TECHNICAL NOTE #04

Volatile Organic Compounds (VOCs) and indoor air quality in healthy buildings

"Sick Building Syndrome" is a consequence of poor indoor air quality that is detrimental to human health and comfort. This technical note reviews various international regulations, literature and health studies on indoor air quality and the risks of Volatile Organic Compounds (VOC) in building and interior design materials.

TECHNICAL CONTRIBUTOR

CBA Technical Committee

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EXECUTIVE SUMMARY

A review of current literature and research on the importance of good indoor air quality in buildings, with a particular emphasis on the risks of Volatile Organic Compounds (VOC).

This technical note provides home builders, designers and architects with up-to-date and accurate guidance on how to build better to improve comfort, health and energy efficiency. We expect that this knowledge will have the biggest benefit in low-income and affordable dwellings in terms of comfort and long-term value.

Reports tabled at the SB10 and SB11 Sustainable Building Conferences, reveal that there are advantages for the health of building occupants for structures which are built with clay brick.

AN INTRODUCTION TO INDOOR AIR QUALITY (IAQ)

As people spend approximately 80 to 90% of their life time indoors, the health and physical well-being of building occupants is therefore important, particularly for the young and the aged. Harmful chemical substances in the indoor air, dust and mould spores, high levels of carbon di-oxide, cigarette smoke, odours from cooking or cleaning detergents can lead to long term health problems. Furthermore the use of certain building materials, furniture or floorings can be responsible for toxic emissions which compromise Indoor Air Quality.

The aspect of room temperature (local comfort conditions varying between 19 - 26 °C) and humidity (40-60 per cent) is also essential for the human well-being, and has a bearing on energy usage for artificial heating or cooling.

The reduction of the heating and cooling demand and the improvement of the energy efficiency of buildings has recently become a goal of new buildings in South Africa. Architects are also increasingly now focusing on a holistic integrated approach to healthy living including air quality, an area which was previously the preserve of Mechanical Engineers. For building occupants energy efficient living does not constitute a dominant priority, but the quality of living represents their main priority.

Other aspects to in-door air quality include asbestos fibres, biological pollutants, carbon monoxide, formaldehyde (in the main from particle-board), lead, nitrogen dioxide, pesticides, radon, respirable particles, secondhand smoke, including tobacco smoke, and emissions from stoves, heaters, fireplaces, and chimneys,spores derived from mould growth, and volatile organic compounds (VOC).

About Sick Building Syndrome

"Sick Building Syndrome" describes the situation which is derived from poor Indoor Air Quality and is diagnosed when several persons living or working in the same building complain of similar symptoms of illness such as irritations of conjunctiva, nasal and throat mucous membranes, reddening, itching, sneezing, headaches, dizziness and tiredness.

Furthermore hypersensitivity or allergy-increasing characteristics, particularly carcinogenic, mutagenic or toxic for reproduction properties may lead to long-term effects. The "Sick Building Syndrome" label applies when the percentage of people showing these symptoms is higher than that in comparable buildings

About Volatile Organic Compounds

Volatile organic compounds (VOC) are emitted as gases from certain solids or liquids. VOC include a variety of chemicals, some of which may have short- and long-term adverse health effects, such as lung disease and even cancer. Concentrations of many VOC are consistently higher indoors (up to ten times higher) than outdoors.

VOCs are emitted by a wide array of products, including: paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials such as: carpeting and rugs, fabrics, compressed wood products, paints, sealants, solvents, wood stains, PVC and synthetic leather, as well as office equipment such as copiers and printers, correction fluids and carbonless copy paper, office and craft materials such as adhesives and permanent markers. All contain organic (carbon based) chemicals of low boiling point which can off-gas to produce noxious fumes. Liquid and gaseous fuels are also made up of organic chemicals.

The two main types of pollution that result from the release of VOCs are as follows:

- Indoor air pollution: When VOCs are released into indoor air, they contribute to poor indoor air quality which can adversely impact human health by contributing to things like headaches, asthma, dizziness, mood disorders, itchy eyes, nose, or throat, nausea, liver, kidney, or central nervous system damage, allergic skin reactions, fatigue, visual disorders, and even cancer

- Outdoor air pollution: When released outdoors, VOCs contribute to the problem of smog or ground-level ozone pollution when they react with other chemicals in the presence of light.

Most Green Buildings assessment systems (LEED, BREAM, Green Star, and the Green Building Council of SA rating tools make providion for a portion of the points on offer to be secured with attention to the low VOC aspects.

Examples of VOCs include: Acetone, Butane, Chlorofluorocarbons, d-Limonene, Ethanol 2-propanol, Fire retardants like PCBs and PBBs, Formaldehyde, Hexanol, Methyl chloride, Methyl tertiary-butyl ether (MTBE), Pesticides such as DDT, Plasticizers such as phthalates, Propane, and Toluene.

Some VOCs are generated during normal, natural processes such as by plants through biosynthesis, as for the aromatic scents of the fynbos, pine and eucalyptus plantations.

General Labeling of Products

It is important for consumers to understand that information on labels or other product literature with broad claims about environmental impact using terms such as "green" or "environmentally friendly" may or may not include some of the VOCs emitted from the product, and therefore may not otherwise consider their adverse health effects.

There are South African and international programs that certify and label products and materials based on their indoor air quality impacts such as various human health and comfort effects including odor, irritation, chronic toxicity, or carcinogenicity. Such programs are likely to include consideration of at least some of the VOCs of concern for indoor air. However, the norms and requirements currently used within the product labeling and certification industry for indoor products are not standardized.

This lack of standardization makes it difficult for the consumer and also design experts to fully understand what the labels and certifications mean in most cases.

Some VOC labels or certification programs are based on the VOCs emitted from the product into the indoor environment however others are limited to VOCs that form photochemical smog outdoors. Therefore VOC labels and certification programs may not properly assess all chemical compounds relevant to indoor air quality. This is especially true of most wet products, such as paints or adhesives that may be labeled as "low-VOC" or "zero VOC". Specifiers should be aware on this detail. It is difficult to find accurate information on healthy choices of materials for floors, walls and ceilings, paints and varnishes and furniture.

The use of wood, which for a long time has been considered as a natural building material brings with it preservatives and pesticides (chromium and arsenic containing), which can cause health problems.

Inorganic building materials however such as bricks, whitewash, plaster roughcasts and artificial stone do not normally cause health problems.

The Natureplus® quality seal stands for health awareness, environmentally-friendly production, the protection of limited resources and suitability of application. Building materials that carry this seal are characterized by particularly high standards for health.

MEASURING VOLATILE ORGANIC COMPOUND CONCENTRATION

A VOC is any organic compound having an initial boiling point less than or equal to 250°C measured at a standard atmospheric pressure of 101.3 kPa.

VOCs are sometimes categorized by the ease they will be emitted.

The World Health Organization (WHO) categorizes indoor organic pollutants as very volatile, volatile, and semi-volatile. The higher the volatility of the material the lower is the boiling point and the more likely the compound will be emitted from a product or surface into the air.

Volatility is indicated by a substance's vapor pressure. It is a tendency of a substance to vaporize or the speed at which it vaporizes. Substances with higher vapor pressure will vaporize more readily at a given temperature than substances with lower vapor pressure.

Knowledge about the VOCs that are present at low concentrations is highly dependent on how they are measured. All available measurement methods are selective in what they can measure and quantify accurately, and none are capable of measuring all VOCs that are present. For example, aromatics such as benzene and toluene are measured by a different method than formaldehyde and other aliphatic compounds.

The range of measurement methods and analytical instruments is large and will determine the sensitivity of the measurements as well as their selectivity or biases. Any statement about VOCs present in a given environment needs to be accompanied by a description of how the VOCs were measured so that the results can be interpreted correctly by a professional. Without it, the statement has limited practical meaning.

US ENVIRONMENTAL PROTECTION AGENCY

The US Environmental Protection Agency regulates VOC outdoors because it can create a photochemical smog that affects ozone formation. The term “VOC” is used for both indoor and outdoor air quality, although it is defined differently to reflect context.

The US Environmental Protection Agency (EPA) Office of Research and Development's "*Total Exposure Assessment Methodology (TEAM) Study*" found levels of about a dozen common organic pollutants to be 2 to 5 times higher **inside** homes than outside, regardless of whether the homes were located in rural or highly industrial areas. TEAM studies indicated that while people are using products containing organic chemicals, they can expose themselves and others to very high pollutant levels, and elevated concentrations can persist in the air long after the activity is completed.

Certified bodies that test building products for VOC levels in the US include: Green Seal, GREENGUARD, Cradle to Cradle, and Scientific Certification Systems.

European Union Regulation

Legal requirements for indoor air quality are part of the European Union Construction Products Regulation. The basic requirements of these regulations deal with the hygiene, health and environmental aspects of construction products throughout their life cycle.

Regulations require disclosure on toxic gases, volatile organic compounds (VOC), greenhouse gases or dangerous particle emissions to or radiation into indoor air during the construction, use and demolition of buildings.

Directorate for Health and Environment of the European Commission

The General Directorate for Health and Environment of the European Commission relies upon the work of SCHER (Scientific Committee on Health and Environmental Risks) regarding its assessment of indoor air quality and according to the German Sentinel-Haus® Institut there are six causes for unhealthy buildings:

1. Building materials
2. causes due to construction (including poor quality construction)
3. minimised air exchange
4. causes due to behaviour
5. causes due to the environment
6. products from industrial chemical applications.

Healthy Buildings in Germany

The "Healthy brick building" in Thalheim, Germany built by KHB-Creativ Wohnbau GmbH in 2008 was a monolithic clay brick construction with a concrete basement. Due to a careful choice of construction products the building achieved superb indoor air quality measurements as conducted by independent testing institutes:

- Formaldehyde 7 µg/m^3 achieved (< 60 µg/m^3 required)
- TVOC 300 µg/m^3 achieved (< 1.000 µg/m^3 required)

According to the German research project "*Building Products: Determining and avoiding pollutants and odours*" issued by the German Umweltbundesamt and the Technical University Berlin, insignificant emissions of volatile organic compounds can normally be expected from the following building materials:

- Traditional building products like masonry units, mortars, steel or glass.
- Synthetic materials may contain a number of inorganic and organic additives such as softeners or flame retardants.

- Natural organic products, such as wood contain waxes and oils, which contain a variety of organic compounds, like resins, and solvents.

Note: So-called "natural" products are not necessarily free from VOCs or pollutants.

VOC regulation and choice of materials in Austria

A study by the Austrian Institute for Healthy and Ecological Building was undertaken to develop a comprehensive system to prevent the use of materials containing toxic pollutants in the indoor air of a building. The study concentrated on the impact of building materials on the indoor air quality of volatile organic compounds (VOC), and on emissions during the use of a building. This was with relevance to multi-storey residential buildings, on new buildings and on preventive measures. The study developed rating schemes for healthy buildings for allocating housing subsidies.

For this purpose the Institute classified construction products in three different groups, according to its relevance for the indoor air quality during the use phase.

Level 0	Construction products which are not - or only for a very small amount - responsible for volatile organic compounds in the indoor air, e.g. those based on mineral raw materials like high mass construction products (concrete and masonry).
Level 1	Construction products containing a low amount of organic additives are emitting toxic pollutants, e.g. untreated solid wood, windows and inner doors made of wood.
Level 2:	Construction materials which extensively use chemicals, such as polymer based floorings and wooden composites, as well as other treated materials, which are responsible for the emission of toxic pollutants

The study of the Austrian Institute for Healthy and Ecological Building comes to the conclusion that the best route for achieving a healthy indoor air quality is the so-called "Construction products management"-method This requires a careful selection of the building materials (as per Specifications and Bills of Quantities) and continuous quality controls at the construction site.

The successful implementation of those criteria must be documented by experts and supplemented with an additional test of indoor air quality. Thus an avoidance of pollutants to indoor air requires the avoidance of problematic constituents in the construction product selection.

Total Quality Building (TQB) certificate in Austria

The Total Quality Building (TQB) certificate in Austria has been developed by the Austrian Institute for Healthy and Ecological Building as the comprehensive solution for an integrated and sustainable building assessment in Austria. The TQB assessment tool for residential buildings consists of five assessment categories each weighted with a maximum of 200 points:

1. location and infrastructure
2. economical aspects and technical quality
3. energy and supply
4. health and comfort
5. resource efficiency

The indoor air quality of a building can secure 50 points.

CONCLUSION

Reducing the concentration of VOCs indoors and outdoors is an important health and environmental goal. However, it is important to understand that there are VOCs of concern indoors and outdoors that do not impact photochemical oxidation and therefore are not regulated by the EPA. It is important to make and understand this distinction when advocating or using strategies to improve indoor air quality.

For indoor air quality, ALL organic chemical compounds whose compositions give them the potential to evaporate under normal atmospheric conditions are considered VOCs and should be considered in any assessment of indoor air quality impacts.

It is noted that by building with clay brick and by giving attention to a low VOC requirement for the paint specification, that designers will be able to ensure a very low level of VOC in buildings.

REFERENCES

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3. Directive 2004/42/CE of the European Parliament and the Council, EUR-Lex. European Union Publications Office.

For further information:
The Clay Brick Association of South Africa
Website: www.claybrick.org