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A SYSTEMS APPROACH TO THE MONITORING OF INDOOR AIR POLLUTANTS

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ABSTRACT

Building design and building construction technology has improved in the past decade and the concern over indoor air pollutants and their health effects has increased. A multi-point, multi-pollutant air sampling and analysis network was installed in a family-occupied residence located in Amherst, Massachusetts, USA, to assess the spacial and temporal variation of indoor air quality. The network includes a ten-point air sampling system interfaced to a gas chromatograph which continuously analyzes domestic air for hydrocarbons, carbon monoxide and carbon dioxide as well as sulfur hexafluoride used to produce continuous infiltration analysis by the tracer dilution method. A five point all-teflon sequential air sampling system is interfaced to a continuous formaldehyde analyzer. On-site ambient meteorlogical conditions, indoor thermal comfort parameters and purchased power are also continuously monitored. The network is controlled by a dedicated microprocessor.

Introduction

The DiNardi/Rush-Hampton house is a 3600 square foot contemporary passive solar house located in Amherst, Massachusetts, USA. This house is instrumented for the continuous analysis of hydrocarbons, formaldehyde, carbon monoxide, infiltration, ambient meteorological conditions, insolation, energy consumption and indoor thermal comfort parameters. This analysis is performed by dedicated sampling and analysis instrumentation located on-site.

The objectives of this research project are two-fold. First, spatial, temporal and seasonal variations in indoor air pollutants will be assessed. Second, correlations will be made between selected indoor air pollutants and 1) ambient meteorolgical parameters (wind speed, direction, dew point, temperature and insolation) and ambient air pollutants; 2) continuous infiltration rate data; 3) indoor thermal comfort parameters, including wet-bulb/dry bulb temperatures, energy consumption for residential space heating and hot water and thermal storage mass temperature; 4) occupants' daily living activities; 5) wood stove use patterns; and 6) unvented natural gas cooking device use (FUTURE).

The analytical instrumentation used in this study is demonstrated in Figure 1.

Indoor Air Pollutants

For the purpose of this project, indoor air pollutants have be classified as particles and gases.

Particles

We are currently considering the instrumentation to continuously monitor particle concentrations (PM10) on an automated basis.

Gaseous Air Pollutants

For the purposes of this project the gaseous air pollutants of importance in the indoor environment will be separated into three catagories: organics, inorganics and formaldehyde.

Organics. The mixture of organics found in the indoor environment is complex and the individual chemicals too numerous to identify. In a recent ASHRAE report more than 300 organics were identified in the residential indoor environment (1). In this study we are interested in observing temporal and spatial variations of organic chemicals as a general unspeciated class.

Sampling and Analysis. This sampling methodology is similar to that used in the ambient environment to monitor non-methane hydrocarbons and will be used to study the temporal and spatial variations of organic chemicals. The analysis for unspeciated hydrocarbons, excluding methane, will be accomplished by a microprocessor-controlled gas chromatograph (Baseline Industries, Lyons, Colorado, Model 1030A) equipped with a flame-ionization detector and a 10-point rotary gas sampling valve (Valco Instruments Co., Houston, Texas, Model AH-10). Cleaned eighth inch o.d. copper sampling lines extend from the 10-point rotary sampling valve in the laboratory to sampling ports located in various rooms of the house. The inlets to the 10-point rotary gas sampling valve are the zero air supply, calibration gas supply, ambient air and seven locations throughout the house including the living room, master bedroom, kitchen, garage, laboratory, family room, and recirculation air plenum.

Inorganics

The inorganic pollutants of major concern in this project are carbon monoxide, carbon dioxide and oxides of nitrogen. Presently the only inorganic pollutant being analyzed is carbon monoxide.

Sampling and Analysis. Samples for this analysis are collected by the 10-point rotary gas sampling system used for the organics analysis. Carbon monoxide is catalytically converted to methane and detected as the hydrocarbon. The gas chromatograph is equipped with a ruthenium catalytic converter that is 95-98% efficient at converting carbon monoxide to methane.

Formaldehyde

Formaldehyde is a common indoor organic contaminant with many sources in the residential environment (7). Concern over formaldehyde arises from its acute irritant properties and its potential chronic effects, including possible carcinogenicity. A separate sampling and analytical system is dedicated to analyzing formaldehyde.

Sampling and Analysis. Analysis is accomplished using the CEA Model TGM 555 Air Monitor (CEA Industries, Inc., Emerson, NJ, USA). This automated analyzer uses the pararosaniline method of Lyles (4) and is modified to increase the sensitivity (5) and to eliminate the mercuric chloride reagent (6). The sample inlet is connected to a 5-point all teflon sequential sampling system (Interscan Instruments Inc., Chatsworth, CA) which is controlled by the microprocessor in the data acquisition system (Figure 1).

The sampling lines are 1/4" o.d. FEP teflon tubing extending from the 5-point sampling system in the laboratory to sampling ports located in various rooms throughout the house. The locations sampled with this system are zero air, permeation calibration source, master bedroom, kitchen and ambient.

Other projects relating to formaldehyde in the domestic environment have been completed or are underway in this live-in laboratory and are presented elsewhere in these proceedings (2, 8).

Infiltration Analysis

For the purposes of characterizing indoor air quality it is essential to have continuous data on the variation of infiltration spacially and temporally. To accomplish this, a continuous infiltration analysis scheme was designed and installed. This device uses the same 10-point rotary gas sampling system referred to above with the addition of a tritiated-scandium electron capture detector (Valco Instruments Co., Houston, Texas) to the analytical gas chromatograph. This system is used to continuously monitor the levels of a tracer gas, sulfur hexafluoride. The data acquisition system then records the concentration of tracer and decides if additional tracer gas should be injected to maintain a predetermined set-point concentration of sulfur hexafluoride. The infiltration rate is a measure of the amount of make-up tracer that has to be added to the structure to maintain the desired set-point concentration. This system is discussed in detail elsewhere in these proceedings (3).

Ambient Meteorological Parameters

A ten meter free standing aluminium meteorological tower is located on-site and equipped with a digital weather station (Heath Company, Benton Harbor, Michigan, Model ID-4001) and a silicon-cell-powered transducer (Dodge Products Inc., Houston, Texas, Model Solar Sensor, SS-100). These instruments monitor wind speed and direction, atmospheric pressure, indoor/outdoor temperatures and insolation and are interfaced to the data acquisition system as demonstrated in Figure 1.

Indoor Thermal Comfort Parameters

To reliably predict the variation of indoor air pollutants it is important to measure the change in indoor thermal comfort parameters. This is acheived by the fabrication of table top air moving devices equipped with wet bulb/dry bulb thermocouples. These temperatures are then recorded along with 130 thermocouples that are monitoring thermal storage mass temperature, vertical temperature gradient in the living room and wood stove stack temperatures.

Energy Consumption

The total energy consumption of this structure is being monitored. The electrical power used to operate the fourteen zones of electrical resistance baseboard heat, the domestic electrical hot water heater and the ancillary hardware items dedicated to this research project are monitored by individual current transformers located at the electrical service entrance panel. This house has a large appature solar design and passively acquires approximately 70% of the energy needed for space heating. This passively acquired energy is monitored by thermocouples located in the storage mass.

Data Acquisition

The data acquisition system utilized in this project is an Apple II Plus equipped with 48K storage and two disk drives. Disk drive I runs the house operating systems (HOS) and the daily data is stored on disk drive II. The daily data disk is transmitted to the University Computer Center's Cyber main frame for detailed statistical analysis and model development work. The Apple II data acquisiiton system is equipped with an ADALAB Data Aquisition Control Package (Interactive Microware, Inc., State College, PA, USA), CPS Multifunction Card (Mountain Computer Inc., Santa Cruz, CA, USA). Several custom-built integrators and A/D converters, as well as software specifically written for the HOS, have been developed.

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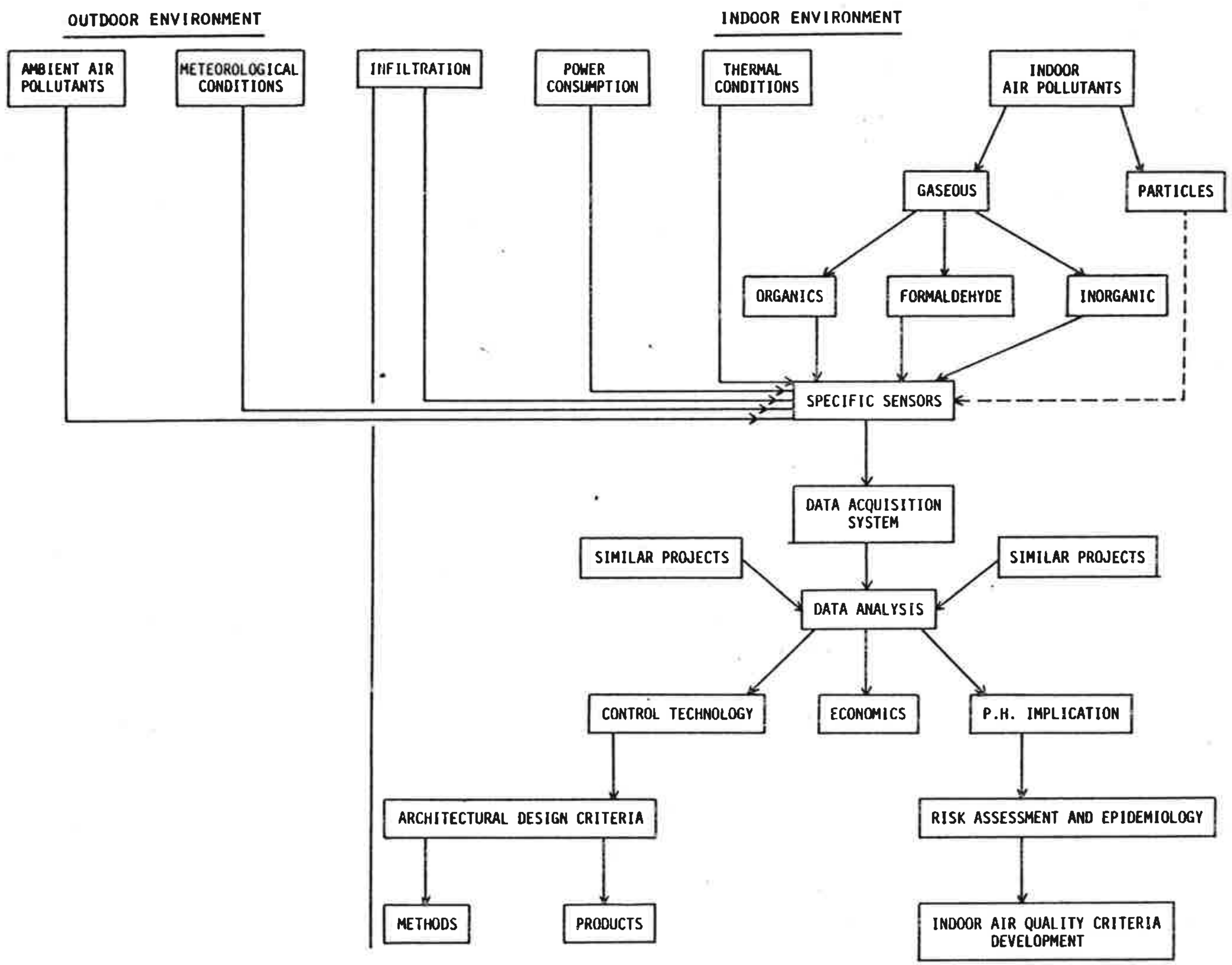

Figure 1
A Schematic Representation of the Overall Research Program in the DiNardi/Rush-Hampton House