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REDUCING INDOOR AIR POLLUTANT LOAD BY SELECTION OF INDOOR MATERIALS

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Background

The traditional approach to maintaining appropriate indoor air quality in homes is to provide exhaust for air contamination sources and provide ventilation to dilute concentrations of indoor pollutants to an acceptable level. However exhaust and dilution alone are now considered as an incomplete strategy by a growing number air quality researchers. The missing link in a complete strategy is *reduction of sources of indoor air pollution so that exhaust and dilution can be more effective.*

Every building has what can be termed an "indoor pollution load". Dilution by ventilation has worked reasonably well under the best of conditions, however ventilation is still largely accidental and poorly controlled in the majority of housing. Only the most recent generation of new housing and major retrofits are likely to have anything approaching controlled and reliable ventilation. Therefore an alternative approach for maintaining indoor air quality is to reduce the pollution load and thereby reduce reliance on ventilation. The pollution/dilution relationship can actually be looked at from another perspective from which it can be said that *buildings with poor indoor air quality do not suffer from inadequate ventilation as much as they do from excessive pollution load (1).* One piece of supporting evidence for this assertion is that while ventilation rates in housing may vary by a factor of two to four times, indoor air pollutant concentrations may vary by a factor of fifty or more.

Sources of Indoor Air Pollution in Housing

The sources of indoor air pollution in homes are numerous. They include

- building occupants (CO_2, H_2O, odors)
- cooking, washing, cleaning (H_2O, volatiles, odors)
- smoking (particulates and gases including carcinogens)
- hobbies (dusts, volatile compounds)
- pets (dander, hair, odors)
- microbial activity (fungal and bacterial particles, volatiles, odors)
- soil gases (radon, methane etc.)
- combustion (CO, CO_2, particulates including carcinogens)
- outdoor air contaminants (pollen, dust, automobile and industrial emissions)
- tracked in soil

Clearly many of these sources are attributable to occupancy, behaviour and building design, however some sources are directly due to materials. These are:

- *volatile organic compounds* (VOC's) emitted by interior materials
- *volatile organic compounds* emitted by cleaning and maintenance products periodically used with those materials
- fiber shed from textiles
- soil, biological materials and odors released by soiled materials.

The Role of Materials as Indoor Pollution Sources

Materials are only one of many groups of indoor air pollution sources. Their role is usually most important in new construction or where special health considerations such as environmental hypersensitivity exist (2).

Historically the health risks from materials has often been considered only as an occupational safety issue for trades persons who handle them. This can be called the "direct and short term" role of materials as indoor pollution sources and is typically of less concern to occupants unless the building is occupied during construction or renovation. The longer term *direct and indirect* emissions from materials are of greater concern. **Direct** material emissions are typically VOC's, dusts and fibers produced by chemical instability (e.g. the degradation of urea-formaldehyde adhesive or plastic polymers) or by physical deterioration (e.g. release of dust or fibers through wear). **Indirect** materials emissions include their function as "sinks" (temporary repositories of air contaminants which will be released over time), their function in trapping soil, their ability to support microbial growth where nutrients, moisture, temperature and light conditions allow and their periodic maintenance requirements.

Periods and Duration of Emissions

Volatile emissions from liquid coatings such as paint tend to be short term, i.e. they decline to a very small fraction of the emission rate when fresh within a few days or weeks. The most toxic emissions from paints and coatings are usually evaporating solvents and a wide variety of aromatics, alcohols, aldehydes etc. which are released by oxidation and other more prolonged chemical reactions. These volatiles are produced not only by solvent based paints but also water based formulations. In fact water based paints may contain up to 12% solvents, though some new formulations contain almost none.

Emissions from many flexible polymers, such as adhesives and caulkings, tend to be longer term due to the "skin" effect which slows the migration of volatiles to the surface. These may take several months to decline to a small fraction of their original emissions rate. The exceptions are materials such as silicone which actually vulcanize at room temperature and catalyzed coatings and adhesives which, if properly handled, become very inert in a short time. The materials with the longest emissions period are the solid sources such as manufactured wood products containing urea-formaldehyde resins and floor coverings, carpets, rubber carpet pads and other materials containing soft plastics. These may still have significant emissions after a year or more.

Secondary emissions of trapped soil and shed fiber are primarily produced by carpet, upholstery and bedding, and textile wall coverings. These tend to increase with age, as soil which is not removed by cleaning accumulates and the fiber begins to deteriorate.

Some types of textiles, such as cut-pile carpets, release larger quantities of fiber than others such as loop pile.

The emissions from materials in residential construction are a concern at three distinct times:

- *Installation:* The exposure to trades persons and building occupants during construction or renovation.
- *Occupant exposure:* The exposure of building occupants to materials emissions during building use.
- *Maintenance and removal:* The exposure of building occupants and trades persons during maintenance procedures and removal or demolition.

The *installation period* (which coincides with the occupancy period if the work is taking place in an occupied building) is the best documented of the three through occupational health research and Material Safety Data Sheets. *Occupant exposures* (typically those risks which extend more than a few weeks after construction) are more difficult to determine. The research data is not complete and few manufacturers have complete information on long term emissions. Much of the information in this category is inferred from knowledge of the chemistry of the materials, from generic product research in the literature (3) and from empirical and anecdotal experience.

The *maintenance and removal risks* are reasonably well known for many existing materials but are difficult to predict for newer materials for which the maintenance performance and removal/demolition practices are unknown.

Internal Dynamics

Materials as indoor air pollutant sources cannot be isolated from the internal dynamics which occur in buildings. Some important effects related to materials are:

- *Sink effect (adsorption/desorption).* Rough and porous materials are actually comprised of microscopic surfaces and cavities which act as traps for molecules and particles. Some pollutants "adsorbed" there will eventually be released. This may occur over several hours or days. This effect explains why a room will smell of smoke or cooking for a very long time after the source is removed. Hard, smooth and non-porous surfaces such as metals and ceramics are least prone to the sink effect.

- *Moisture and temperature.* Moisture in materials will increase their deterioration, increase emissions from formaldehyde sources and support microbial growth. Elevated temperature has similar effects. Solid woods, hard plastics, plasters, masonry, ceramics and metals are least prone to this effect.

- *Light.* The ultraviolet component of sunlight is a potent oxidizer and accelerates the deterioration of pigments, plastics, coatings and other materials. Enameled surfaces, metals and ceramics are least prone to this effect.

- *Microbial activity.* Soiled materials containing moisture will support bacterial and fungal growth, particularly where bright light is not present. Non-porous or sealed materials are least prone to this effect.

- *Soiling and cleaning.* Depending on use, materials may be periodically soiled and require cleaning. Cleaning may disturb and spread soil and introduces further exposures to cleaning products and procedures. Floor coverings are the most critical materials in this regard. Non-porous floors with minimal seams and low maintenance coatings are the least prone to this effect.

- *Physical aging.* As materials deteriorate over time they are more likely to release dusts and fibers. The stronger the structure of a material the less it is prone to this effect.

Prediction of Emissions

Because complete data on materials emissions is lacking, a comprehensive method using laboratory sampling would be useful for predicting indoor pollutant load. However this is costly, time consuming and not always conclusive due to the variability of test protocols and instruments. Its best application is probably as an occasional "arbiter" where difficult decisions are encountered. It is not currently practical for general use.

A reasonable basis for prediction can be applied using generic information from air quality research (3), manufacturers information where available, association by chemical/physical structure and some information from material safety data sheets. For example liquid coatings with complete MSDS disclosures listing only inert ingredients and "safe" solvents such as propylene glycol, or those with solvents with a high vapour pressure (i.e. they evaporate rapidly) are generally the best. There are however two significant shortcomings to this approach: the variability of products and the potential for combined effects (synergy).

A generic materials selection approach relies on the typical chemical/physical nature of a material even though there is wide variation in some industries between different manufacturers formulations and methods. The problem is that variation between manufacturers, and even between different production runs by the same manufacturer, may be greater than differences between entire categories of generic materials. This is, unfortunately, a necessary limitation of materials selection which only experience can overcome.

However generic categories can be further divided by using additional descriptions. For example the generic category "latex paint" can be divided into those which meet Environment Canada's Environmental Choice Standards, those which go further and reduce biocides (anti bacterial and anti fungal agents) and volatiles to a minimum, and those which go even further and are formulated entirely from traditional, proven-safe ingredients, many of which are edible.

The other variable which is problematic is synergy; "the combined effects of exposures which may exceed the sum of the individual exposures". A good example is the well known fact that formaldehyde, as a potent respiratory irritant, can dramatically increase sensitivity to other agents such as dusts and pollens. There is no recognized method of dealing with synergy because so little is known about it.

Eugene Tucker's work for the EPA has shown that, though there is still a lot to learn, there are some measures which can be taken using total volatile organic compounds (TVOC's) as a predictive tool (4,5,6).

Furthermore there are several current initiatives in classifying and cataloging interior materials as sources of indoor air pollutants. For example:

- CMHC is preparing a source book of construction materials for healthy housing which will be available in the Summer of 1993. It is based on the combined experience of several researchers and practitioners.

- The US. EPA is funding further analysis and classification work for the database of materials emissions (3).

Practical Selection Methods

One approach to practical materials selection is to use two basic steps. The first is to determine which materials are the highest priority for selection, and the second is to choose based on experience and research.

Some of the key points to consider in selecting low emission materials are (7):

* <u>Quantity.</u> How much of the material will be exposed to indoor air?

* <u>Location.</u> How close will the material be installed to occupants?

* <u>Duration.</u> How long are emissions expected to continue and will the building be occupied?

* <u>Emissions.</u> What compounds are likely to be emitted into the air from the product during installation and in use? And to what extent will it adsorb and desorb odors and trap soil?

* <u>Toxicity.</u> What hazard level is presented by the gases and dusts emitted?

* <u>Durability.</u> How much is the material likely to break down during it's service life?

* <u>Maintenance requirements.</u> How much cleaning, waxing, stain resistance treatment and other high impact maintenance will it require?

These considerations will lead to a "<u>most significant contributors</u>" list for the project. A typical list, roughly in order of priority, may look like this :

1) Floor coverings

2) Cabinets and furniture

3) Wall and ceiling coverings

4) Paints and other liquid finishes

5) Window coverings

Material Selection Example

In this example only materials located inside the airspace of the house appear. This is because the "location" consideration has placed exterior materials low on the priority list, which is typical for many circumstances.

The next step is to assemble generic research on materials which might be chosen for the project. These are then further researched by evaluating manufacturers testing and specification information and by reading MSDS's where full disclosures are available (8). This requires some experience, though comparative evaluations can be mastered even by someone with a limited science background.

EXAMPLE: For the selection of four important indoor materials for a home the following was determined.

- For **hard surface areas** (where acoustics and other considerations allow) the choices, in order of preference were:

  1) Quarry tile set in thinset mortar with a low-emission acrylic sealer.

  2) Linseed polymer linoleum or rigid vinyl tile set on an exterior plywood or gypsum underlayment with low-emission water dispersion adhesive and sealed with a factory bonded urethane coating.

  3) Hardwood plank with a two-part, water dispersed urethane finish.

  All choices are durable, low maintenance and inherently low emission (9). There are no solvent based products in the systems and no flexible plastics.

- For **soft surface areas** the choices, in order of preference, were:

  1) Area rugs of traditional, knotted construction.

  2) Fusion bonded nylon carpet with polyester fiber pad on an exterior plywood or gypsum underlayment fastened with tack strips.

  3) Fusion bonded nylon carpet with a sponge PVC backing on an exterior plywood or gypsum underlayment fastened with a dry adhesive.

  All choices contain no SBR latex or liquid flooring adhesive (the main sources of carpet emissions) (9) and no urea-formaldehyde bonded underlayment.

- For **cabinets and millwork** the choices, in order of preference were:

  1) Formaldehyde free (urethane bonded) particle board cabinets with solid hardwood trims, water dispersed acrylic lacquer finish and polyester or acrylic composite tops.

  2) Formaldehyde reduced (Exposure I type) particle board or exterior plywood cabinets with water dispersed urethane finish and phenolic laminate veneers.

Both choices have reduced formaldehyde content and low toxicity finishes.

- For **walls and ceilings** the choices, in order of preference, were:

  1) Gypsum fiber board with a low biocide, low volatiles acrylic latex primer and paint.

  2) Standard gypsum board with an ecologo listed acrylic latex primer and paint.

Both choices have reduced biocide and volatiles content. The fiber gypsum board is more durable and eliminates paper exposed to the airspace.

Industry Trends

Industries are responding to demand for lower emission materials as well as to regulation. For example some manufacturers are producing "low emission" carpets which have some significant advantage such as *fusion bonded* backing, an alternative construction which eliminates latex bonding, an important source of indoor air pollution. Some manufacturers are also now producing very low emission water dispersion adhesives and water dispersed, low-toxicity paints with similar performance to solvent based products. Two part water dispersion urethanes which are very durable and suitable for commercial use are also now available for wood floor finishing. Low emission or formaldehyde-free manufactured wood products are also now available for interior applications. They are cost effective substitutes for urea-formaldehyde bonded materials, particularly where sealing measures to reduce emissions are not practical.

Conclusion

Materials screening for emissions, though not highly developed, is a procedure which can now be applied as a general selection process to reduce the air contamination load in buildings. The benefits are better air quality with modest ventilation rates and reduced exposure to trades and building occupants. Though there is still a lot of uncertainty in this area there is now enough practical information to begin to screen indoor materials for their emissions properties.

It is possible to demonstrate that low-emission materials selection can reduce sources of many volatile organics by about 50% and will noticeably improve air quality, particularly during the first 3 to 6 months after construction. A process of determining priorities and screening individual materials is recommended. Selecting materials which also have less soil trapping ability and shed less fiber has also been shown to be effective in reducing airborne allergens and reducing the need for cleaning. Though little quantified verification of this approach has been done, there is substantial predictive and empirical evidence that material selection is effective in improving indoor air quality.

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