed to remain on their surface.

The pH of Durisol is about 11 to 12 (e.g. it is alkaline) after reaction with atmospheric carbon dioxide. Upon delivery, the pH is even higher, so the alkalinity is highest when the product is still wet from production and construction. This level of alkalinity makes the growth of fungi and even viruses practically impossible. This is also the reason that lime was historically used to whitewash buildings and stables. (In fact, this practice continues today in dairy barns and other installations where hygiene is important).

The same reasoning applies to interior finishes. Lime and cement-based plasters are alkaline enough that mould growth is stymied, and their breathable properties reduce the likelihood that sufficient moisture will be available for growth in any event. Durisol is an ideal substrate for plasters, allowing cost savings by dispensing with the need for wire mesh.

"Atmungsfaehig" or Breathable Walls

Breathable walls are often discussed in terms of healthy housing, especially by those who study and practice Baubiologie, but the term itself is used in an imprecise manner in the English language.

At the simplest level, breathable walls are diffusion open and hygroscopic. In essence this allows water vapour and other gases to be adsorbed and released, regulating the room climate and hence indoor air quality. Walls that allow slow and controlled airflow through them are the ideal breathable wall. While several of these "dynamic wall" houses have been built in Canada, Sweden, and Japan, they require special design and all successful dynamic wall homes have used mechanical ventilation to provide the required level of control.

Although other gases will also diffuse through walls (exchanging CO_2 and oxygen for example), water vapour is one of the primary determinants of a healthy room climate and, as such, is often considered in depth. In most healthy houses the design of the enclosure and interior partitions is based on ensuring water vapour breathability.

Using a detailed computerized finite element package, we have calculated the amount of moisture released into a room by several different wall systems. Each wall comprised a 200 mm layer of material. Some of the walls were finished with lime plaster, others with gypsum drywall and various paints. The simulation considered a wall and room initially at 80%RH followed by a sudden drop in room air moisture content to 30%RH. Over the period of a week the simulation calculated the water vapour given off each half hour. A summary of some of the results is provided on the following page in Table 1.

Table 1: Water vapour released in one week by walls exposed to a 50%RH change in indoor humidity

Rating [g/m²]	Assembly Description
<30	Any system with vapour retarding paint (including oil based) or "high-quality vinyl" wall paper
50	Gypsum drywall on poly on wood frame, primer + 2 coats latex
90	Concrete, unfinished
200	Softwood logs, unfinished
330	Modern extruded brick, unfinished
470	As above, finished with 12.5 mm lime plaster
610	Durisol Wall Form System with unfinished drywall
630	Strawbale wall with 1" lime plaster
700	Durisol Surface-Bonded Wall System, finished with lime-plaster skimcoat
740	Durisol Wall Form System, finished with 12.5 mm lime plaster
820	Durisol Wall Form System, stained or unfinished

Table 1 shows that there is an order of magnitude between the behaviour of some common wall systems. The plastered Durisol Wall Form System provides about 15 times more vapour control to the indoor environment than the walls used in a typical modern home. The Baubiologie movement has for years supported the use of heavy timber, unfinished brick, cement-bonded wood fibres, and lime-plaster finished brick. While the results above do not attempt to exhaustively rate each assembly (more complex discussions and calculations are necessary for this), it does provide a relative ranking which clearly shows the problems associated with the use of the most common modern building systems.

The simulation results also show the clear superiority of lime plaster over pure cement-based plaster. The hygroscopic and highly vapour permeable nature of lime plaster provides a very fast response (e.g. several minutes) to changes in the vapour content of the interior air while substrates like Durisol and brick provided much more moisture storage, storage which participates at longer time scales (e.g. several hours). The worst possible finish is a high-grade vinyl wall, which not only off-gases VOC's but also returns vapour values of less than about 30.

Air at 20 ºC requires about 1.2 g per cubic meter to increase its relative humidity by 10%. Exterior walls that cover 20 m^2 of a 3 x 5 meter, 37.5 m^3 volume room will need to release about: 37.5 m^3/20 m^2 x 1.2 g/m^3 = 2.25 g/m^2 of wall area to maintain the RH in the room in this scenario. This amount of moisture release is easily and quickly (less than one hour) possible for walls rated over about 200 in Table 1, it is not possible for walls rated less than about 50.

Through-wall Vapour Diffusion

The water vapour permeability of the entire enclosure assembly is one measure of how the water vapour content in the interior air is connected to the that of the exterior air. Walls that use 4 or 6 mil polyethylene have a total vapour permeance of 3 to 5 metric perms (1 metric perm equals 1 $ng/Pa/s/m^2$).

The total vapour permeance of several different wall assemblies has been calculated and is summarized in Table 2.

Table 2: Water vapour permeance of selected wall systems

Rating [metric perms]	Assembly Description
3 - 5	Any system with polyethylene vapour retarders
6 -12	200 mm concrete, unfinished
20-30	200 mm Softwood logs, unfinished
25-90	Brick cavity wall, unfinished or with 12.5 mm lime plaster
40-45	Durisol Wall Form 30 System with painted drywall
50-55	Durisol Wall Form 30 System, stained, unfinished or with 12.5 mm lime plaster
125	Strawbale wall with 1" lime plaster
130	250 mm Durisol Surface-Bonded Wall System, finished w/ lime-plaster skimcoat
150	250 mm Durisol Surface-Bonded Wall System, unfinished

The through-wall vapour permeance of a wall system is not as important for indoor air quality as its moisture storage properties. Nevertheless, the large difference between typical modern homes (3-5 perms) and walls generally considered healthy (25 to 150) suggests that it can play a role.

Conclusions

The indoor air quality of a home directly impacts on the health of its occupants. Reducing the use of synthetic, chemically-based materials, controlled ventilation, proper design, and materials choice can provide good indoor air quality. Durisol building products, including the roof and floor panels not discussed here, can clearly contribute to healthier homes, and in many instances provide the best possible combination of characteristics.

Bibliography and Selected Readings

Baggs, S. and J., *The Healthy House: the Gaian approach to creating a safe healthy and environmentally friendly home*, Harper & Collins, Sydney, 1996.

Bower, J., *Healthy House Building*, The Healthy House Institute, Unionville, Indiana, 1993.

Krusche, P, Weig-Krusche, M., Althaus, D., Gabriel, I., *Oekologisches Bauen*, Bauverlag, Berlin, 1982.

Kuenzel, H., "Muessen Aussenwaende 'atmungsfaehig' sein?", *wksb*, Nov., 1980, pp. 1-4.

Marinelli, J. and Bierman-Lyle, P., *Your Natural Home*. Little, Brown, & Co., Boston, 1995.

Miller, G.T., *Living in the Environment*, Wadsworth, Belmont, Calif., 1992.

Pearson, D., *The Natural House Book*, Simon & Schuster/Fireside, New York, 1989.

Roodman, D.M., and Lenssen, N.*, A. Building Revolution: How Ecology and Health Concerns are Transforming Construction*. World Watch Institute, Washington, D.C., 1995.

Rousseau, D., Rea, W.J., Enwright, J. *Your Home, Your Health, and Well-Being*. Hartley & Marks, Vancouver, 1989.

Scanada Consultants, *Mould in Finished Basements*, Canada Mortgage and Housing Corporation, Ottawa, 1995.

van Vliet, J., *Building Materials for the Environmentally Hypersensitive*, Canada Mortgage and Housing Corporation, Ottawa, 1995.