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Proactive IAQ Management in New Construction: A Case Study

by E.M. Sterling and J.A. Ross
Theodor D. Sterling and Associates Ltd.

[Editors Note: *This article is the first part of a two-part series on the proactive management of indoor air quality concerns in new construction and outlines the elements of a good management program; the second part of the series focuses on the case studyof a bank under construction and explores our ability to improve indoor air quality during a building's construction.*]

Problems relating to indoor air quality in buildings have been associated with energy conservation strategies, such as increased air tightness of the building envelope, and with the use of synthetic building products, architectural materials, and interior furnishings and finishes[1]. In response to potential IAQ problems due to emissions in new construction, designers may select low-emitting materials for use indoors[2]. Designers cannot accurately predict airborne concentrations and exposures because there is no standardized model to use as a baseline of emissions or off-gas data from building materials, equipment, and occupants. Therefore, regularly scheduled proactive air quality testing is required to determine the effectiveness or performance of the building systems in controlling the indoor environment.

Features Of Proactive IAQ Management

A proactive IAQ management program has been developed for new and existing buildings that is based on a phased approach developed by

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Proactive IAQ Management

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the authors for investigating IAQ problems in buildings[3]. The objective of the program is to prevent IAQ problems before they develop . This is done by monitoring exposure levels, monitoring building performance over time, and providing archival records of results. The components of the IAQ management program include: 1) a review of plans and specifications; 2) walkthrough inspections; 3) air quality measurements; and 4) documentation of results.

Review of Plans and Specifications

Information about the physical building is collected from the following sources for the initial assessment:

- Architectural plans to review the overall building design and the physical layout.
- Mechanical plans to review factors affecting air distribution.
- Materials specifications for a general emissions review of products and materials.

The review of plans and specifications is typically undertaken only during the initial assessment of the building prior to the first on-site testing.

Walkthrough Inspections

The purposes of walkthrough inspections are to observe installed products, furnishings, and equipment; examine the components of the HVAC systems; determine air distribution patterns; and select sampling sites for the air quality measurements. Checklists to assist the walkthrough inspection process have been published by other investigators.[4,5] (See pages 7 and 8 for an example of a checklist.)

Air Quality Measurements

To characterize the indoor air quality and to indicate the general IAQ performance of the new facility, the following parameters are monitored:

- Total Volatile Organic Compounds (Total VOC or TVOC) as a general indicator of overall exposure levels to VOC from emissions indoors.
- Formaldehyde as an indicator of formaldehyde offgassing from new furnishings and finishes.
- Respirable Suspended Particles (RSP) as an indicator of filtration effectiveness and the general dust loading of the indoor environment.
- Carbon dioxide (CO_2) as an indirect indicator of the adequacy of the outside air supply and ventilation effectiveness.
- Carbon monoxide (CO) as an indicator of the infiltration of combustion byproducts into the building.
- Temperature and relative humidity as indicators of occupant thermal comfort.

The monitoring for TVOC and formaldehyde use integrated sampling techniques that require sampling times of up to eight hours. The monitoring for RSP, CO_2, CO, temperature, and relative humidity use direct reading instrumentation at sampling locations throughout the building and outdoors, adjacent to the HVAC system air intakes. Sampling locations are selected to reflect different uses of a space and to provide a typical representation of the indoor environment of a building. To evaluate diurnal variations in the indoor environment, multiple sampling passes at each site are conducted throughout the workday.

In addition to the integrated sampling and the instantaneous sampling passes, one or more continuous monitoring stations are set up to record daily trends in carbon dioxide, carbon monoxide, temperature, and relative humidity over several days. The monitors are normally installed in locations that are typical of entire office areas.

Additional IAQ monitoring may be conducted if specific point sources of indoor pollution are identified or if requested by the client. Additional monitoring may include sampling and analysis for airborne fungi and bacteria, radon, ozone, lead, and nicotine.

Documentation of Results

Following each regularly scheduled testing period, the results of the IAQ monitoring are summarized and compared with the results of previous baseline IAQ monitoring in the building and with available standards and guidelines (such as American National Standards Institute (ANSI) and American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*, and ANSI/ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*[6,7]).

Proactive IAQ Management and Building Commissioning

The Vancouver City Savings Credit Union (Vancity) designed and constructed an office building to house their Head Office in Vancouver, British Columbia, Canada, which is energy efficient and uses environmentally friendly construction materials. The design of the building is also meant to provide a superior indoor environment for occupants. To monitor indoor environmental conditions as the dynamics of the new building changes over time, a proactive IAQ management program was implemented in the Vancity building upon completion in 1995.

In addition to providing a characterization of the indoor environment over time, the proactive IAQ management program also identified several concerns related to the commissioning of the Vancity building.

The results of the smoke pencil testing during the first post-occupancy testing period identified slight negative pressurization of the Vancity building relative to the underground parking garage, resulting in the infiltration of CO-laden air into the building through the parking garage elevator lobbies and adjacent stairwells. Although the results of the instantaneous CO measurements did not indicate significantly elevated CO concentrations on any floor during the day on-site, the continuous CO data collected at the fourth floor continuous monitoring location confirmed significant CO infiltration had occurred through the identified pathway. After inspection of the fan unit serving the parking garage elevator lobbies showed the unit was not in operation, the problem was subsequently corrected by the building operator and design engineer.

In addition to the relative air pressurization relationships identified within the building, the IAQ Management Program has proven useful in identifying improper sensor calibrations relating to the CO_2 and CO sensors integrated with the EMCS of the building.

Comparison of the indoor CO_2 data collected during the first post-occupancy test period with CO_2 data collected from the return air duct sensors on each floor showed disagreement between the measured levels. Continuous CO_2 analyzers were therefore installed side by side with the EMCS CO_2 sensors in the return air ducts on several floors. The results of the *in situ* sensor testing showed the EMCS CO_2 data varied from the precalibrated CO_2 analyzer data by up to 80%.

The identification of CO infiltration into the building from the underground parking garage prompted building operations staff to request side by side testing of the EMCS CO sensors located on each level of the garage with the continuous CO analyzers. The results of the *in situ* testing of the parking garage CO sensors also indicated several sensors required recalibration.

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SAMPLE IAQ HVAC INSPECTION CHECKLIST

HVAC COMPONENT	CONDITIONS	OK	ACTION REQUIRED	COMMENTS
CENTRAL EQUIPMENT				
Boiler	• fuel/gas leaks or odors • water leaks			
Cooling Tower	• water leaks • microbial growth • discharge to O/A intake			
Chillers	• condensate leaks/spills • refrigerant storage			
AIR HANDLING EQUIPMENT				
Outside Air Intake	• clean • location • obstruction • water incursion • bird screen • damper position			
Mixing Plenum	• clean • air intake obstruction			
Filters	• clean • rips or tears • improper fit • microbial growth			
Coils	• clean • condensate leaks/spills			
Humidifiers	• clean • scale build-up • water leaks • microbial growth			
Fans	• clean			

SAMPLE IAQ HVAC INSPECTION CHECKLIST

HVAC COMPONENT	CONDITIONS	OK	ACTION REQUIRED	COMMENTS
MECHANICAL ROOM				
Floors, Walls, and Surfaces	• clean • dry • cracked or peeling paint • microbial growth			
Use as a Storage Area	• cleaning supplies • maintenance supplies • construction supplies			
AIR DISTRIBUTION				
Ductwork	• clean • moisture • obstructions			
Diffusers and Grills	• clean • obstructions			
Terminal Boxes	• clean • obstructed drain pans			
Return Air Plenum	• clean • moisture • insulation			
OCCUPIED SPACE				
Thermostat Locations	• adjacent to source of heating or cooling			
Diffuser/Grill Location	• short circuiting • poor air distribution			
Terminal Boxes	• noise			

Proactive IAQ Management in New Construction: A Case Study

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Editor's Note: *The following article is the second in a two-part series on proactive indoor air quality management during and after construction. In this second part, we examine the construction of a bank.*

Findings From A Case Study

The Vancouver City Savings Credit Union (Vancity) designed and constructed an office building to house their Head Office in Vancouver, British Columbia, Canada that is energy efficient and uses environmentally friendly construction materials. The design of the building is also meant to provide a superior indoor environment for occupants. To monitor indoor environmental conditions as the dynamics of the new building changes over time, a proactive IAQ management program was implemented in the Vancity building upon completion in 1995.

Building Description

The new Vancity building is a 12 story, 118,000 square foot structure. The lower three floors above grade are not typical office configurations but include mixed retail, in-house amenities, and a high security main frame computer room and associated support rooms. Floors four through twelve include typical office configurations, such as a mixture of enclosed private offices, open plan office areas, and enclosed special use rooms, except the seventh floor which is unfinished, unfurnished, and unoccupied. The building also includes a multi-level underground parking garage.

Each of the twelve occupied floors of the Vancity building are served by similar independent HVAC systems. Outside air is drawn into a mechanical room on the floor through outside air intakes located on the north side of the building. The outside air is filtered (40% filtration efficiency as determined in accordance with ANSI/ASHRAE Standard 52.1-1992 *Gravimetric and Dust Spot Procedures for Testing Air Cleaning Devices Used in General Ventilation for Removing Particulate Matter*[1]), tempered, and ducted directly to variable air volume (VAV) boxes located in the suspended ceiling. Return air on each floor is drawn back to the mechanical room unducted through the common suspended ceiling plenum, where a portion is drawn into the supply air system and the remainder is exhausted directly outdoors. All HVAC systems are integrated and controlled by a central computerized energy management control system (EMCS) that uses multiple sensor inputs, such as indoor/outdoor temperatures and return air CO_2 concentrations for controlling environmental conditions indoors.

The energy and environmental features of the Vancity building include low E glass exterior curtainwall to reduce solar gain, low power density lighting, non phase-out chlorine free HVAC refrigerants, CO_2 sensors in return air ductwork, VAV HVAC systems capable of supplying 100% outside air to each floor, water-based paint, and recyclable carpet throughout. In addition, the underground parking garage uses CO (and propane) sensors as part of the computerized EMCS.

The IAQ performance of the new facility is being assessed over time through collection of baseline air quality data for TVOC, formaldehyde, RSP, CO_2, CO, temperature, relative humidity, total viable fungi, bacteria, and radon. The IAQ man-

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agement program consists of air quality testing prior to occupancy, approximately two months after occupancy, and then semi-annually on an on-going basis. This case study presents the results from the first three proactive testing periods.

Results

The results of the air quality measurements in the Vancity IAQ Management Program are summarized in Tables 1.1 (page 11) and 1.2 (page 12). Table One shows the means and ranges of levels of the air quality parameters TVOC, formaldehyde, RSP, CO_2, temperature, relative humidity, ozone, CO, fungi, bacteria, and radon collected during the pre-occupancy testing period and the two post-occupancy testing periods. Table 1.2 shows the ranges of levels of CO_2, temperature, relative humidity, and CO at the Level 4 and Level 10 continuous monitoring locations during each pre- and post-occupancy testing period.

The results of the air quality parameters related to new building products and construction materials, the TVOC and formaldehyde data, showed initial pre-occupancy concentrations that were slightly higher than would be expected in an occupied building. However, the TVOC

FIGURE 1.1 TVOC LEVELS

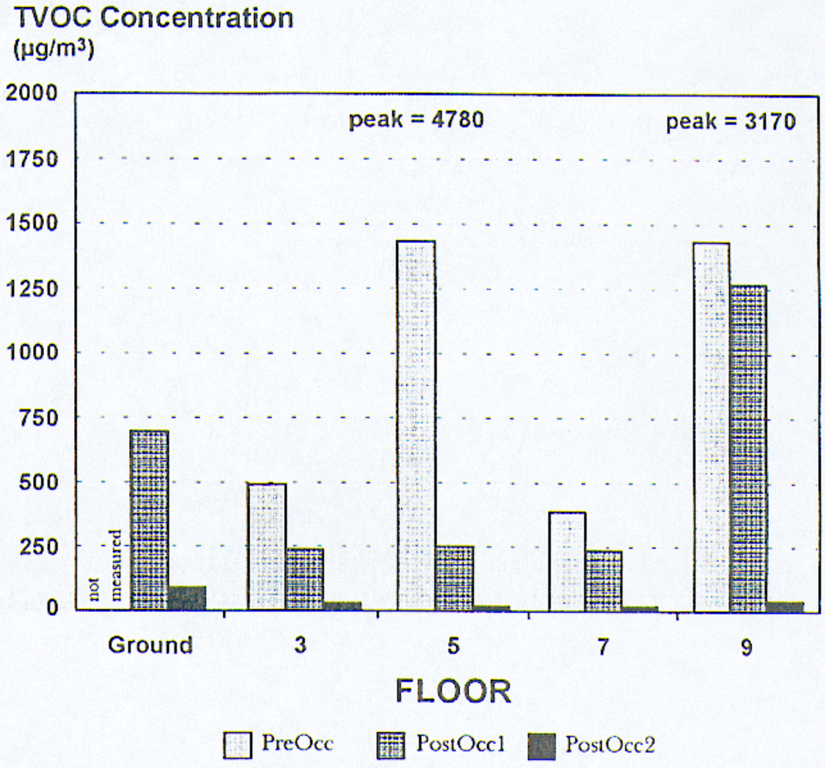

FIGURE 1.2 FORMALDEHYDE LEVELS

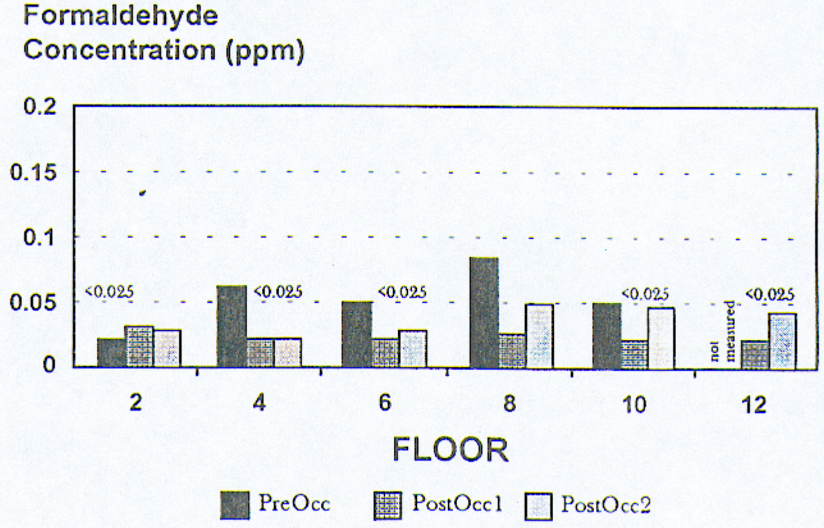

TABLE 1.1 SUMMARY OF AIR QUALITY MEASUREMENTS: INDOOR MEANS (AND RANGES) AND OUTDOOR MEANS VANCITY HEADQUARTERS BUILDING

Test Period	TVOC ($\mu g/m^3$)	Formaldehyde (ppm)	RSP ($\mu g/m^3$)	CO_2 (ppm)	Temperature (F)	R.Humidity (%)	Ozone (ppm)	CO (ppm)	Fungi (CFU/m^3)	Bacteria (CFU/m^3)	Radon (pCi/L)
Pre-Occupancy October 6, 1995	2200 (370-4780)	0.053 (<0.025-0.080)	24 (20-28)	440 (390-590)	70.2 (63.0-73.4)	48.8 (40.8-68.7)	<0.05 All <0.05	0.6 (0.2-1.3)	22 (9-62)	115 (18-194)	<0.4 All <0.4
Outdoor	NM	NM	27	380	58.3	65.4	<0.05	1.4	285	181	NM
Post-Occupancy November 30, 1995	524 (200-1290)	0.027 (<0.025-0.033)	15 (11-19)	502 (400-665)	71.2 (64.8-73.0)	39.2 (35.3-59.3)	<0.05 All <0.05	0.7 (0.3-1.6)	38 (9-132)	246 (62-494)	NM NM
Outdoor	NM	NM	23	365	53.0	72.3	<0.05	2.2	93	146	NM
Post-Occupancy June 19, 1996	40 (24-74)	0.037 (<0.025-0.049)	18 (15-22)	436 (390-510)	72.7 (69.8-74.5)	38.5 (33.2-45.6)	<0.05 All <0.05	1.4 (1.0-2.0)	16 (9-26)	42 (18-71)	NM NM
Outdoor	NM	NM	26	353	66.3	49.6	<0.05	2.3	75	80	NM

NM= Not Measured

and formaldehyde data collected during the two subsequent post-occupancy test periods show significant decreases over time. The trend of decreasing TVOC and formaldehyde levels from the pre- to post-occupancy testing periods are illustrated on page 10 in Figures 1.1 and 1.2, respectively.

RSP concentrations were generally low and also decreased from pre-occupancy to post-occupancy testing periods, indicating minimal residual dust from previous construction activities and adequate filtration of the supply air by the mechanical systems.

The results of the CO_2 monitoring showed generally low concentrations during all testing periods, with one exception. The continuous CO_2 data at the fourth floor monitoring location measured up to 1100 ppm on December 6th and 7th of the first post-occupancy test period, indicating a period of minimal volumes of outside air being supplied to the floor on those days. Building operations staff subsequently reported that due to mechanical equipment malfunctions, the supply fans serving several floors were operating only intermittently on December 6th and 7th during diagnostics and maintenance of the mechanical systems.

The results of the overall CO_2 data confirm that the volume of outside air supplied to the new building is in accordance with ANSI/ASHRAE Standard 62-1989.

The results of the temperature and relative humidity measurements show slight variations between testing periods. However, the measured thermal levels in the Vancity building have generally been within the ANSI/ASHRAE occupant comfort ranges for temperature of between 68°F and 74°F in winter and between 73°F and 79°F in summer, with one exception. An episode of elevated temperatures ranging between 77°F and 86°F occurred at the fourth floor continuous monitoring location on December 6th, when the main supply fan to the floor was out of operation. Relative humidity levels were also within the ANSI/ASHRAE occupant comfort range for humidity of between 20% and 60%. With the exception of the December 6th episode on the fourth floor, the results of the temperature and humidity data collected during each test period indicate adequate thermal control of the indoor environment by the mechanical systems. The results of the ozone monitoring during each testing period show all O_3 concentrations have been less than 0.05 ppm, the detection limit

TABLE 1.2 SUMMARY OF CONTINUOUS MEASUREMENTS: LEVEL 4 AND LEVEL 10 SEVEN DAY RANGES

	CO_2 (ppm)	Temperature (°F)	Relative Humidity (%)	CO (ppm)
LEVEL 4				
Pre-Occupancy October 2-6, 1996	410 - 700	71.6 - 84.5	26.8 - 46.3	0.9 - 2.0
Post Occupancy November 30 - December 7, 1995	400 - 1150	71.2 - 83.7	15.5 - 33.7	0.1 - 8.0
Post Occupancy June 19-26, 1996	410 - 520	70.7 - 77.9	33.0 - 49.3	0.0 - 2.0
LEVEL 10				
Pre-Occupancy October 2-6, 1996	395 - 700	71.2 - 77.7	40.0 - 51.2	0.9 - 2.0
Post Occupancy November 30 - December 7, 1995	400 - 770	68.4 - 72.9	20.0 - 34.2	0.3 - 3.8
Post Occupancy June 19-26, 1996	395 - 500	72.3 - 77.0	34.7 - 39.9	0.0 - 2.5

for the analytical method. These results indicate the presence of O_3 from electronic office equipment, such as photocopiers and laser printers, has not been a concern in general office areas during the three testing periods.

The results of the CO data collected during each testing period showed typically low levels in the Vancity building, with one exception. The continuous CO data collected at the fourth floor monitoring location showed elevated CO concentrations of up to 8.0 ppm on December 6th and coincided with the elevated CO_2 and temperature levels when the main supply fan to the fourth floor was out of operation.

The results of the monitoring for total viable fungi and bacteria show indoor levels similar in magnitude to or lower than outdoor levels, indicating that microbial contamination through amplification indoors has not been a concern in the building. All radon samples collected during the initial pre-occupancy test period measured less than 0.4 pCi/L, the limit of detection for the analytical method. Based on these initial results, radon monitoring has not been included in subsequent proactive test periods.

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