A Data Base on the Sources
of Indoor Air Pollution Emissions

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ABSTRACT

The Indoor Air Branch (IAB) of EPA's Air and Energy Engineering Research Laboratory (AEERL) has been working during the past three years to develop a data base that covers the international technical literature on sources of indoor air pollution. This computerized system provides an archive for experimentally determined data from source characterization studies. It focuses on organic emissions and can provide pollutant profiles and emission rates for a variety of building materials and unvented combustion sources.

The operations of the data base can be divided into three segments: data query, data input, and data output. Data query is a user-friendly set of menu screens that allow the user to manipulate up to three variables to describe and locate a specific data need. Data input is accomplished through a set of similar screens by responding to menu-driven prompts. This feature allows the user to customize the data base for his or her personal data needs and can also facilitate the exchange of information between users. Data output is through screen displays or a printer interface.

The data base will be made available to the public in a version that is user friendly and does not require knowledge of a programming language.

An overview of the data base is presented, and its potential for use in the development of pollutant profiles and emission rate data will be demonstrated.

INTRODUCTION

Potentially high concentrations of pollutants in the indoor environment are often traceable to indoor sources. The effective mitigation of this problem involves identifying the sources, evaluating their emissions, and targeting the sources for a suitable control option. Informed decisions as to the best control option are predicated on the existence and availability of source characterization data.

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The Indoor Air Branch (IAB) of EPA's Air and Energy Engineering Research Laboratory (AEERL) has been working during the past three years to acquire emissions data and to develop a data base on the sources of indoor air pollution. The objective of this effort is an indoor air data base that focuses on organic emissions and would meet the following criteria:

1. able to satisfy the needs of a broad range of users

2. user friendly

3. easy to update and modify

4. readily accessible

The study of indoor air pollution is a relatively new area in which most of the research has occurred within the past six years. Unfortunately, the results of these experiments are not readily available to decision makers. This paper presents AEERL's effort to create an archive for the growing pool of indoor air source data and make it readily accessible.

HISTORY OF THE SOURCE DATA BASE EFFORT

AEERL's in-house effort to create an indoor air data base started in 1985 with the development of a conceptual design of a data base to archive available information on emission factors for indoor sources of air pollutants. The design phase was accompanied by a computerized literature search and the compilation of emissions data for the years 1979-1984, inclusive. The search targeted construction materials and combustion sources. This effort continued into 1986 with the development of a prototype data base entitled Indoor Air Source Emissions (IASE).

The data base consisted of five individual data bases arrayed in a hierarchial structure (Figure 1). This structure was designed to accommodate those circumstances in which a single journal article would report emissions data for a set of pollutants emanating from one or more material sources and evaluated over a range of conditions using different analytical methods (Table 1).
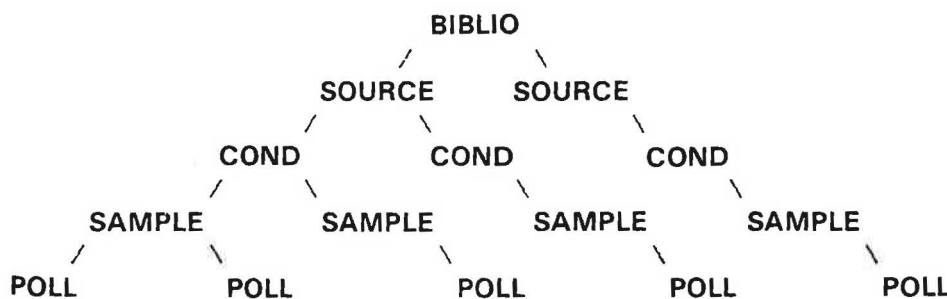

Figure 1   Data base structure

TABLE 1
Component Data Bases and Associated Data Fields for an Indoor Air Data Base

Bibliographic Data Base

Primary Citation
Abstract
Test Facility Category
Test Facility Description

Source Data Base

Category
Class
Type
Source Description

Conditions Data Base

Conditioning	Size of Material
Duration	Loading
Test Description	Fuel Rate
Operating Parameters	Fuel Consumption
Temperature	Fuel Value
Humidity	Quality Assurance Plan
Ventilation Rate	Other Conditions

Sample Data Base

Sample type
Sample Rate
Sample Duration
Sampling Method
Sample Size
Analytical Method
Detection Limit

Pollutant Data Base

Pollutant
CAS number
Time Taken
Measurement
Calculated Emissions
Comments

At the top of the hierarchy was a bibliographic data base that contained the primary citation for that article, an abstract, and any available descriptive data on the test facility data. The second level was the source data base, which housed a description of the source and any information on pretest treatment. The third level contained the conditions data base which included information on such test conditions as temperature, humidity, and ventilation rates. The sample data base was on the fourth level and included data on the sampling and analytical methods. Lastly, the pollutant data base provided a record for each pollutant detected, as well as data on, concentrations and emission rates.

In its finished form, the prototype contained 37 articles branching to cover 84 individual source records, more than 672 different test condition entries, and 1850 pollutant entries. This represented the total usable emissions data for the 1979-1984 period.

A DATA BASE OF INDOOR AIR POLLUTION SOURCES (dIAPS)

IASE was determined through peer review to be adequate, but it failed to satisfy all of the design criteria. In October 1986, AEERL entered into a cooperative agreement with a university's Department of Environmental Science and Engineering, to update the literature search, evaluate the data-processing problems, and modify the search algorithms, as needed, to meet the design criteria. The key constraint placed on the effort was that the finished product be operable from a desktop computer system.

The product of this cooperative effort, retitled a data base of Indoor Air Pollution Sources (dIAPS), is a great improvement over the original IASE data base. The new dIAPS was configured around the original five data base components of IASE; however, a major modification was made in how these data bases were accessed. The original IASE linking provided sequential access to each database component beginning at the top of the hierarchial array and searching to the bottom. The dIAPS system searches a target data base within the hierarchy and writes the matching record to a separate file. This file can be combined via logical operators with other similiar files in the case of multiple search parameters and the resulting data set is presented to the user through specially formatted screen displays.

This targeted access reduces the search time and provides a simultaneous display of the output data associated with each of the databases. This searching algorithm has reduced search time from nearly two hours to approximately 33 seconds for the most detailed search. The decrease in search time, coupled with a reduction in the data storage demands, has enhanced the accessibility of the data base on a desktop system.

The user-friendly criterion was met through the increased use of on-screen menus that do not require prior programming knowledge.

The user also has the ability to correct any keyboard entry error and can move through the program backwards to modify parameters and thus avoid restarting.

The criterion requiring the data base to satisfy a broad range of users was met through an improved data entry feature, which allows the user to enter new data into the existing structure via a prompted "fill-in-the-blank" data entry screen. The data entry feature includes user-definable fields, allowing the user to update the data base with his own work or that of his colleagues in a specific area of interest.

A Typical dIAPS Data Search

The content and capability of dIAPS is best demonstrated by going through a quick routine search. After the system is started, the first screen available to the user is a title screen that presents essential descriptive attributes. The main menu screen is next after the title screen. It offers the user four options: exit the system to DOS, update the data

base, initiate a search, or undertake some changes in program-related function. For the purpose of this paper we shall select the search option.

Selection of the search option brings up the search parameter selection menu (see Figure 2). From this screen, the user can target an area of the data base to search by typing the first letter of the labels highlighted on the left of the screen. Several additional program options are offered at the bottom of the screen, which include an on-line help feature, a return to the main menu screen feature, and the F10 key that initiates a search. The "Selections" box at the lower right of the screen indicates the parameters that have been selected for searching. Up to three search parameters can be designated and search on simultaneously.

SEARCH PARAMETERS SELECTION MENU

| GROUP |
| CATEGORY |
| MATERIAL |
| POLLUTANT |
| AUTHOR |
| JOURNAL |
| DATE PUB. |

< PROGRAM OPTIONS >
HELP   RETURN TO MAIN MENU

F10 SEARCH DATABASE

< SELECTIONS >
BENZALDEHYDE

Figure 2   Search parameter selection menu

For example, we shall select the "Pollutant" option. The selection of this option brings up a menu selection screen that is specific for pollutants (see Figure 3). This menu displays a listing of all of the pollutants available for search.

A pollutant selection from this screen is made by typing the number associated with the pollutant of choice. The system records the selection at the appropriate location in the logical structure and then routes the user back to the search parameter selection menu. The selection is displayed in the "Selections" box, and the user is queried for additional search parameters. The additional parameters can come from any of the highlighted listings (see Figure 2). For example, the user can search for the occurrence of one or more pollutants from a specific material, search for additional pollutants, or restrict the focus to a single entry.

After the parameters that limit the data query have been specified, the search is initiated by keying the F10 key. In response, dIAPS presents the user with the logic display screen and asks for a confirmation of both search parameters and the assigned search logic. At this point, the user has the option to reassign any parameter or initiate the search.

After the search is initiated, the computer keeps a running tally of the number and location of the records in each data base that match the search criteria. It compiles the

```
┌─────────────────────────────────────────────────┐
│  POLLUTANT                                        │
│  ┌──────────────────────────────────────PgUp┐    │
│  │                                           │    │
│  │  34: DECANEN-          44: HEPTANE, 1-    │    │
│  │  35: ETHANOL           45: HEPTANE, N-    │    │
│  │  36: ETHYLACETATE      46: HEXANE, N-     │    │
│  │  37: ETHYLBENZENE      47: HEXANOL, N-    │    │
│  │  38: FLUOROANTHENE     48: ISO-OCTANE     │    │
│  │  39: FORMALDEHYDE 2    49: KETONE, C5     │    │
│  │  40: FORMALDEHYDE1 4   50: KETONE, C5     │    │
│  │  41: FLUOROANTHENE     51: LIMONENE       │    │
│  │  42: FORMALDEHYDE      52: METHANE        │    │
│  │  43: FORMALDEHYDE      53: METHY-2-BUTANONE, 2 │
│  │                                           │    │
│  │                                      PgDn │    │
│  └───────────────────────────────────────────┘    │
│  ENTER THE NUMBER OF THE POLLUTANT OF INTEREST:   │
└─────────────────────────────────────────────────┘
```

Figure 3   Pollutant menu

in separate files, combines the files by the assigned logical operation, and displays the results in a series of summary screens.

The bibliographic display screen is the first screen up after the search is completed (see Figure 4). The first article that met the search criteria is displayed at the top of the screen and the user is presented a series of options for viewing the output. The user can request either the data for the highlighted article or the abstract, move at random through the list of articles, or return to the main menu screen.

If the user selects the data option, he is presented with a series of data summary screens. In addition to the targeted pollutant, data summary screen 1 displays each pollutant that is listed in the article along with the associated test conditions (see Figure 5). This provides the user an opportunity to review the contents of the article. The original search target is distinguished by a delta and can be selected by moving the highlight bar and keying the F10 key.

Data Summary Screen 2 provides a listing of source materials and measured emissions that correspond with the pollutant/condition selected from the previous data screen (see Figure 6). The user can position the highlight bar and further select data for the desired material.

The final set of screens are the data output screens. There are three of these screens, the first of which is shown in Figure 7. Each screen allows the user to page through associated test data, sampling information, and any comments or user-defined fields that are present.

Constraints on the Application of dIAPS Data

This computerized system is intended to provide an archive for experimentally determined data from source characterization studies. The data are generally developed through chamber studies, test house studies, and to a lesser extent, highly controlled field studies. Unfortunately, the world of indoor source characterization data is currently very small. The time interval between 1984 and 1986 only contained 12 articles that dealt with
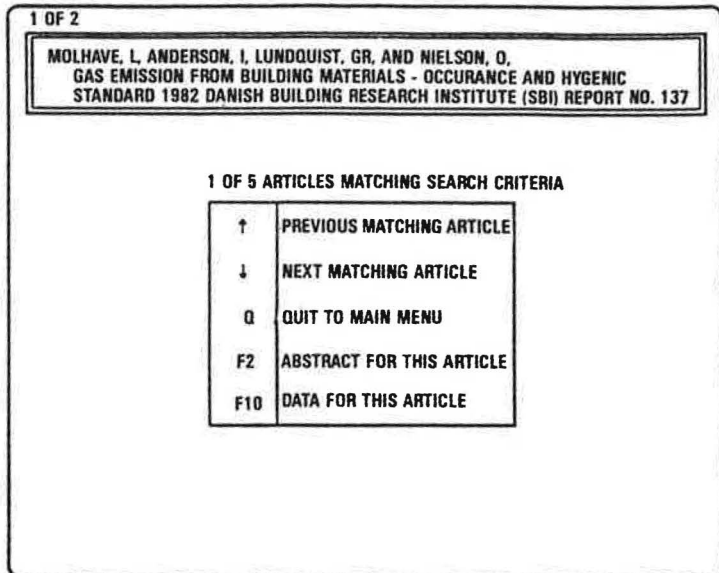
MOLHAVE, L, ANDERSON, I, LUNDQUIST, GR, AND NIELSON, O,
GAS EMISSION FROM BUILDING MATERIALS - OCCURANCE AND HYGENIC
STANDARD 1982 DANISH BUILDING RESEARCH INSTITUTE (SBI) REPORT NO. 137

1 OF 5 ARTICLES MATCHING SEARCH CRITERIA

↑	PREVIOUS MATCHING ARTICLE
↓	NEXT MATCHING ARTICLE
Q	QUIT TO MAIN MENU
F2	ABSTRACT FOR THIS ARTICLE
F10	DATA FOR THIS ARTICLE

Figure 4   Bibliography display screen

MOLHAVE, L, ANDERSON, I, LUNDQUIST, GR, AND NIELSON, O,
GAS EMISSION FROM BUILDING MATERIALS - OCCURANCE AND HYGENIC
STANDARD1982 DANISH BUILDING RESEARCH INSTITUTE (SBI) REPORT NO. 137

ALKANE	9	TEST CONDITIONS
ALKANE,c10-	7	TEST CONDITIONS
ALKANE,c7/c13	1	TEST CONDITIONS
ALKANE,c8-	2	TEST CONDITIONS
ALKANE,c8/c10-	1	TEST CONDITIONS
ALKANE,c9-	41	TEST CONDITIONS
AMINES	1	TEST CONDITIONS
BENZALDEHYDE	1	TEST CONDITIONS
BENZENE,c3-	11	TEST CONDITIONS
BENZENE,c4-	5	TEST CONDITIONS

↑↓ MOVE CURSOR BAR   F10 SELECT ITEM
R   SELECT ANOTHER REFERNECE ARTICLE

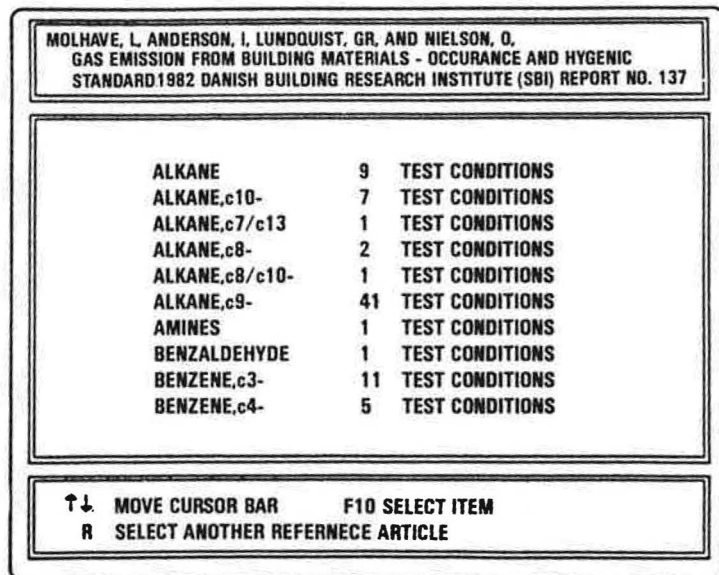Figure 5   Data summary screen one

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<<<POLLUTANT = AMINES>>>

MATERIAL                      MEASURED EMISSION

VINYL COATED WALLPAPER        NOT DETECTED
FLOOR VARNISH                 NOT DETECTED
PLYWOOD                       NOT DETECTED
CHIPBOARD                     3 ppm
CAULKING COMPOUNDS            NOT DETECTED
NEEDLE FELT                   NOT DETECTED
INSULATION SHEETS             NOT DETECTED
FLOOR/WALL COVERING           NOT DETECTED
CALCIUM SILICATE SHEET        NOT DETECTED
WALL COVERING                 NOT DETECTED
INSULATION FOAM               NOT DETECTED
JOINTING COMPOUND             NOT DETECTED
NEEDLE FELT                   NOT DETECTED
LINOLEUM FLOOR COVERING       NOT DETECTED
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Figure 6   Data summary screen two

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MOLHAVE, L, ANDERSON, I, LUNDQUIST, GR, AND NIELSON, O,
    GAS EMISSION FROM BUILDING MATERIALS - OCCURANCE AND HYGENIC STANDARD
    1982 DANISH BUILDING RESEARCH INSTITUTE (SBI) REPORT NO. 137

0.06 mg/m3  BENZALDEHYDE


        TEST DATA

        MEASURED EMISSION: 0.06 mg/m3
        DESCRIPTION: MEASUREMENTS MADE AT EQUILIBRIUM: 140 HRS.
        DURATION: ns

        MATERIAL: FIBERBOARD
        MATL. PRE-CONDITIONING: ns
        OPERATING PARAMETERS ns
        ROOM/CHAMBER VOLUME 1.8 CUBIC METER
        VENTILATION RATE: 0.69 1 pm +/- 5%

        TEMP (C) 21.1 +/- 1.7
        HUMIDITY (%RH) 40-45%



DATA SCREEN: 1 2 3

◄ MORE  PgDn NEW MATERIAL PgUp Prev Material  R RETURN  Q QUIT dIAPS
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Figure 7   Data output screen one

source characterization (see Table 2). The relatively small amount of data on a given source reduces the confidence that a user can place in the accuracy of the data.

Furthermore, the data that are available suffer from the absence of standardized protocols or quality assurance. For a given source, the literature can contain a wide range of test methods, test conditions, sample collecting techniques, and analytical equipment. This is compounded by a general lack of clear descriptions of all the variables and phenomena involved in a derivation of specific emission rate.

As a consequence of this variability in approach to indoor air measurements, one can expect difficulty in comparing the data between researchers for a single source. Use of dIAPS should, therefore, include an element of caution. Awareness of the limitations must be coupled to sound technical judgment as a condition of use.

TABLE 2
EPA Literature Search for Indoor Sources (1984-1986)

On-line Abstracts	# Articles found in Search	# Reviewed	# Selected
Biological	428	89	33
Chemical	52	9	1
Environmental	309	50	17
NTIS	272	18	7
Total	1061	166	58
Total Entered into dIAPS = 12			

Potential Applications of dIAPS

If used appropriately, dIAPS can become an extremely useful tool for decision-making. It can provide the user with a sense of the kinds of compounds and their emission factors that can be anticipated from a specific source (see Table 3). In this case, a caulking compound can be seen to have a complex emissions profile.

The data base can also be used to determine the sources that may contribute to the total exposure to a specific pollutant. Formaldehyde, for example, is known to be emitted from presswood products. However, there are other potential indoor sources whose emissions, when combined, can have a significant impact on indoor formaldehyde levels (see Table 4).

Solvent-based materials are the most common source of organic emissions to the indoor environment. A listing of the most commonly occurring solvents were reported by Tichneor and Mason (1987). An interesting application of dIAPS is in the examination of the pollutant/source relationship to identify specific sources and emissions for those organics most commonly reported in the indoor air (see Table 5). Note in this table that only approximately 40% of the typically occurring organics have associated emissions factors. This is indicative of source characterization research needs.

The dIAPS can provide insight into the behavior of emission sources. For example environmental chamber studies of formaldehyde released from presswood have shown a strong dependence on temperature and conditioning. One study contained in dIAPS, however, goes further to describe an experiment in which particle board was paired with plywood, insulation, and carpet (Pickrell et al. 1984). In this study, the formaldehyde release was less than the sum when each product was tested independently. These data

TABLE 3
Organic Constituents of Caulking Compound

Compound	Emission factor $(mg/m^2 \cdot h)$
c-10 alkane	1.23
c4-alcohol	<0.01
n-decane	6.82
n-undecane	<0.01
toluene	0.02
ethylbenzene	7.32
2-xylene	1.02
3-xylene	2.77
4-xylene	24.20

TABLE 4
Potential Indoor Sources of Formaldehyde

Particle board	Plywood	Paneling
New Clothing	Ceiling Panels	Air Ducts
Fiberglass	Insulation	Drapery Fabric
Upholstery Fabric	Latex Backing	Blend Fabric
Carpet	Vinyl-Coated Wallpaper	Linoleum Floor Covering
Adhesives	Floor Lacquer	Floor Varnish
Laminated Plastics	Gypsum Board	Unvented/Leaking Combustion Sources

suggested that samples of plywood, insulation, or carpet can act as a sink for the higher emitting particle board. The presence of this sink effect and its overall impact on the emission profile for a source have been borne out in AEERL's small chamber research.

The data base can also provide information from which to evaluate control options. For example, field and chamber studies reported in one paper contained in dIAPS indicate that the ASHRAE ventilation rates may not adequately control exposure to environmental tobacco smoke. The author concludes that the separation of smokers and nonsmokers is more effective in achieving major reduction in exposure to tobacco smoke than the more expensive increases in ventilation (Repace and Lowery 1982).

In a more qualitative sense, the availability of emission factors, coupled with a knowledge of the amount of material used in a building, and estimates of the air exchange and rates, can be used to estimate indoor concentration from a given source.

A case in point involves a suggestion from ASHRAE IAQ '86 that it would be prudent to avoid, where possible, materials that create indoor concentrations of organics greater than $1000\ ug/m^3$ for more than a few days or weeks (Tucker 1986). If one assumes a space 10 ft $\times$ 10 ft $\times$ 8 ft and an air exchange rate of 0.4 ach for a residence or 1.25 ach for a commercial building, this can be translated into an emission rate for organics

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TABLE 5
Potential Sources and Associated Emission Factors for Solvent-Based Organic Compounds Typically Found in Indoor Air

Class[a]	Source[b]	Emission Factors[b] $(mg/m^2 \cdot h)$
N-alkanes		
nonane	wallpaper	<0.01
	floorcovering	0.06-0.12
	adhesive	0.25
	jointing compound	0.01
	cement flagstone	<0.01
	chipboard	<0.01
decane	wallpaper	0.02
undecane	chipboard	<0.01
	caulking compound	<0.01
	needle felt	<0.01-0.01
	wallpaper	0.03
	adhesive	0.10
	jointing compound	0.07
	floor varnish	0.28
	wall covering	<0.01-0.15
	cement flagstone	<0.01
	gypsum board	<0.01
Iso-alkanes		
iso-octane	floor covering	0.08
	floor varnish	0.03
iso-nonane		
isodecane		
cycloalkanes		
cyclohexane	floor covering	0.03
Aromatics		
benzene		
toluene	solvent-based adhesive	0.006-0.055
	water-based adhesive	0.75
	calcium silicate sheet	<0.01
	caulking compounds	0.02
	needle felt	<0.01-0.02
	vinyl-coated wallpaper	<0.01
	wallpaper	<0.01-0.05
	linoleum floor covering	0.11
	jointing compound	0.02-0.04
	wall covering	<0.01
	floor covering	0.04-0.16
	edge seal molding tape	<0.01
	paint	0.15
	floor lacquer	0.31
	chipboard	<0.01

(a) Tichneor and Mason 1987

(b) Database of indoor air pollution sources

xylene (3 isomers)	caulking compound	0.01-24.2
	needle felt	<0.01
	wallpaper	<0.01-0.02
	adhesive	<0.01-67.35
	jointing compounds	0.03-0.08
	floor covering	<0.01-0.04
	floor lacquer	0.11-0.53
	floor/wall covering	<0.01-0.02
	vinyl-coated wallpaper	<0.01
	linoleum floor covering	<0.01
trimethlybenzene	caulking compounds	<0.01
	needle felt	<0.01
	vinyl-coated wallpaper	<0.01
	wallpaper	<0.01-0.01
	linoleum floor covering	<0.01
	adhesive	0.12
	jointing compound	<0.1
	floor varnish	<0.05
	cement flagstone	<0.01
	chipboard	<0.01

Ketones
  acetone
  methyl ethyl ketone

Alcohols

n-propanol	chipboard	<0.01-0.01
isopropanol		
n-butanol	jointing compounds	7.26
	edge sealing molding tape	<0.01
	floor lacquer	0.76
	cement flagstone	0.04

Esters
  ethylacetate
  butylacetate

Aldehydes
  pentanal
  hexanal

Terpenes

Generic	adhesive	<0.01-23.9
	jointing compound	<0.01
	chipboard	<0.01
limonene	adhesive	0.19
	paint	0.05

Chlorinated Compounds
  carbon tetrachloride
  dichloromethane
  trichloroethane
  dichloroethylene
  trichloroethylene
  tetrachloroethylene

TABLE 8
Typical Total Vapor Phase Emissions for Selected Building Materials
That Can Generate Concentrations Greater Than 1000 ug/m³

Material	Compound	Emission Factor (mg/m² · h)
Floor Covering	VOC	7.4
Floor Varnish	VOC	1.3
Floor Lacquer	VOC	4.1
Insulation Foam	VOC	2.3

CONCLUSIONS

Potential sources of indoor air pollution are numerous and variable. Unfortunately, at this time, emissions data from sources are limited. The most recent literature search was intensive but only added 12 new articles to the dIAPS bibliography. However, the datapool is growing and could benefit from some early organization to increase its usefulness to the general public.

The dIAPS represents a response to the complex picture of indoor air pollutant sources. It is a flexible data storage/data retrieval system that can be molded to an individual user's need. It is intended to be an archive for quantitative data derived from the technical literature and individual research efforts. It can also be used as a source of qualitative information including, for example, user-loaded Material Safety Data Sheet information.

This tool, when combined with sound technical judgments, can aid professionals in the evaluation of indoor pollutant sources and in the selection of appropriate alternative responses.

REFERENCES

Pickrell, J.A.; L.C. Griffis; B.V. Mokler; G.M. Knapilly; and C.H. Hobbs. 1984. "Formaldehyde release from selected consumer products: Influence of chamber loading, multiple products, relative humidity, and temperature." 1 Environmental Science and Technology.

Repace, J.L., and A.H. Lowery. 1982. "Tobacco smoke, ventilation, and indoor air quality." *ASHRAE Transactions,* Vol. 88, Pt. 1, pp. 895-914.

Tichneor, B.J., and M.A. Mason, 1987. "Organic emissions from consumer products to the indoor environment." Presented at the 80th Annual Meeting of APCA, New York, June 21-26.

Tucker, W.G., 1986. "Research overview: sources of indoor air pollutants." IAQ '86, Managing indoor air for health and energy conservation. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

DISCUSSION

M. Kuzyk, Canadian Auto Workers, Willowdale, Ontario: We at the Canadian Centre for Occupational Health and Safety have a similar data base which is available to the public at no charge.

D. Chow, State of Washington, Everett: Is the EPA considering setup of retrievable data bases that users can access through telecommunications?

J.B. White: We have no intentions now to put dIAPS on the mainframe or provide a telecommunications interface.

J.C. Dionne, IRSST, Montreal, Quebec: Do you have a standard protocol for the entry in the data base? Is it possible to get from your data bank some extracts utilizing not the source but the type of building (e.g., school, hospital).

White: Yes. The data base includes a user prompted data loading routine.

J. Muchow, E.L. Foust Co., Elmhurst, IL: Is there a matching data base or information source for specific sensitivity and toxicity levels?

White: No.

S. Khandefar, Engineering Interface, Willowdale, Ontario: Do you propose to expand the data base to include health effects, recommended levels, and measurement techniques?

White: Measurement techniques are included already. Health effects are beyond the scope of our laboratory.

D.T. Grimsrud, Lawrence Berkeley (CA) Laboratory: How will data base updates be merged with data that has been entered by the user?

White: We will handle that in house. The exact process is yet to be determined.

M.A. Berry, US Environmental Protection Agency, Research Triangle Park, NC: EPA is beginning to table concentration of gas phase organics and their effects odor threshold, eye and skin irritation, etc. EPA will work to integrate the source emission data base, indoor air models, and health effects projections.