INTEGRATING INDOOR AIR QUALITY AND LIFE CYCLE ASSESSMENT IN SUSTAINABLE BUILDING DESIGN

Hal Levin
Building Ecology Research Group, 2548 Empire Grade, Santa Cruz, California 95060 USA
hlevin@cruzio.com

INTRODUCTION

Many interests and issues compete for professional building designers' attention and priorities. Indoor air quality and "sustainable design" have been increasingly among these interests in recent years [1]. While neither has yet gained widespread acceptance or general use in the building design professions, both are now being used more frequently in the United States and certain parts of Europe. The tools available to designers include several directly using or derived from life cycle assessment (LCA) software and concept approaches.

LCAs that have been done on building materials have either ignored indoor air quality (IAQ) or have actually stated that integration of IAQ into LCA practice is either impractical or infeasible [2]. Their assertion hinges around their perception of the relative availability of data and the complexity of its analysis for general environmental impacts and for IAQ impacts [2]. Generally LCA practitioners lack awareness of the methods and practices available to evaluate or compare products' IAQ performance.

Design of a "healthy" building requires consideration of the impacts on humans from both material production and installation in buildings as well as the impacts on building occupants through indoor air quality effects. Therefore, indoor air quality must be assessed and the results must be integrated in LCAs on building materials.

IAQ is neither more complex nor are relevant data any less available than data on materials' impacts on the general environment. Labelling and classification schemes for material emissions have been developed and applied in Denmark, Finland, Germany, and the USA.

METHODS

Various methods for developing IAQ evaluations of candidate products can be integrated into life cycle assessments. Data needs, accuracy, availability and quality are important criteria for selection of methods. Each method was developed by the author and has been applied in various building design projects to assist architects in product selection. All three methods should include determination or estimation of IAQ profiles from installation through the end of the product service life.

Surface Protection, Maintenance and Cleaning Products

Many materials require periodic surface treatments and cleaning in order to perform well. For example, many non-textile flooring products require lacquer and wax applications to protect their material surface and improve their appearance. The total life cycle emissions from such products can easily exceed those from the material to which they are applied. Therefore, emissions from products routinely used with a given material should be included in analysis of Life Cycle IAQ. They should also be used in building material selection processes based solely on IAQ. So-called "green" paints that are not easily cleanable result in more frequent painting and, therefore, potentially larger emissions over the life cycle.

The following criteria have been used to evaluate the alternative methods:

- Accuracy; Are the results accurate and reliable?
- Health-Based Results; Are the results directly related to health impacts?
- Data Availability; Are the necessary data readily available and reliable?

- Time Required to Perform Analysis: How much effort and time is required by the designer to perform this type of analysis?
- Communication of Results: Can the results be easily communicated to and understood by the users?

RESULTS

The results include description of the three methods used in various projects and the comparison using the criteria described above.

Method A: IAQ Concentration Calculation and Assessment

The first method is the most theoretically complete and comprehensive IAQ assessment, designated here as Method "A." It requires acquisition of data on emissions from a product or material as the it will be used in a projected building. Product specific data are obtained from manufacturers or suppliers who have tested their products or from other tests. Calculations are made of indoor air concentrations of chemicals of concern attributable to the candidate product over the life of the building [3-4]. These concentrations can be compared to a reference value, for example, 1/40 the TLV or MAK value, as suggested by Nielsen et al [5]. Method A involves high data intensity, low data reliability, and the difficulty or impossibility of acquiring all necessary data. Generic product emissions data may be available, for example, for other products of the same class or type, but data for the specific products being evaluated may be lacking. The ratio of the calculated concentrations to the reference value can then be plotted alongside the typical LCA plots of other inventory items (e.g., greenhouse gas emissions, energy consumption, toxic chemical emissions, etc.). Since designers actually choose from among different brands of similar products, product-specific data unavailability could be a major barrier to use of this method.

Mthd B: Potential Emissions "Indicators"

Method B involves calculations based on simple, reasonably accessible and reliable data on product contents. Just as for emission

are not available. For wet products or thin films, these data include the total mass of the chemical compounds of concern in the product and the vapor pressures for these chemicals. For dry products with thickness >1 mm, the diffusion coefficient should also be determined for the chemicals of concern and for the specific product being evaluated. A simple calculation produces a dimensionless number that can be used to compare alternative products.

Since designers are generally choosing from available products for a particular application, the relative potential emissions can be used for a first order estimate of IAQ impacts. If differences are not large in the emissions of chemicals being compared (e.g., <2x), then the IAQ impacts can be considered similar. The actual values can be plotted and displayed as relative potential life cycle emissions, concentrations, or exposures.

Method C: TVOC Concentration Calculation

Method C involves obtaining emissions data for TVOC values only and using them to develop estimated concentrations and life cycle exposures. These estimates are then compared. The projected or estimated TVOC concentrations can be compared for each alternative product. A ratio of each product's calculated result to the lowest calculated result can produce a simple reduction of the data to a value that can be easily understood by non-indoor air quality specialists. Alternatively, the life cycle concentration and human exposure values can be used directly in the comparison.

DISCUSSION

Table 1 summarizes a comparison of the methods showing the advantages and disadvantages of the three methods. None is free of problems, but all can be used as screening or selection tools.

Method A is the most accurate for developing an IAQ profile. It compares calculated concentrations to a health-based reference concentration, thus enabling decision-makers

Method A include the high data intensity, the low data reliability, and the difficulty or impossibility of acquiring all necessary data.

Table 1. Advantages and Disadvantages of the Three Methods

	Method A: IAQ Concentration Calculation and Assessment	Method B: Potential Emissions "Indicators"	Method C: TVOC Concentration Calculation
Accuracy	Moderate to High	Moderate	Low to Moderate
Health-Based Results	Yes	No	Imprecise, potentially inaccurate
Data Availability	Low	High	Moderate
Time Required to Perform Analysis	Large	Small	Moderate
Communication of Results	Difficult	Difficult	Moderate

Data are generally far more readily available for Method B except when manufacturers refuse to divulge their products' chemical contents. There is a general trend toward more disclosure as companies compete to be regarded as "environmentally-friendly." The disadvantage of Method B is that the potential impacts of the chemical emissions reported as "TVOC" cannot be related directly to health-based standards. Bornehag *et al* concluded that there is no scientific basis for stating whether TVOC can be used as indicator of VOC health effects [6]. However, TVOC emission values can be compared as semi-quantitative estimates of potential emissions.

Method C has the advantage that TVOC data are more readily available than individual VOC data. However, since TVOC values cannot be used as an indicator of health effects, therefore, Method C does not provide results that can be related directly to impacts.

CONCLUSION

Based on the comparison of the three methods, it is clear that one will not always be more practical, useful, and reliable than the others. In general, Method B is more frequently feasible and provides results that have an order of accuracy as good as or better than many indicators used for LCAs. These three methods can be used for product IAQ assessments whether or not LCA is being conducted. The total building life cycle material emissions' impacts on indoor air quality. Further work needs to be done to develop data to make IAQ assessments more practical and reliable. This is also the case for most factors in typical LCAs and should not be considered a barrier to inclusion of IAQ in LCA practice.

REFERENCES

1. Levin, H. 1997. "Systematic Evaluation and Assessment of Building Environmental Performance," Keynote lecture in S. Nibel et al (Eds) 1997. *Proceedings, 2nd International Buildings and Environment Conference*, Paris..
2. Jönsson Å**.** Life Cycle Assessment and Indoor Environment Assessment, *Proceedings, CIB World Congress 1998***,** Gävle, Sweden, 7-12 June 1998**.**
3. Levin, H., 1996. "Estimating building material contributions to indoor air pollution." In *Indoor Air '96, Vol 3.* Nagoya, Japan. 723-728.
4. ASTM, 1997. D5116-97, Guide for Small Scale Environmental Chamber Determination of Organic Emissions from Indoor Materials/Products. W. Conshocken, PA: ASTM.
5. Nielsen, G.D., L F. Hansen, B. A. Nexø, and O. M. Poulsen, 1996. Nordic Committee on Building Regulations, NKB, Indoor Climate Committee. NKB Committee and Work Reports 1996:11E.
6. Bornehag, C.-G., *et al*, 1996. "TVOC and health in non industrial indoor environments; Report from a Nordic scientific consensus meeting at Långholmen in Stockholm." Borås: Sweden, National Testing and Research Institute.