PREVALENCE OF POTENTIAL SOURCES OF INDOOR AIR POLLUTION IN U.S. OFFICE BUILDINGS

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ABSTRACT
As part of its effort to collect baseline information about office buildings, the U.S. Environmental Protection Agency collected information on the prevalence of sources in or near 100 randomly selected office buildings in the USA. Indoor sources surveyed included special use areas (e.g., kitchenettes, parking garage, laboratories, print shops), cleaning product and pesticide use, renovation activities, water damage, and storage. Outdoor sources surveyed included nearby construction, heavy traffic, power plants, industrial stacks, emergency generators and trash dumpsters. For some sources, the frequency of use is also presented. These data can be used by as model inputs to estimate concentrations and exposure as well as be used to assist policy makers making decisions about which sources deserve attention.

INDEX TERMS
Prevalence of sources, Office buildings, Sources, Water damage

INTRODUCTION
Sources of indoor air pollution have a major impact on indoor air quality. For this reason considerable effort has been expended on developing methods for measuring emissions of pollutants from sources and measuring those emissions. (See for example, Teichnor, 1996.) However, equally important is information regarding the prevalence with which those sources occur in buildings. To date, relatively little effort has been expended on developing this information. Such information can be used by modelers to estimate exposures, by architects and ventilation engineers to design buildings and their ventilation systems and by policy makers to assist in decisions about which sources deserve the most attention, e.g., to determine emissions, to develop guidance on better management of sources, etc. In addition, regression analysis can be conducted to test associations with other parameters measured in the study, e.g., concentrations of pollutants or reported symptoms of building occupants.

The U.S. Environmental Protection Agency conducted a major cross-sectional study, the Building Assessment Survey and Evaluation study (BASE) to collect data on key characteristics of indoor air quality and occupant perceptions and symptoms in 100 randomly selected public and commercial office buildings in the USA. As part of this effort, data on the prevalence for many potential sources of indoor air pollution were collected. This paper presents some of the results of that study.

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METHOD

The BASE study collected data from 100 office buildings across the continental USA in cities with populations over 100,000. To collect baseline information on "typical" office buildings, these buildings were randomly selected without regard to any indoor air concerns, except that buildings with highly publicized indoor air quality were excluded. A standardized protocol was used to collect data over a one-week period, either during the summer or winter (U.S. Environmental Protection Agency, 1994). Data were collected from building plans, interviews of building representatives and by direct observations by the BASE field. In this context, source is used to denote not only a material with the potential to emit pollutants but also an activity or area within the building using materials with the potential to emit pollutants. While additional observations were made in a randomly selected test space within the buildings, the data presented in this paper represent the entire building and not just the test space.

RESULTS AND DISCUSSION

Outdoor air can be an important source of pollution indoors because outdoor containing pollutants is typically used as ventilation air without any air cleaning, other than filtration for particulate matter. Table 1 lists several major, potential sources of outdoor air pollution and their prevalence. This table lists the prevalence of dumpsters and emergency generators that were adjacent to the building, while the other ambient sources listed were within 0.8 km of the building. Data in Tables 1 and 2 were previously presented at HB2000 and are incorporated in this paper only to provide a context for other data (Burton, Baker and Hanson *et al*., 2000). Clearly many office buildings are located near potential sources of air pollution and their indoor air could be strongly affected by such sources. Of special note is the high prevalence of emergency generators near office buildings and of construction activities.

Table 1. Prevalence of ambient sources near the office buildings studied in BASE.

Ambient Source	Prevalence
Garbage & Trash Dumpsters	81 %
Emergency Generator	66 %
Heavy Motor Vehicle Traffic	61 %
Construction	56 %
Industrial Stacks	35 %
Power Plants	26 %

Special use areas of a building can also contain potential sources of air pollution indoors. These special use areas of the buildings were also noted and are listed in Table 2. The data in Table 2 clearly reflect that office buildings represent more than just a collections of cubicles and individual offices. Many activities requiring specialized spaces are also present, sometimes to a surprising degree. While it is hardly surprising that parking garages are present in 37 % of the buildings, it is noteworthy that 53 % contain print shops, 25 % contain graphic arts facilities and 34% contain laboratories (which include dental and medical labs).

While data on the presence of smoking lounges are reported in Table 2, these data may be a less accurate reflection of the true prevalence of smoking lounges than for other special use areas. Smoking policies for office buildings appeared to be changing rapidly during the BASE data

collection phase and can have a large impact on smoking lounge prevalence. More extensive analysis is needed to account for trends in this source of pollution.

Table 2. Prevalence of special use areas in the office buildings studied in BASE.

Special Use Area	Prevalence
Kitchenette	93 %
Food Vending	90 %
Computer Room	87 %
Conference Room	75 %
Loading Dock	73 %
Print Shop	53 %
Commercial Kitchen	47 %
Parking Garage	37 %
Laboratory	34 %
Graphic Arts	25 %
Smoking Lounge	21 %

Table 3. Prevalence of renovations in the office buildings studied in BASE.

Renovation Activity	Total Prevalence	Past Renovation Prevalence	Continuous Renovation Prevalence
Painting	93 %	53 %	33 %
New Carpet	81 %	60 %	16 %
Partition/Wall Work	78 %	44 %	14 %
New Furniture	70 %	36 %	28 %
Roofing	33 %	27 %	3 %

Renovation activities were also noted and are listed in Table 3. Renovation work described in this table refers to both renovations occurring on a continuous basis and those that occurred in the past. The sum of past and continuous renovation rows for a given activity does not equal 100% because, for some buildings, no response was given for past or continuous renovation.

While not generally considered an indoor air pollutant, data on the water damage and leaks were collected because of their potential association with the presence of biocontaminants, especially mold. This information is presented in Table 4. Total prevalence relates to the number of buildings that had water damage or leaks. It does not relate directly to the sum of the location of damage or leaks because a building may have damage or leaks in multiple locations.

Table 4. Prevalence of office buildings that had water damage or leaks in the BASE building set and the location of the water damage and leaks.

	Total Prevalence	Basement	Roof	Mechanical Rooms	Occupied Space
Past Water Damage	85 %	28 %	50 %	17 %	71 %
Current Leaks	45 %	13 %	15 %	3 %	34 %

The number of buildings that have past water damage is, perhaps, not unexpected and may be related to the age of a building, with older buildings having more opportunity to develop water damage. However, the percentage of buildings with current leaks is less expected and has strong implications for guidance on building operations and maintenance, especially in view of the percentage occurring in occupied spaces. Overall, the percentage of buildings that have or have had problems with water suggests the need for building designers and product specifiers to address this issue.

Information was also collected on the prevalence of office cleaning and various types of cleaning activities and is presented in Table 5. This table also contains information about pesticide applications broken down according to whether the application is exterior to the building or within the building.

As illustrated by Table 5, overwhelmingly, most cleaning activities occur daily in office buildings. In contrast to pesticide applications outside of buildings, which typically either don't occur at all or only as needed, it appears that regular, monthly pesticide applications to building interiors (at 34%) is not unusual. This suggests that office building occupants' exposure to pesticides may be larger than previously thought.

Table 5. Prevalence and frequency of office cleaning and pesticide applications in the BASE building set.

Activity	None	As Needed	Daily	Weekly	Bi-weekly	Monthly	Less Frequent Than Monthly
Office Cleaning	0 %	3 %	89 %	4 %	1 %	1 %	1 %
Dry Mopping	23 %	4 %	70 %	3 %	0 %	0 %	0 %
Wet Mopping	0 %	3 %	86 %	8 %	1 %	2 %	0 %
Vacuuming	0 %	3 %	78 %	16 %	1 %	1 %	0 %
Exterior Pesticide Application	33 %	33 %	1 %	3 %	0 %	11 %	17%
Interior Pesticide Application	15 %	31 %	0 %	3 %	2 %	34 %	9 %

Table 6 provides further information about the prevalence and frequency of use of various types of cleaning materials. Not all cleaning materials used in these buildings are listed in this table. Some cleaning materials were recorded in the "Other" category and are not listed because they will require more extensive analysis. The high prevalence of use of various cleaning materials as listed in Table 6 suggests the need for emissions data on this source category.

Table 6. Prevalence of use of various cleaning materials in the BASE building set.

Bathroom Cleaner	Window Cleaner	Liquid Soap	Carpet Cleaner	Floor Wax	Furniture Cleaner	Bleach
93 %	84 %	77 %	73 %	60 %	60 %	33 %

Table 7 lists the prevalence of various material according to their storage location. Overall, it appears that storage of cleaning materials, pesticides and trash in occupied spaces is not common.

Table 7. Prevalence of building interior storage of cleaning materials, pesticides and trash in the BASE building set.

Stored Material	Occupied Space	Stairwell	Freight Elevator Lobby	Loading Dock	Janitorial Closet	Storage Room	Mechani-cal Room
Cleaning Materials	4 %	--	--	--	87 %	61 %	--
Pesticides	2 %	--	--	--	--	--	6 %
Interior Trash	2 %	1 %	5 %	28 %	--	--	–

CONCLUSIONS

Information on the prevalence of sources within office buildings has been collected by the BASE study. In addition, for some sources, information on the prevalence of sources by location in the building or the frequency of use for certain products was also collected. While many of the data confirm what has already been suspected regarding source prevalence, in some cases, the data present surprises, e.g., the prevalence of laboratories and print shops in office buildings or the high percentage of office buildings with current water leaks. Even in those cases when the data confirm what has been believed, the data will provide numerical inputs with a statistical basis for models used to estimate concentrations and exposure. In addition, the data also provide sound information for policy makers making decisions regarding which sources or aspects of building operations should receive attention, e.g., to determine emissions from the sources or to develop guidance on better management of sources. These data can also be used to test associations with other parameters measured in the study such as concentrations of pollutants or reported symptoms of building occupants.

ACKNOWLEDGMENTS

This study was supported by the U.S. Environmental Protection Agency (EPA) but was not subjected to U.S. EPA's formal peer review. The conclusions in this paper are those of the authors and are not necessarily those of the U.S. EPA.

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