Detailed Instrumentation of a Building Bake-Out Procedure

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Buildings newly constructed or retrofitted and their contents may emit pollutants and these pollutants may turn the building into a “sick building. ” New paint, carpets and furniture may emit volatile organic compounds (VOC) and formaldehyde. Typically, such a building can be “cured” with a flush-out, which is simply ventilating a building for a period of time using only outside air. Unfortunately, such a process can be difficult during hot or cold weather when most HVAC systems are not designed to handle 100 percent outdoor air.

A bake-out, on the other hand, can take advantage of a weekend or holiday period to heat up a building for a couple of days and then flush-out the contaminants using outside air.

Southern California Edison chose to bake-out one of its newly acquired buildings and use the opportunity to collect data before and after the process. Indoor-contaminant emission rates were assessed for a six-week period, three before the bake-out and three after. Simultaneous measurements were taken of the indoor- and outdoor-contaminant concentrations and the outside air exchange. The outside air exchange rate was determined by using a tracer-gas technique.

A significant drop in the emission rates of many organic compounds immediately followed the bake out. After a couple of days however, the level of organic compounds rebounded to previous levels.

Introduction

There have been few studies of the effect of building bake-outs on indoor-contaminant concentrations. Usually, those studies have included only a few measurements in time (typically one measurement before and one or two after the bake-out). Also, building-ventilation rates usually were not measured in these studies, precluding the calculation of building-contaminant emission rates. This study evaluated the impact of building bake-out on the emissions of indoor air contaminants over a six-week period taking measure on a weekly basis.

The site was a recently renovated two-story office building in San Dimas, California. Renovation included new carpet, paint, ceiling tiles, and furniture. Renovations were completed in August 1992; employees moved in between September 3 and 21, 1992.

The San Dimas office is mechanically ventilated with three main air handlers on the roof delivering ventilated air to the building. Supply air for individual zones is controlled by variable air volume boxes connected to ceiling diffusers. Normal building ventilation system operation includes an outside air economizer to control the quantity of outside air in the supply air and variable speed motors controlling the speed of the supply fan.

During the study, the economizers were disengaged and the building ventilation system operated using a minimum of outside air (i.e., return air dampers open and outside air dampers closed to a minimum). Normal system operational hours were maintained during the entire six-week monitoring period (i.e., 6 a.m. to 8 p.m. Monday through Saturday and shut down on Sunday), except during the bake-out when the system operated continuously.

Methods

To assess the impact of the building’s bake-out, indoor contaminant emission rates were measured before and after the building bake-out. Selected indoor and outdoor contaminants, as well as the building’s outside air-ventilation rate, were simultaneously measured. This data was then used to calculate the net indoor-contaminant emission rates. To distinguish between the normal decrease in contaminant-emission rates associated with material aging and that caused by the building bake-out, the contaminant-emission rates were measured once a week for a six-week period. The 72-hour bake-out occurred between the third and fourth week of measurements (i.e., test days: 0, 8, 15, 21, 28, 35 with bake-out days 16-20).

Building Bake-out Schedule

The building bake-out was conducted over a four-day holiday weekend. On the evening of November 24, 1992, all room thermostats were set to maximum heat. The air handling units were set for continuous operation. The percentage of outside air was kept at a minimum. During the bake-out, the building temperature gradually increased. By the morning of November 27, the indoor air temperature on the second floor reached 34°C (94°F). On the morning of November 28, the temperature decreased to 32°C (90°F) when the building's boiler underwent an unplanned shut-down. The boiler was returned to service the next day. At noon on November 28, the air conditioning was turned back on and all thermostats were reset to 24°C (75°F). The outside air percentage was set to 100 percent for the flush-out. On the morning of November 29, the outside air percentage was set back to minimum and the time clocks returned to normal operation.

Ventilation Rate Measurements

Local air exchange rates during the first measurement period were calculated using a tracer gas-decay technique and age-of-air analysis. A gas chromatography with an electron-capture detector determined the concentrations of tracer gas in air samples. Sulfur hexafluoride gas was injected into each of the three main air handlers over a five-hour period; the injection rates to each air handler were adjusted to achieve a uniform and constant indoor concentration of tracer gas throughout the building. The supply of tracer gas was terminated and air samples collected in syringes at each measurement location. Researchers analyzed the samples and calculated the local air exchange rates at each location and then calculated the average building air exchange rate as the arithmetic average of these four measurements. To track changes in the total building ventilation rate during the subsequent six-week study period, researchers measured the tracer-gas concentration steady-state decay rate in each air handler zone following a single-shot injection and a one-hour equilibrium mixing period. The average building ventilation rate for each set of measurements was then calculated as the average of the tracer-gas decay rates in the three air handling units.

Indoor Air Quality Measurements

Technicians measured the indoor and outdoor concentrations of total volatile organic compounds, individual volatile organic compounds and formaldehyde between 10 a.m. and 3 p.m. on each of the six measurement days. While the building bake-out was anticipated to only affect emission rates of volatile organic compounds and formaldehyde, the emission rates of a number of other indoor air contaminants were measured as well. These included carbon dioxide, carbon monoxide, nitrogen dioxide, ozone, total airborne viable fungi and total suspended particles.

Results

See Table 1. Concentrations of all measured pollutants in the San Dimas building fell within recommended health guidelines for residential and office occupancies. A relatively high concentration of airborne viable fungi of cladosporium and penicillium was found in the first and third week of measurements. A water leak from the roof was suspected to be the cause.

The concentrations of some volatile organic compounds, such as propanone, toluene and n-nonane, were found to be significantly higher in the second week's measurements. It was later determined that the lobby reception desk had been refinished with polyurethane on the same day samples were collected.

The formaldehyde and total volatile organic compound net-emission rates appeared to decrease significantly immediately following the bake-out. However, the rates appeared to return to their pre bake-out levels within two weeks.

Discussion

In comparing the net emission rates of the individual volatile organic compounds, there is a significantly higher decrease in the emissions of many of these compounds between the third and fourth week than had been noted in previous weeks. This suggests that the bake-out was helpful in reducing emissions of these compounds. Equally interesting is the subsequent rebound of the emissions within the week following the bake-out (Figures 1-3).

This pattern of a drop in net emissions immediately following the bake-out, followed by an increase during the next week, occurs for many of the organic compounds measured. One explanation is that the bake-out was able to reduce the emissions from secondary contaminant sources, but not from the primary sources, such as paints, caulks

Table 1. Results of Building Bake-Out Procedure

Contaminant	Emission Rates ($mg/m^3/h$) Prior to Bake-out Week 1	Week 2	Week 3	After Bake-out Week 4	Week 5	Week 6
Carbon Dioxide	312,000	319,000	261,000	304,000	289,000	265,000
Carbon Monoxide	<2000	<2000	<2000	<2000	<2000	<2000
Nitrogen Dioxide	1	-8	-1	-10	3	7
Ozone	-95	-173	-67	-85	NA	-85
Total Airborne Viable Fungi	-99	4.5	-160	-113	-42	-57
Total Suspended Particles	-13	-33	-15	-15	-4	-2
Formaldehyde	21	24	17	11	19	11
Volatile Organic Compounds						
TVOC (as carbon)	179	446	285	177	266	120
Individual Compounds - GC/MS						
2-Propanone (acetone)	14.7	30.6	13.7	0.3	24.6	12.3
2-Propanol	12.3	15.6	17.7	-0.6	69.7	6.3
1,1,1-Trichloroethane	9.1	22.3	13.6	0.4	11.4	11.5
Trichloroethene	8.2	1.1	4.0	0.5	1.6	1.0
Toluene	4.3	22.6	6.6	-2.3	13.4	4.8
Tetrachloroethene	-0.3	3.9	0.3	-0.3	2.1	1.0
Hexanal	9.1	12.7	6.0	3.4	8.6	4.3
n-Nonane	0.6	37.5	1.7	<0.2	0.7	0.4
m-,p-Xylene	-2.3	8.5	1.1	-2.6	6.9	1.8
alpha-Pinene	10.5	3.9	5.7	1.6	5.5	3.3
n-Decane	1.4	70.8	6.6	0.5	3.6	2.1
Limonene	12.1	10.8	13.8	5.2	21.7	15.9
2-Butoxyethanol	18.4	27.1	3.9	<0.2	24.3	6.5
n-Undecane	1.9	33.8	16.0	2.8	22.4	14.3
Decamethylcyclopentasiloxane	6.4	10.6	13.6	3.4	12.7	10.0
2-Ethyl-1-hexanol	3.2	7.1	4.3	<0.2	5.6	1.9
n-Dodecane	2.9	10.1	10.9	2.1	18.0	11.3
4-Phenylcyclohexene	0.2	0.6	0.6	0.2	0.6	<0.2
Siloxane Compound	14.2	21.7	18.8	4.9	21.3	12.1
Texanol Isomers	32.5	27.8	24.5	4.6	28.7	13.5

and adhesives. Primary sources are often separated from direct contact with indoor air by surface skins or materials.

Since the increased temperatures of the bake-out will increase contaminant diffusion rates through the covering materials by only about 10 percent, the bake-out should not have a significant impact on the emission rates of the primary sources. Secondary-contaminant sources, however, are high-surface area materials, such as carpets and ceiling tiles that are in direct contact with indoor air and can transfer contaminants to and from the indoor air. The contaminant transport rate between the indoor air and surfaces is influenced by the bake-out temperatures, increasing contaminant vapor pressures by as much as 300 percent. During the post bake-out period, the lower indoor air concentrations can substantially increase the diffusive transport from the surfaces to the indoor air.

Thus, the high ventilation rates during the 24-hour purge period following the bake-out may have temporarily reduced the concentration of contaminants adsorbed onto the high surface-area materials. These materials then acted as a significant indoor sink until contaminants from the primary sources re-contaminated the surfaces, reducing any further enhanced sink action. In summary, it appears that this building bake-out caused only a modest and temporary reduction in the net emission rates of formaldehyde and volatile organic compounds.

The bake-out was conducted nine weeks following the building renovation and six weeks after the installation of office furnishings. In addition, this six-week study was conducted with the building occupied and thus the contaminant emissions came from both the building materials and furnishings, and the building occupants and equipment. Further research is required to assess the effectiveness of this and other ventilation mitigation strategies designed to reduce the concentrations of building material contaminants. A more controlled study of the impact of building bake-out strategies would have been possible if the building had been unoccupied throughout the test period.

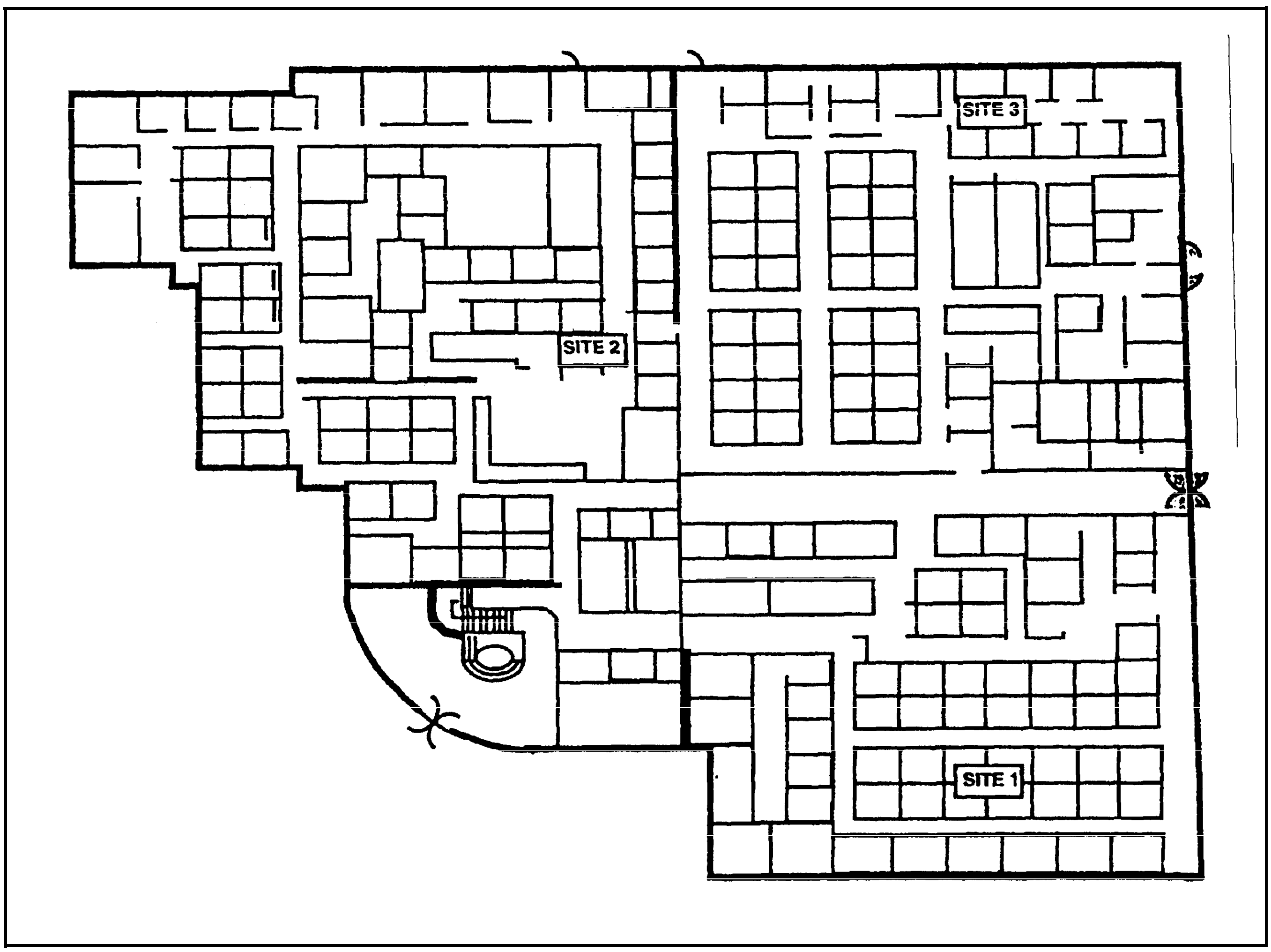

Figure 1. Locations of Monitoring Stations on the First Floor

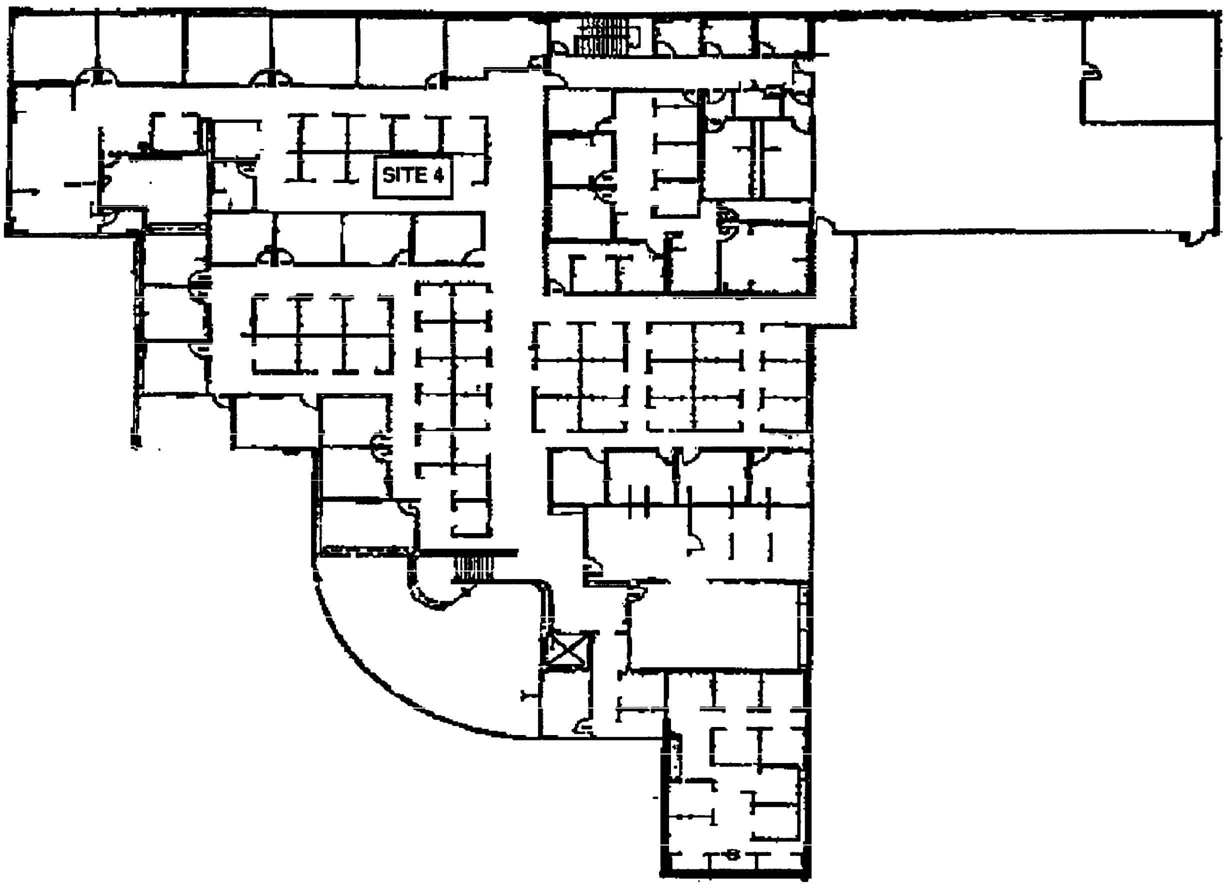

Figure 2. Locations of Monitoring Stations on the Second Floor

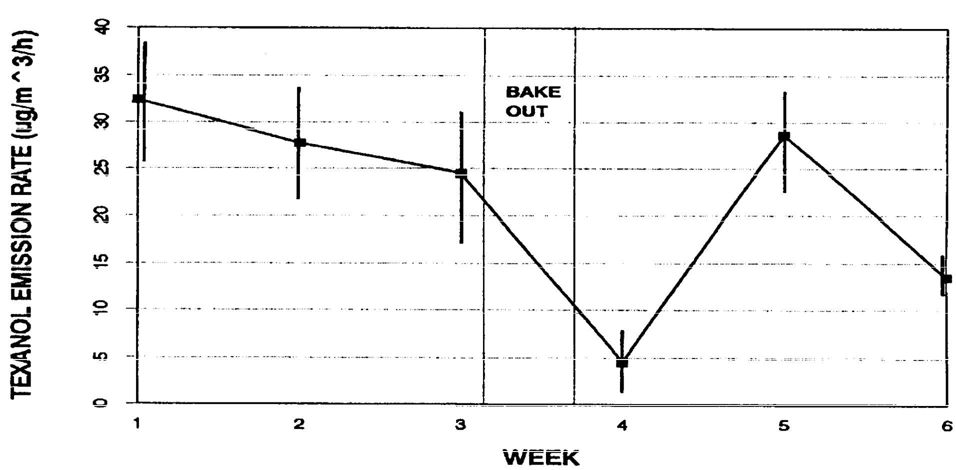

Figure 3. Texanol Emission Rate Before and After Bake-Out