National Expenditures for IAQ Problem Prevention or Mitigation

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LBNL-58694

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June 2005

Prepared for
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Office of Radiation and Indoor Air
U. S. Environmental Protection Agency

In fulfillment of
Interagency Agreement EPA-DW-89-93988901

Acknowledgements

This work was supported by the Indoor Environment Division, Office of Air and Radiation, U.S. Environmental Protection Agency under InterAgency Agreement DW-89-93988901, through the U.S Department of Energy under Contract No. DE-AC02-05CH11231. The author thanks Ed Vine, Jed Waldman, William J. Fisk, and David Mudarri for their helpful comments on various drafts. The author also thanks Eugena Bendy and Shela Ray for their work in obtaining some of the data used in the report and to the many professionals who gave generously of their time to provide valuable insights and information.

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1.0 PURPOSE AND SCOPE

The objectives of this study were to develop an initial semi-quantitative estimate of costs of indoor air quality problem prevention, mitigation, and remediation activities in U.S. buildings and to provide useful information for a more comprehensive and accurate survey. This is intended to be more of a map of the territory rather than a precise cost estimate.

2.0 METHODS

Major sources of data were interviews, peer reviewed publications, summary reports of market studies, consultant and laboratory cost data obtained directly or available on the web, or from other published sources.

Key informants were contacted to identify important elements of the costs and useful contacts for further follow-up. One of the purposes of these interviews was to obtain information for the definition of IAQ mitigation and remediation. Literature and web resources were accessed, and lists of consultants and laboratories were used to place phone calls and send emails requesting cost information and IAQ mitigation and remediation-related services revenues.

Data obtained from interviews, emails, price lists, and web sites were entered into spreadsheet files to facilitate computation and comparison. In some cases, totals could be calculated. Approximately 45 laboratories and 40 consultants were contacted. Additionally, professional and trade associations were contacted to obtain overviews of their members' services, numbers, and revenues. The budgetary limitations of this project prohibited a systematic sample design and data collection process.

2.1 Data Collection

Interviews with Knowledgeable Personnel

The initial source of information for this study was obtained from key personnel in various IAQ market segments, such as IAQ mitigation firms and laboratories, trade associations, insurance companies, and manufacturers. These individuals were contacted and interviewed. This data was supplemented with information in the literature and on the web.

Key personnel to be interviewed were identified from the following sources.

IAQ Consultants and Mitigation Firms

- AIHA Consultant list and their online consultant search tool accessed at http://www.aiha.org/ConsultantsConsumers/html/consultantsclient.asp. This search engine allows the user to select firms by specialty and state. The majority of the consultants and mitigation firms contacted and subsequently interviewed were selected from this list.

- Indoor Air 2002 Conference Registration list. The list was scanned for potential interview candidates. Although the largest fraction of participants represented academic and research institutions, a small fraction of the interviewees were obtained from the list.

- *Indoor Air BULLETIN* subscriber list.

- California Department of Health Services' Listing of IAQ Consultants. In order to avoid unbalanced representation of California firms, some non-California firms were also chosen from this list.

IAQ Laboratories

- Laboratories providing IAQ-related services on lists published by the California Department of Health Services and the American Industrial Hygiene Association as well as those advertising in newsletter and other industry publications.

- Literature received in the mail. Occasionally brochures and literature in the author's files were received from various IAQ firms. Whenever a firm's literature was on hand, it was added to the list. The majority of such available information was from laboratories.

Other Contacts

- Executive directors or other key individuals of IAQ trade associations, standard setting organizations, insurance companies, and government officials.

- Personal contacts of the author

The major sources of information were the following:

- Key informants were identified and contacted by phone, email, or in-person to discuss the project and to obtain suggestions for the best ways to obtain the desired information. Additionally, these informants were asked for suggestions of other individuals as well as to provide rough estimates of major segments of the IAQ mitigation market.
- IAQ consultants were contacted and asked for information about the normal professional fees for various types of activities.
- Laboratories performing commercial analysis of indoor air samples (including microbial, chemical, and particle) were contacted and key informants were interviewed; company web sites were examined where available; price lists were obtained for various types of sample analysis.
- Interviews were conducted with key informants from organizations with significant or dominant roles in establishing standards for IAQ and for developing guidance for investigation, diagnosis, and remediation of IAQ problems.
- Specific individuals with demonstrated knowledge were contacted to discuss aspects of the study, inquire about potential resources to acquire missing information, or discuss IAQ questions.
- Associations were contacted to request information on the represented industry.

IAQ consultants, mitigation firms, and laboratories known to be active in the field and with whom the investigators had prior contact were interviewed first to assess the scope of the field and the potential for obtaining cost data at an individual firm level and also at the level of a profession or association. This was followed by interviews with individuals identified though other sources. During each interview, individuals were asked for suggestions of other contacts that might be good sources for the information being sought. These suggested contacts were also contacted, interviewed if they were available, and asked for suggestions of other contacts. Ultimately, approximately 150 people were interviewed, 130 of whom provided useful information.

Extended follow-up interviews were carried out with individuals who expressed a willingness to be interviewed in depth. Approximately 20 such interviews were conducted, on several occasions with follow-up email correspondence.

When information was identified as potentially important in terms of costs but not available from other sources, key informants were contacted again for assistance. Many of these individuals spent considerable time offering their knowledge and opinions on critical subjects. Approximately 10 individuals contributed at this phase of the project. These individuals included consultants, laboratory staff, and trade association staff executives.

Building Data

Department of Commerce and Department of Energy data were consulted for building data. The majority of the building data were taken from the August 2004 version of the *Building Energy Databook*, (DOE. 2004).

2.2 Analysis of Data

In order to attribute the expenditures of building designers, contractors, owners, and occupants to "IAQ problem prevention or mitigation," it is necessary to establish the boundary between building-associated expenditures that are considered to be "standard practice" and those that are specifically incurred to avoid or solve IAQ problems. For the purposes of this study, such expenditures were defined as follows:

> Expenditures that are attributable to IAQ problem prevention or mitigation are those that are incurred primarily to avoid or mitigate IAQ problems, and that were not considered standard practice prior to the early 1970's, when IAQ first started to be recognized as a national concern.[1]

[1] The early 1970's in the United States is the historical "baseline" at a point before IAQ was recognized even by advanced researchers as a significant factor in occupant health and well being or in the proper functioning and life of buildings and their contents. In the mid-1970s, EPA funded two projects demonstrating some recognition of the emergence of IAQ. These projects, both performed by GEOMET, included a review of indoor air standards and guidelines at all levels of government in the US and a review of IAQ research. At the same time, some of the Department of Energy's (DOE's) laboratories began investigating IAQ and publishing reports on the findings. ASHRAE changed the name of its ventilation standard to include the term "Indoor

Ultimately, the author's judgment informed by discussions with experts and available data led to the list of expenditure categories shown in Table 2-1

Table 2-1. Expenditure Categories for IAQ Problem Prevention of Mitigation

Consultant Services for IAQ problem investigation, diagnosis, and resolution
Building remediation for IAQ
Laboratory Services pertaining to IAQ diagnostics or related aspects of building design
Emission Testing for certification/labeling
Air Duct Cleaning
Purchase and use of improved filtration
IAQ Litigation and Insurance
Radon Mitigation and Prevention
Asbestos and lead abatement

Many expenditures that could fall within the definition were not included in this analysis because of the difficulty in establishing viable estimates. These include:

- Significant reduction in source strengths of pollutants through product modifications. [Note: in many cases, such modifications may have been driven by requirements of the Clean Air Act for outdoor air, rather than indoor air quality protection (Hodgson and Levin, 2003)];
- Design, construction, and operating costs for meeting the improved standards and guidance for ventilation system design, construction and operation (ASHRAE, 1989; 2001, 2004);
- The elimination or restriction of smoking in public access buildings (Repace, 2004; California law; 1994; Delaware law, 2002);
- Costs of building managers and operating personnel to investigate and address complaints related to indoor air quality,
- IAQ training courses and seminars; and,
- Development of IAQ standards and guidelines and implementation of IAQ programs.

Cost data were converted to 2003 dollars using the Department of Labor's Consumer Price Index, where such conversions would substantively affect the results, after rounding (BLS, 2005). Some data sources that were used are not identified due to requirements by the sources for confidentiality.

Air Quality" in 1981, changing it from ASHRAE Standard 62-1973 "Standards for Natural and Mechanical Ventilation" to Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality." This latter title remains through the current version, Standard 62-2004.

3.0 RESULTS

The results presented in this report are summarized in Table 3-1. The estimate of annual expenditures for IAQ prevention and mitigation is approximately $15.9 billion (in 2003 dollars) considering the cost items for which estimates were prepared. These estimates may be considered conservative because many IAQ-related expenditures are not included due to the difficulty of obtaining reliable data, but these excluded expenditures are likely to be substantial. Considering the great uncertainties, and the approximate nature of this estimate, it is more appropriate to consider a range of $12 - $20 billion annually which represents plus or minus ~25% of the central estimate.

Among the major components accounting for the central estimate of expenditures are

- Asbestos and lead abatement of approximately $4 billion annually
- Duct cleaning of approximately $4 billion annually
- Commercial building remediation (includes mold) of approximately $3.4 billion annually
- IAQ consultants services of approximately $2.1 billion annually, and
- Air cleaning and improved filtration of approximately $1.5 billion annually

Table 3-1. Annual National Expenditure Estimates for IAQ ($ billion)

Activity	Estimate	Factors Included	Basis for Estimate
Consultant Services for IAQ problem investigation, diagnosis, and resolution	$2.1	Includes consultant investigations and diagnostic services. Does not include in-house diagnostic services or in-house response to or resolution of complaints.	Based on FMI-NEMI (2002) data for commercial buildings and Benda (2002) data for residential buildings normalized to the NEMI/Benda ratio for commercial buildings.
Laboratory Services	$0.1	Testing of mold, lead, asbestos, and VOCs.	Based on disparate information from individual labs and other reports.
Building Remediation for IAQ	$3.4	Covers mostly remediation of HVAC (repair and upgrade of controls, ventilation, filtration system,) and contaminant removal	Based on commercial, institutional, and multifamily residential data in FMI-NEMI (2002). Duct cleaning and residential remediation expenditures were excluded.
Duct Cleaning	$4.0	Residential and commercial	Based on National Air Duct Cleaning Association data
Air cleaning and improved filtration	$1.5	Includes sales of residential units, and annual expenditures to operate residential and commercial.	Based on reports of sales from major manufacturers and AHAM (2005). Operating expenses were independently estimated.
Expenditures for certification or labeling	$0.1	Both testing and certification expenditures	Based on information from major certification programs.
IAQ Litigation and Insurance	$0.5	All litigation and insurance claim payments	Information on settlements found through web searches, and data from Benda (2002, 2004). A gross adjustment was made to try and exclude those payments that may have been used for mitigation and remediation accounted for elsewhere.
Radon Mitigation and Prevention	$0.2	Radon testing, mitigation, and radon resistant new construction	Annualized cost data provided by EPA and that is used to calculate costs and benefits of radon mitigation and prevention.
Asbestos and lead abatement	$4.0	Residential and commercial for asbestos, residential for lead.	Disparate information on asbestos abatement, plus EPA(1979) and HUD (2004) reports for lead .
Total Annual Expenditures for IAQ*	**Approximately $15.9 .billion ($12-20) billion**		

* Considering the large uncertainties and approximate nature of the estimates, a range of $12 to $20 billion is considered most useful. It represents roughly ± 25% around the central approximate estimate of $15.9 billion.

4.0 DISCUSSION

This section of the report contains commentary on the estimates in Table 3-1.

4.1 Consulting Services for IAQ Problem Investigation, Diagnosis, and Resolution

Information received from consultants varied as to the basis for annual costs. In some cases, firms were willing to simply state the total annual revenues. In other cases, they were willing to state their charges for services on an hourly or daily basis or for a typical range of services including surveys and investigations.

Three reports estimating the total market were available. These three estimates, shown in Table 4.1, resulted in reasonably consistent totals although they did not use consistent categories, and they did not all address exactly the same market segments.

Table 4.1. Selected Estimates of the Cost of IAQ Mitigation in the US ($ millions)

Source: Sector:	BCC (2004)[1]	Benda (2002)[2]	NEMI (2004)[3]
Consumer		2,400	
Residential		1,200	
Commercial		1,600	
Investigations			1,200
Remediation			5,500
Equipment	3,527		
Consulting/Testing Services	1,027		
Environmental Services	1,575.6		
Total IAQ Services	6,666	5,200	6,700

(1) Values for 2004 extrapolated from figures reported for 2003. Source: Business Communications Inc., 2004, Press release: ` Business Communications Company, INC., 25 Van Zant Street, Norwalk, CT 06855, Telephone: 203 853-4266. http://www.bccresearch.com/environ/E091.html

(2) Benda, George. 2004. *"Briefing 2004: emerging opportunities in IAQ."* Chelsea Group, Ltd. Maunaloa, HI.

(3). FMI, 2002. NEMI Indoor Air Quality (IAQ) Market Research, June 2002. National Energy Management Institute. Note that NEMI data exclude the "residential" sector but do include the "industrial" sector.

These total estimates from the three reports are all within the same general magnitude although the categories and apparent coverage differ. For the purposes of this report, we used the NEMI data as the center point for our estimate since it most cleanly fit into the categories for this report, and then made adjustments to include some information from the Benda report.

None of the BCC data was used for this report because of disparities between BCC estimates and other information. Consultants from three large national firms estimated remediation costs at about three to ten times consultant costs, and this was confirmed by several smaller IAQ consulting firms. Since the values in the BCC report are in considerable disagreement with the responses from consultants, the BCC estimates were not used. However, the BCC report is instructive because it estimates a substantial growth potential in the market for environmental services.

The NEMI data for investigations was used for commercial consultant services. The Benda data for residential was used for the residential consulting services, but it was first normalized to the NEMI baseline by multiplying the Benda data for residential services by the NEMI/Benda ratio in the commercial market. The resulting estimate is therefore $1,200 million for commercial consultant services, and $900 million for residential consultant services, or $2.1 billion for both commercial and residential.

4.2 Laboratory Services

Total laboratory expenditures are estimated based on individual estimates for mold, bacteria, asbestos and lead, and VOC testing. These analyses suggest a total expenditure of approximately $100 million per year.

Mold
Mold sample analysis costs range from $18 to $225 per sample, according to price lists received from the laboratories themselves. For PCR analysis costs were quoted as high as $380 per sample. The mold analysis and abatement peak seems to have occurred in 2002, according to consultants and laboratories alike. According to one inside source, the 3 largest US labs alone did about $50 million in mold analysis in 2002, but this was off 20% in 2003 and another 30 - 40% in 2004, bringing the current annual volume to around $20 - $28 million for mold for these three labs alone. Other labs may be doing as much as $20 to $30 million in mold analyses. Based on the available data, the cost of mold analysis is estimated at $50 million per year.

Bacteria
While there are other very important airborne bacterial respiratory illnesses, Legionnaire's Disease dominates the illnesses of concern due to contaminants in indoor air and sampling and analysis of *Legionella sp.* from cooling tower water dominates the laboratory analysis of bacteria related to indoor air quality control. No costs are available for other bacteria.

Certainly an important known bacterium in indoor air, *Legionella* analysis is likely to continue and perhaps even increase in the future due to its potentially fatal effects. When cooling tower water spray drifts into air intakes and is distributed in a building, there is a potential for infection and pneumonia or Pontiac fever. Prices for analysis range from $85 to $140 per sample.

There exists a wide range of practices related to the frequency of *Legionella* sampling and analysis. In Atlanta, home of the Centers for Disease Control, it is uncommon to find a high-rise office building or hotel without regular (annual or semi-annual) sampling and analysis as well as inspections and cleaning where necessary. Discussions with personnel at the two main laboratories in Atlanta suggest that annual expenditures for the region could be in the $5-10 million range. But Atlanta does not appear to be typical. The Centers for Disease Control has not recommended routine testing, and in general, only large buildings are regularly testing for *Legionella*, and among those, some are only doing so once a year, at most.

Given these considerations, it is conservatively estimated that annual expenditures for Legionella testing is approximately $20 million annually.

Asbestos and Lead Analysis

Data were not obtained that would allow a reasonably good estimate of annual laboratory costs for asbestos and lead sample analysis. Data were obtained for some individual analyses from more than forty labs. However, not all of them are providing all analytical services.

Costs for analysis of asbestos and lead samples reported by laboratories that perform the services vary by lab and by the details of the analysis being performed. For example, asbestos analysis can range from as low as $5.50 to as high as $250 per sample, while lead analyses range from $6 to $69 per sample.

A large firm is reportedly doing $3 million /yr in lead analysis for HUD to assess the entire house. This is reportedly a 3 to 5 year contract. One laboratory reported $450,000 in lead testing and $1.43 million in asbestos testing. Two other labs reported approximately $1.5 million per year in asbestos testing revenues. About half the labs contacted provided total revenue figures or details from which totals could be computed. .From this information, a conservative national estimate from all labs of $20 million per year appears reasonable.

VOCs, Particles, Pesticides and other SVOCs

Individual laboratories reported doing upwards of $1 million in VOC analysis, but we do not know how many labs are doing such significant volumes of analysis. Many labs that do indoor air VOCs are not primarily indoor air laboratories, and some of the data obtained may not be accurate. The situation is similar for particle analysis, pesticides, and other SVOCs. Clearly there is a lot of activity in these areas, but estimate of the magnitude is not practical with the available data. We assume that such expenditures are at least $10 million annually.

Thus, summing the estimates provided above, total annual expenditures for laboratory analysis are estimated to be approximately $100 million ($0.1 billion).

4.3 Building Remediation for IAQ

Details of the NEMI data for the remediation services are provided in Table 4.2

Table 4.2. Market for remediation. (millions of Current $)

Remediation	% of Market	Value
Controls	5%	$275
Reduce/ remove contaminant	10%	$550
Improve ventilation	15%	$825
Improve air filtration	10%	$550
Clean duct work	25%	$1,375
HVAC repair/ replace	25%	$1,375
Seal or cover duct work	10%	$550
Total	**100%**	**$ 5,500**

(source: FMI-NEMI, 2002. "Exhibit 14: Estimated Market Size for IAQ Remediation")

For the purposes of this report, the NEMI estimate for duct cleaning is subtracted from the NEMI total for remediation because duct cleaning is covered as a separate category. In addition, the portions of these estimates that relate to industrial were also removed. The industrial values are not considered within the scope of this report. Thus, the modified results are provided in Table 4.3

Table 4.3. Details of Remediation Expenditures – (Millions of 2002 $)

Remediation	Commercial	Institutional	Multi-family Residential	Total
Controls	113	75	31	219
Reduce/ remove contaminant	226	151	62	439
Improve ventilation	340	226	93	659
Improve air filtration	226	151	62	439
HVAC repair/ replace	566	377	156	1099
Seal or cover duct work	226	151	62	439
Total (2002 $)	1697	1131	466	3294
Total (2003 $)	1736	1157	477	3369

(adapted from NEMI 2002)

Thus, annual expenditures for IAQ remediation in 2003 $ are therefore approximately $1.7 billion for commercial, $1.2 billion for institutional, and $0.5 billion for multi-family residential for a total annual expenditure of approximately $3.4 billion.. Estimates for single family residential are not available from NEMI and are not included in Table 3-1.

4.4 Air Duct Cleaning:

The National Air Duct Cleaners Association reported members experience for the first 8 months of the year 2004 based on responses from 41 of its 600 members. NADCA officials estimate the total number of duct cleaning companies in the United States at 4,000 to 5,000. The results presented here were calculated from the NADCA data. The proportion of NADCA members on whom the data were based was used to extrapolate to national totals by assuming that the NADCA sources were representative of the entire population but using the lower number provided by NADCA as an estimate of the total number of duct cleaning companies. The estimated annual expenditures for residential and commercial air duct cleaning are provided in Table 4.4.

Table 4.4. Duct Cleaning (2003 $ million)

	U.S. total #	U.S total $ millions
Residential	2,168,694	$1,001.3
Commercial	670,329	$3,000.1
Total	2.8 million	$4,001

The total revenues for both residential and commercial duct cleaning are estimated to be approximately $4 billion per year.

4.5 Air Cleaning and Filtration

Sales of Residential Air Cleaners

The estimate of annual expenditures for this general category are pieced together from an amalgam of different sources. The estimate represents expenditures for air cleaners, filter replacements, and operational costs. It includes both portable stand alone units, as well as whole house units.

The market for portable air cleaners has shown exceptional growth over the past several years, and reflects, in part, a shift in the proportion of all air cleaning units toward the portable market (Fredonia, 2004). The shift toward portable units appears even more dramatic since that report, spurred by Sharper Image's entry in the market with its Ionic Breeze. Sales of Ionic Breeze reportedly exceeded $330 million in 2003 and accounted for more than half the company's total revenue. The unit costs just under $350 (retail) when purchased through the company web site. The company has announced two new "professional" models that sell for $400 and $500 each through the web site (http://www.sharperimage.com/). Customers can obtain a second unit for 50% of the cost of a single unit, so it is likely that more than a million units were sold in 2003.

Alpine Industries is a privately held, multi-level marketing plan that claims to have between 75,000 and 100,000 active dealers nationwide (FTC, 2002). The flagship product of Alpine Industries (also known as Living Air) is the XL-15, which sells for approximately $550 per unit. Other products sell for $400 to $700 and are claimed to clean a wide range of room areas. At the time of their litigation in 2001(Alpine Industries, 2001), Alpine reportedly had sold more than 3,000,000 units since 1987. That's somewhere between $1.2 and $1.6 billion in retail sales or $0.6 to $0.7 billion per year if the sales were evenly distributed over time, and they would likely be higher assuming an upward market trend. If Alpine sales have grown reasonably proportionally to the market growth project by Fredonia, current sales may have now reached $1 billion per year or more. However, no data have been obtained to determine whether that proportional growth has occurred. It is also possible that Sharper Image's Ionic Breeze and the newer products based on similar technology have taken some of the potential market.

The Association of Home Appliance Manufacturers estimates that 5 million room scale and portable air cleaner units were sold in 2003. It is not clear whether this estimate includes only units manufactured by non-AHAM members. Many of the units on the market are far less costly than the Ionic Breeze and the Alpine/Living Air products. Units ranging in price from $25 to $75 can be found in drug stores, hardware stores, and discount department stores. If all 5 million were sold at an average price of $50, the total sales would be $250 million for the low end products. AHAM reported 8.6 million units shipped at a total wholesale value of approximately $215 million in 2004, a growth over 2003 consistent with other indications and reports (AHAM, 2005).

Considering both the low and high end air cleaners, a conservative estimate for all portable air cleaning sales would be approximately $1.0 billion annually

Residential whole house filtration systems are normally installed in a home's heating and air conditioning duct system. A market study put the wholesale value of whole house air cleaning at $115 million in 2001 and projected a value of $140 million in 2006. A linear extrapolation would imply sales of approximately $123 million in 2004. However, since wholesale costs represent approximately half of retail costs, the retail expenditures for whole house air cleaning systems is estimated to be approximately $250 million annually.

Combining the estimate for portable and whole house air cleaners yields an estimate of approximately $1.2 billion in annual sales. This does not include filter replacement costs which could be large. However, much of the recent growth in this market is sales of units that do not require filter replacement but do require the user to clean the filter periodically. It is also not clear that the recent rise in portable air cleaner sales will be maintained. Considering all these factors, no additional expenditures are added for filter replacement.

Operating Costs of Residential Air Cleaners and Improved Commercial Filtration
No actual usage data are available for an estimate of the energy costs associated with residential air cleaners. Nevertheless, some rough calculations provide a useful estimate. If 5 million portable stand alone units with an approximate average fan power of 50 watts were each run for 2,000 hours per year (less than 6 hours per day), the annual electricity consumption would be approximately 500 million kWh/yr. At an average electricity price of $0.10 per kWh, the electric cost would be $50 million per year. Actual energy requirements and hours of use will vary widely among devices and their owners.

Likewise, it may be useful to contemplate the energy attributable to whole house filtration using the HVAC system in homes. If, for example, 3% the nation's 110 million homes run the HVAC system with a 300 watt fan for ¼ of the total hours of the year just for filtration, at $0.10 ¢/kWh, the cost of electricity would be approximately $200 million/year.

Air filtration has long been standard practice in commercial buildings largely because some filtration is needed to protect furnace equipment. However, advanced filtration systems which include improved filtration efficiency have come about because of the increased concern for indoor air, and buildings are increasingly upgrading the filters that are used. It is assumed that this improved efficiency is equivalent to an average improvement of one MERV unit, where "MERV" is a filter rating system of ASHRAE. Using information from Fisk et al (2002) as a basis, it is estimated that each unit increase in MERV increases monthly utility costs by approximately $0.096 per worker or approximately $1.15 per year per worker. If approximately 50 million of the 89 million non-industrial white collar workers occupy the commercial building sector to which this increase applies, the increase of commercial utility costs would be less than $100 million dollars.

Thus, given expenditures for the purchase of air cleaning devices of approximately $1.2 billion annually, and operating costs of residential and commercial air cleaners and improved filtration of a few hundred million, it is estimated that total expenditures for air cleaning devices and operating expenses are approximately $1.5 billion per year.

4.6 Emissions Testing for Certification/Labeling

A main product emission labeling program currently operating in the U.S. is GreenGuard. Checking the GreenGuard web site, 1399 products were listed as certified as of November 11, 2004, (GreenGuard, 2004), an, increase of 305 from October 18, 2004). Clearly this is a rapidly growing number. Multiplying the number of certified products by the annual fee of approximately $25 thousand per product per year (although higher values have been reported) yields a total of $35 million. The value of $25 thousand per product per year may be quite low in certain cases because some products, such as furniture, require more costly testing. Furthermore, the actual total certification fees are related to the size of the company and the market for the product being certified. Nevertheless, $35 million appears to be a reasonable conservative estimate for this program.

There are other certification programs, most prominently, the Carpet and Rug Institute's Green Label program, recently updated to Green Label Plus. Fees for CRI's Green Label are also likely based on company size and market share. Another labeling program is Green Seal. However, Green Seal does not test for emissions per se, but rather certifies products based on their chemical content. No specific certification fees were obtained for Green Seal.

There are other emission testing costs not related to or included in the certified products. The GreenGuard site listed 1399 certified products, but many products that have been tested for emissions are not GreenGuard certified. A quick comparison, for example, of the four paints certified by GreenGuard and the very much larger number known to key informants or the author to have been tested indicates that in some product categories, for example, paints and coatings, only a tiny fraction of the products that have been tested are GreenGuard certified products. Finally, the Resilient Flooring Manufacturers Association has just announced its own labeling program in conjunction with Scientific Certification Systems. The costs associated with this program are also unknown but are likely to follow a pattern similar to that of the Carpet and Rug Institute's programs.

The Carpet and Rug Institute (CRI) Green Label program testing fee for carpets, cushions, and adhesives is reportedly about $3.7 thousand per year per product. CRI also certifies vacuum cleaners. As of November 11, 2004, 117 carpets, 65 adhesives, 23 carpet cushions, and 363 vacuum cleaners were listed as carrying the Green Label on CRI's web site (http://www.carpet-rug.com/drill_down_2.cfm?page=8&sub=11&listid=2). CRI may add more for the label. The new "Green Label Plus" may be as much as double that cost. As of 20 June 2005, 69 products were listed as Green Label Plus certified. Some of the Green Label and Green Label Plus listed products may not have all been tested if they were similar to other products that had been tested.. The cost of the CRI vacuum cleaner testing is not known.

Additional tests are being conducted in commercial laboratories for other purposes. Best guesses without adding up the products is that the total number is considerably more than $5 million per year. Thus, it appears to be a very small industry at this stage.

Considering all these factors, it appears that annual expenditures for product testing and labeling in excess of $100 million annually, and this is used as a reasonable conservative estimate.

4.7 IAQ Litigation and Insurance

Litigation expenditures include settlements and judgments for which almost no data are available. Legal costs are included here because they are an important cost category and also a driver for preventive and proactive measures to achieve or maintain good indoor air quality. Legal actions usually are resolved by settlements rather than by judgments in law suits for reasons discussed elsewhere. The amount of settlements and judgments combined that could easily be found by searching the web was on the order of hundreds of millions of dollars annually. Whether this is the majority or a just a small fraction of the total is not known.

Data are not generally available for insurance claims and payments primarily because of the way insurance companies classify claims. However, the surge in mold-related claims has resulted in compilation and availability of some data. During the height of the mold mitigation fury, several 100-percent increases in premiums were reported in homeowner's insurance rates in Texas, and substantial increases were reported elsewhere. Benda (2004) shows tremendous growth in mold claims during the late 1990s and early 2000s, rising from a few hundred claims in 1997 to approximately 10,000 claims in 2002. Data and reports of claims and lawsuits can be accessed for several years a month at a time[2]. Typical entries report settlements and judgments ranging for the high tens of thousands of dollars to the low tens of millions of dollars.

A very conservative estimate of national annual expenditures for all indoor air quality litigation and insurance pay outs was developed by assuming that the 10,000 mold claims for 2002 using Benda's data had an average pay out of $100,000 and that this total of $1 billion represents all the insurance claim payments and all of the litigation payments for all IAQ issues. While it is probable that true expenditures are considerably more than that, it is also true that some of the expenditures are used to pay for mitigation and remediation expenses already accounted for elsewhere in this report. This figure is thus further reduced to $0.5 billion to account for this potential double counting.

[2] Substitute the month and year of interest into the following url. http://www.facworld.com/Facworld/ENVPOLL.NSF/FacWorld/September2004North%20America?OpenDocument&Ref=HotTopics#Toxic%20Mold

4.8 Radon Mitigation[3]

The EPA has estimated the costs and benefits of the national radon program. That program encourages home owners to test for radon and to install a radon mitigation system for homes whose radon levels exceed 4 picocuries per liter. The system uses a fan to draw radon gas from under the foundation and exhaust it through a vertical pipe to the outside. It also encourages home builders to use radon resistant new construction (RRNC) techniques, particularly in known high radon areas of the country.

According to EPA estimates, the amortized cost of a radon mitigation system is approximately $243 per year. This includes testing, installation, annual energy costs, and costs of replacing the fan every ten years. As of 2004, EPA estimates that there were 576,000 homes with active mitigation systems. Accordingly, it is estimated that approximately $140 million is spent annually on radon mitigation systems.

Similarly, EPA estimates that the amortized cost of radon resistant new construction is $14 per year. These systems do not employ a fan, so that the installation cost is simply amortized over the life of the home. As of 2004, the EPA estimates that there were 1,300,000 homes with RRNC. Accordingly, it is estimated that approximately $18 million is spent annually for RRNC.

These figures are conservative in the sense that the amortization is carried out over a 74 year period. To account for this discrepancy, it is estimated that approximately $0.2 billion is spent annually to prevent or mitigate radon exposure.

4.9 Asbestos and Lead Abatement

Asbestos Abatement Activity
In 1988, EPA reported to Congress that 750,000 public and commercial buildings in the United States contained asbestos and that the abatement effort could cost $50 billion. Other estimates have put the potential cost for asbestos removal in the United States as high as $100–150 billion (Jennings Group, 1993). In the United States, an asbestos abatement industry with about $3 billion in annual revenue has arisen since Occupational Safety and Health Administration (OSHA) and EPA regulations went into effect (Global Environmental & Technology Foundation, 1997.) In addition according to the American Chemical Society’s publication, *Chemical Innovation*, management of asbestos has become a $3 billion per year industry. However, comments by independent sources suggest that such an estimate is high.

Lead Abatement Activity
According to a HUD 1990 survey, there are approximately 57 million homes with lead based paint, and the average cost for abatement is approximately $6,000 ($2-12,000 range (HUD, 2004). While only limited specific data on annual expenditures could be found, this data from HUD constitutes a very large potential abatement cost. If, for example, just one tenth of the homes are abated over a period of 20 years, the annual cost would be more than $1 billion annually. Approximately $1 billion in grants to states for lead abatement have been made by

[3] Data for this section was provided by the Indoor Environments Division at the U.S. Environmental Protection Agency

EPA, HUD, and CDC combined (Farquhar, 2005). A small amount of additional federal funding has provided by the Department of Agriculture and other agencies. No data on private funding of lead abatement could be obtained although the magnitude could be substantial.

Considering the $3 billion estimate for asbestos abatement and that lead abatement expenditures appear to be roughly one-quarter to one-third of those for asbestos, a total expenditure estimate for both asbestos and lead of approximately $4 billion per year appears reasonable.

5.0 CONCLUSION

The total annual cost of IAQ problem prevention and mitigation activities in the United States is estimated at approximately $15.9 billion with a range of $12 billion to $20 billion. This estimate does not include activities that were considered typical or routine in the early 1970s before public awareness of indoor air quality became more common. The diverse sources used for this report included direct interviews with key personnel at IAQ consulting companies and laboratories, associated industries, as well as information obtained from company literature, the World Wide Web, and published reports. While not precise, this estimate does indicate that the level of expenditure is substantial. It is also apparent that expenditures are growing and the market is shifting within the various elements of the market. Finally, many products and services routinely used to control indoor air quality such as mold removal and air freshener products were not included in the report's estimates but would certainly increase the total amount spent substantially. It is recommended that further investigation be based on a systematic sample of the IAQ services reported here. It is also recommended that EPA consider efforts to estimate the effectiveness of these expenditures in meeting the expectations of those who make the decisions to purchase the products and services in terms of their expected performance at improving indoor air quality.

References

AHAM, 2005. Total Air Treatment Shipment Values to the US, downloaded June 6, 2005 from http://www.aham.org/report/Report.CFM?GetFiles=Yes&ReportID=17.

Alpine Industries, 1999. News release, Nov 1, 1999. http://www.alpineindustries.com/ruling01.htm

Alpine Industries, 2001, http://www.alpine-air-purifiers-us.com/.

Benda, George, 2002. PowerPoint presentation: "The State of IAQ Markets -- Briefing 2002: Value Mapping the Future."

Benda, George, 2004. PowerPoint Presentation: "Briefing 2004: Emerging Opportunities in IAQ." Chelsea Group.

Bureau of Labor Statistics, 2005. Inflation Calculator, Consumer Price Index Home Page, accessed at http://www.bls.gov/cpi/home.htm.

Business Communications Company, Inc. 2004. RE-091 U.S. Indoor Air Quality Market and Trends, accessed at www.bccresearch.com.

Carpet and Rug Institute, 2004. http://www.carpet-rug.com/drill_down_2.cfm?page=8&sub=11&listid=2

DOE, 2004. Buildings Energy Databook, U.S. Department of Energy, August 2004. Downloaded from http://buildingsdatabook.eere.energy.gov September 9, 2004.

ENR, 2004. ENR's Sourcebook Market Survey. Source: *Engineering-News Record*, 2004. http://www.enr.com/people/sourcebooks/top500Design/environmental/asbestos.asp

EPA, 1979. *Asbestos-Containing Material in School Buildings: A Guidance Document;* U.S. Environmental Protection Agency (EPA) Document C00090; U.S. EPA: Washington DC, March 16, 1979.

EPA, 1996. "Final Report for the Comprehensive Abatement Performance Study, Volume II: Detailed Statistical Results." EPA 230-R-94-013b, April 1996. Office of Pollution Prevention and Toxics, U.S. EPA, Washington, DC 20460.

Faraquhar, Doug, 2005. Personal communication based on unpublished data from the National Conference of State Legislatures.

Federal Trade Commission (1998), William Converse Position Paper, IAQ Publications, FTC Document 0010371.

Fisk WJ, Faulkner D, Sullivan D (2004) Outdoor airflow into HVAC systems: an evaluation of measurement technologies. LBNL-56397. Lawrence Berkeley National Laboratory Report, Berkeley, CA.

Fisk WJ, Faulkner D, Palonen J, and Seppanen O (2002) Performance and cost of particle air filtration technologies. *Indoor Air* 12(4):223-234. LBNL-47833

FMI-NEMI, 2002. `Indoor Air Quality (IAQ) Market Research, National Energy Management Institute, June 2002. http://www.nemionline.org/download/hvac/4_Indoor%20Air%20Quality.pdf

Fredonia Group, 2004. http://freedonia.ecnext.com/coms2/summary_0285-19430_ITM.

FTC, 2002. http://www.ftc.gov/opa/2000/04/alpineindustries2.htm.

FTC, 2001. File Nos. C-3614; X980005; Civil Action No. 2:97 CV 509 (E.D. Tenn.)

GreenGuard, 2004. http://www.greenguard.org/DesktopDefault.aspx?tabid=12, downloaded November 12, 2004.

Global Environmental & Technology Foundation, 1997. *Market Assessment: Asbestos Abatement Technologies.* Global Environmental & Technology Foundation: Annandale, VA.

Hodgson, A.T., and Levin, H., 2003. "Volatile organic compounds in indoor air: A review of concentrations measured in North America since 1990." (To be submitted to *Atmospheric Environment* 2003). LBNL-51715.

HUD, 2004. Evaluation of the HUD Lead-Based Paint Hazard Control Grant Program, Final Report Prepared for: The U.S. Department of Housing and Urban Development, Office of Healthy Homes and Lead Hazard Control, The National Center for Healthy Housing and The University of Cincinnati Department of Environmental Health. http://www.centerforhealthyhousing.org/HUD_National_Evaluation_Final_Report.pdf

Jacobs, David E., 2005, Personal Communication, Director, Office of Healthy Homes and Lead Hazard Control, U.S. Department of Housing and Urban Development.

Jalbert, Phillip, 2004. Personal communication (email), September 14, 2005.

Jennings Group, 1993. *A Comprehensive Market Study and Business Analysis of the Industry.* The Jennings Group: Columbia, NJ,

Repace, J. 2004. "Respirable Particles and Carcinogens in the Air of Delaware Hospitality Venues Before and After a Smoking Ban." *Journal of Occupational Medicine*, Volume 46, Number 9, September 2004: pp. 887-905.

Sharper Image, 2004. http://www.sharperimage.com/

Appendix. In-depth interviews and individuals as sources of information

Many individuals provided cost data and other useful information. Many of these individuals requested that their identities be confidential. The following individuals granted permission to list them as sources for this report:

In-depth Interviewees (permission received to list names)
H.E. Barney Burroughs, Atlanta, GA
George Benda, Chelsea Group, Ltd.
Alfred T. Hodgson, Lawrence Berkeley National Laboratory
Philip Morey, Air Quality Sciences
Francis J. Offerman, Indoor Environmental Engineering
Lisa J. Rogers, formerly of Clayton Group Services, Inc.
John Tiffany, Tiffany-Bader Environmental Inc.
Donald Weekes, Abacus Environmental Inc.
Dave Witham, UVDI
James E. Woods, Jr. Building Diagnostics Research Institute, Inc.
Chin S.Yang, P&K Microbiology Services, Inc.

Many other individuals who were very helpful have not been listed either because they did not grant permission or did not respond to request for permission to list their names.