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INDOOR AIR QUALITY: POTENTIAL AUDIT STRATEGIES

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Indoor Air Quality: Potential Audit Strategies

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ABSTRACT

Energy-conserving measures to reduce infiltration rates in buildings can lead to elevated levels of indoor-generated air contaminants capable of impairing the health and/or comfort of occupants. Typical indoor contaminants include gaseous and particulate pollutants from indoor combustion processes (such as cooking, heating, and tobacco smoke), toxic chemicals, odors, and odor-masking chemicals from cleaning activities, odors and viable micro-organisms from humans, and a wide assortment of other chemicals released from ground soil, construction materials, and furnishings. Any residential energy-conserving retrofit program should include an indoor air quality audit in order to protect the occupants from being exposed to excessively high levels of such pollutants. Carbon monoxide, nitrogen dioxide, formaldehyde, radon and particulates are five significant pollutants found indoors that should be addressed in an indoor air quality audit. The basic audit strategy proposed in this paper would minimize the number of actual on-site pollutant measurements. This approach is efficiently accomplished in two steps. First, compile an inventory of indoor pollutant sources (through an owner questionnaire or visual audit) and assess the amount of pollutants injected into the home from "known" sources -- sources with a narrow range of emission rates (e.g., gas stoves). Second, measure the pollutant source strengths of "unknown" sources -- sources with emission rates that vary widely (e.g., radon). This strategy suggests that future research should be directed toward characterizing the pollutant emission rates of all indoor sources and developing reliable field techniques to characterize unknown sources.

keywords: air pollution, audits, carbon monoxide, energy conservation, formaldehyde, indoor air quality, infiltration, nitrogen dioxide, particulates, radon, ventilation.

INTRODUCTION

Recently, considerable attention has been paid to the issue of indoor air quality. In part, this interest was fueled by our increased need, as a nation, to conserve energy -- particularly the energy used to heat and cool buildings. Energy-conserving measures to reduce infiltration rates in buildings can lead to elevated levels of indoor-generated air contaminants capable of impairing the health and/or comfort of occupants. At present, proposed residential retrofit programs include an energy audit but do not consider the ramifications of retrofit measures on indoor air quality. Incorporating an indoor air quality audit in a residential energy audit is simple, on a procedural basis, and has two significant advantages: first, the auditor would be able to identify those buildings with an existing or potential indoor air quality problem and take this information into account in recommending appropriate retrofits; second, such an audit may uncover a significant indoor pollution source which, if eliminated, would allow infiltration rates to be reduced without endangering building occupants. The second advantage points out that an indoor air quality audit can be viewed as an energy-conservation strategy as well as a health and safety measure since exposing and eliminating a pollutant source permits the infiltration rate to be safely lowered to its energy-efficient optimum.

Typical indoor contaminants include gaseous and particulate pollutants from indoor combustion processes (such as cooking, heating, and tobacco smoking), toxic chemicals, odors, and odor-masking chemicals from cleaning activities, odors and viable micro-organisms from humans, and a wide assortment of other chemicals released from ground soil, construction materials, and furnishings. Extensive research has already been conducted on many of these pollutants and their sources.[1-5] The following table lists some of the major sources of indoor air pollution in residences and the specific pollutants they emit.

Source	Pollutants
Combustion appliances a) Gas stoves b) Indoor water heaters c) Unvented space heaters d) Forced-air gas furnaces e) Gas wall heaters	CO, NO_2, formaldehyde, particulates
Smoking	CO, NO_2 HCN, organics, particulates
Ground soil, tap water, concrete	Radon
Particleboard, plywood, household furnishings	Formaldehyde
Insulation	Formaldehyde, asbestos
Attached garage	CO, NO_2, Pb, particulates
Consumer products	Miscellaneous chemicals
Bathrooms	Odors, microbes

Given the wide variety of pollutants encountered in the indoor environment, to measure all of them in an energy/indoor air quality audit would be both expensive and difficult. Of the major indoor pollutants listed, we have singled out for discussion CO, NO_2, formaldehyde, radon, and particulates as the most critical.

Carbon monoxide (CO)

Although long-term health effects from exposure to low levels of CO are suspected, exposure to high levels of CO for a short period of time can cause more serious and immediate health problems, even death.[6,7] Typically, CO levels high enough to cause "short-term" health effects are generated by a blocked combustion flue, a faulty or poorly tuned combustion appliance, or running a car in an attached garage. Several commercially available instruments -- all electrochemical real-time monitors -- reliably measure CO levels. The cheapest units cost between $900 and $1300, and are portable. (Two such units are marketed by General Electric Co., Wilmington, MA and Energetics Science, Inc., Elmsford, NY.) Two advantages of using a real-time monitor are that the results are known immediately and the technique does not require laboratory analysis; that is, indoor CO problems can be discovered simply by turning on the combustion appliance for a specified time interval and measuring the resulting CO levels.

An alternative to monitoring each appliance for CO emissions is to measure the average CO concentrations over a longer period of time, probably one week. From such longer-term CO measurements, it should be possible to identify a residence that has high intermittent CO levels. In general, a home with a high average CO concentration will have high CO peaks. Under development for residential use is a passive monitor capable of measuring average CO concentrations. Passive monitors require no external power and measure average pollutant concentrations, usually over a period of 24 hours to 7 days.[8,9]

Nitrogen Dioxide (NO_2)

At present, NO_2 is the easiest indoor pollutant to measure. A recently developed passive device, called the Palmes sampler[10] (named after its inventor) collects NO_2 through a diffusion tube at a known rate. The collecting agent, triethanolamine (TEA), captures NO_2 very efficiently and the TEA-NO_2 complex is quite stable over time -- an advantage in an audit program since it permits the analysis to be performed months after the sampler was exposed. The Palmes sampler weighs seven grams and is very inexpensive to fabricate and to analyze. A standard laboratory spectrometer is the only major item needed for analysis. It is well suited for auditing long-term indoor NO_2 levels in large-scale programs. (This device is marketed by MDA Scientific, Inc., Glenview, IL.)

Formaldehyde

One of the more difficult contaminants to measure is formaldehyde. The methods currently available are both expensive and cumbersome to use. A concentrated research effort to develop a passive analyzer is needed before formaldehyde could be included in a large-scale air quality audit. On the other hand, the identification of homes with a formaldehyde problem may not be difficult. Recent evidence indicates that formaldehyde outgassing from indoor sources is time-dependent; thus older homes (without new furnishings) could be eliminated from consideration. A simple questionnaire for the homeowner may be sufficient to reveal the presence of a formaldehyde problem. More research is needed in this area, especially in determining formaldehyde emanation rates from various materials of different ages.

Radon

Radon in buildings has received considerable attention in recent years.[11] Two existing devices for monitoring radon may be adaptable to an energy/indoor air quality audit program. The first device is a passive environmental radon monitor (PERM),[12,13] whose reliability has been established in over a year of use in the field by the Lawrence Berkeley Laboratory and others. The second device, also recently developed, utilizes a detector capable of monitoring alpha particles from radon and radon-daughter decays. This device measures radon more reliably than radon-daughters, the latter being primarily responsible for adverse health effects. (The latter device is called a "track-etch" detector and is marketed by Terradex Corp., Walnut Creek, CA.)

Particulates

The best method for sampling particulates is to collect them on a filter for subsequent laboratory analysis. This procedure is easily accomplished with a small constant-flow pump and a filter holder. For purposes of estimating health effects, it is the respirable fraction (less than 2.5 micrometers in diameter) that should be collected. To separate out the large particles, several techniques can be employed. Two have been used successfully in the field, one which employs a 10-mm nylon cyclone to eliminate the large particles[14] and the other which passes the airstream through a coarse pre-filter before collection.[15,16]

Infiltration

Determining infiltration rates is an integral part of any energy or indoor air quality audit. The techniques for measuring infiltration rates have been significantly advanced by the recent development of an infiltration model based on the "effective leakage area" of a house. In this model, effective leakage area is measured by pressurizing the house to a specified level and measuring the flow necessary to maintain that pressure. Preliminary testing of this model has indicated that the infiltration rate of any given house can be accurately predicted from the effective leakage area measurement, combined with data on local weather and terrain conditions.[17]

POTENTIAL AUDIT STRATEGIES

While a complete set of passive long-term air quality monitors similar to the Palmes sampler may be well suited for indoor air quality audits, such monitors are not available for many pollutants associated with residential buildings. Accordingly, to determine simple, cost-effective indoor air quality audit procedures for use in residential energy audits, we need to explore other potential strategies.

One alternative approach is to collect long-term integrated samples for subsequent laboratory analysis. Samples could be collected in a teflon-lined container pumped to a sufficient vacuum level before transporting to the field. The container would be uncapped on site and air would be slowly pulled into the container through a small capillary tube. The initial vacuum level should provide a pressure difference across the capillary tube great enough to ensure constant flow sampling over the entire sampling period. Once the sample is collected, it could then be shipped to a central laboratory for analysis of the pollutants of concern. Considerable research is needed before field usefulness and reliability of such a system can be established. In this connection, two issues need to be addressed: (1) the possibility that certain reactive pollutant concentrations might change after the sample is in the container, and (2) determination of the sample size necessary to insure proper laboratory analysis. These and other considerations do not make this approach a promising alternative.

A second alternative strategy, and one that would require extensive research, is to establish the pollutant emission rates of all indoor pollution sources so that an auditor could take an inventory of pollution sources and simply read from a table the infiltration rate necessary to ensure adequate indoor air quality. If the current infiltration rate in the residence were low, then no energy-conserving measures aimed at reducing infiltration (e.g., caulking, weatherstripping, etc.) would be recommended. On the other hand, if the infiltration rate exceeded the minimum rate required for adequate air quality, reductions could be recommended and implemented with confidence. As noted earlier, if a significant indoor pollution source was uncovered and remedied (or if other indoor pollution control strategies were implemented), infiltration rates could be safely lowered.

The drawback to this approach is that source strength and emission rates vary considerably for some pollutants. Examples of sources with "unknown" source strengths are those associated with radon, carbon monoxide, and combustion products from appliances, such as forced-air furnaces and wood-burning stoves, that are designed to vent pollutants outside. The primary source of indoor radon in the U.S. is the ground under and around buildings. Radon source strengths vary widely (by factors of 1000 from house to house[18]) because of variations in the radium concentrations in the soil and variations in building types and construction practices. Wide variations in carbon monoxide emission rates from indoor combustion appliances have also been observed. These variations are largely due to badly tuned appliances that could be corrected by a utility serviceman. Finally, wide variations can occur in the source strength of forced-air furnaces and wood-burning stoves. These appliances are designed to remove all combustion products from a house through flues. If the flues are functioning properly, no pollutants enter the house and the pollutant source strength is zero. On the other hand, if the flue is blocked or otherwise malfunctioning, massive amounts of pollutants can enter the interior living space, dramatically increasing the pollutant source strength. (A device that has proved useful in detecting malfunctions in forced-air furnaces and wood-burning stoves and their flues is the "Gas-Trac" detector, model #NGX-4, marketed by J & N Enterprises, Wheeler, IN.) Future research on unknown sources may reveal relationships that would allow such sources to be quantified without on-site measurements and included in the list of sources with known emission rates.

Other indoor sources have a relatively narrow range of emission rates. Some have already been characterized (gas stoves, for example[1,19]) while others need considerable research to assess the nature of their emissions. As suggested, sources with a narrow range of emission rates could simply be inventoried by means of a questionnaire and/or an on-site visual inspection. An indoor air quality audit incorporating the inventory approach could adopt the following procedures:

(1) Compile an inventory of pollution sources via an owner questionnaire and/or an on-site visual inspection to assess, for example:

   (a) the amount and age of indoor particleboard in the residence

   (b) the amount of smoking occurring in the residence

   (c) the amount of concrete and other materials known to emit radon or formaldehyde

   (d) the number, location, and ventilation schemes of all combustion appliances.

(2) Quantify emission rates for all unknown sources (e.g., those associated with radon, CO, and combustion appliances designed to vent pollutants outside).

(3) Determine from tables the infiltration rate required to maintain acceptable indoor air quality based on the results of (1) and (2).

(4) Measure the effective leakage area/infiltration rate.

(5) Devise appropriate energy-conservation recommendations from the results of (3) and (4).

Such an audit procedure would assure that all important pollutants are addressed and, in houses where no indoor air quality problems exist, recommendations to reduce infiltration could be followed without fear. Two important advantages of addressing indoor air quality issues as an integral feature of energy conservation programs are that the auditing agency could avoid lawsuits (and possible forced termination of its auditing program) and be in a position to provide important survey data on indoor air pollutants to epidemiologists and other researchers throughout the country.

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REFERENCES

1. G.W. Traynor. 1979. Gas stove emissions. Energy and Environment Division Annual Report, 1979. Lawrence Berkeley Laboratory report, LBL-11650.

2. C.D. Hollowell, J.V. Berk, and G.W. Traynor. 1979. Impact of reduced infiltration and ventilation on indoor air quality. ASHRAE Journal, 21:49-53.

3. C.D. Hollowell, J.V. Berk, M.L. Boegel, R.R. Miksch, W.W. Nazaroff, and G.W. Traynor. 1980. Building ventilation and indoor air quality. Lawrence Berkeley Laboratory report, LBL-10391.

4. C.D. Hollowell, J.V. Berk, C. Lin, W.W. Nazaroff, and G.W. Traynor. 1979. Impact of energy conservation in buildings on health. Lawrence Berkeley Laboratory report, LBL-9379.

5. W.W. Nazaroff, M.L. Boegel, C.D. Hollowell, and G.D. Roseme. 1980. The use of mechanical ventilation with heat recovery for controlling radon and radon-daughter concentrations. Lawrence Berkeley Laboratory report, LBL-10222.

6. J.S. Kelley, and G.J. Sophocleus. 1978. Retinal hemorrhages in subacute carbon monoxide poisoning: exposures in homes with blocked furnace flues. JAMA, 239:1515-1517.

7. E.P. Savage, J.W. Malberg, H.W. Wheeler, and J.D. Tessari. 1976. Accidental carbon monoxide poisoning in Colorado and Wyoming, 1971-73. Public Health Reports, 91:560-562.

8. E.D. Palmes, and A.F, Gunnison. 1973. Personal monitoring device for gaseous contaminants. Am. Ind. Hyg. Ass. J., 34:78-81.

9. E.D. Palmes and R.H. Linderboom. 1979. Ohm's law, Fick's law, and diffusion samplers for gases. Anal. Chem., 51:2400-2401.

10. E.D. Palmes, A.F. Gunnison, J. DiMattio, and C. Tomczyk. 1976. Personal sampler for nitrogen dioxide. Am. Ind. Hyg. Assoc. J., 37:570-577.

11. C.D. Hollowell, J.V. Berk, M.L. Boegel, J.G. Ingersoll, D.L. Krinkel, and W.W. Nazaroff. 1980. Radon in energy-efficient residences. Lawrence Berkeley Laboratory report, LBL-9560.

12. A.C. George. 1977. A passive environmental radon monitor. Radon Workshop. Health and Safety Laboratory report, HASL-325.

13. M.L. Boegel, W.W. Nazaroff, and J.G. Ingersoll. 1979. Instructions for operating LBL passive environmental radon monitor (PERM). Lawrence Berkeley Laboratory report, LBL-10246.

14. W.A. Turner, J.D. Spengler, D.W. Dockery, and S.D. Colome. 1979. Design and performance of a reliable personal monitoring system for respirable particulates. J. Air. Poll. Cont. Assoc., 29:747-749.

15. T.A. Cahill, et. al. 1977. Analysis of respirable fractions in atmospheric particulates via sequential filtration. J. Air Poll. Cont. Assoc., 27:675-678.

16. R.D. Parker, G.H. Buzzard, T.G. Dzubay, and J.P. Bell. 1977. A two stage respirable aerosol sampler using Nuclepore filters in series. Atmospheric Environment, 11:617-621.

17. M.H. Sherman and D.T. Grimsrud. 1980. Infiltration-pressurization correlation: simplified physical modeling. Lawrence Berkeley Laboratory report, LBL-10163.

18. A.V. Nero, M.L. Boegel, and C.D. Hollowell, J.G. Ingersoll, W.W. Nazaroff, and K.L. Revzan. 1981. Radon and its daughters in energy-efficient buildings. Presented at the Second Special Symposium on Natural Radiation Environment, January 19-23, Bombay, India (proceedings forthcoming).

19. R.L. Himmel and D.W. DeWerth. 1974. Evaluation of the pollutant emissions from gas-fired ranges. American Gas Association Laboratories research report, No. 1492.