ventilation systems, on particles with diameters ranging from 0.01 to 3 µm. These particles are important because they are respirable and remain airborne for long periods of time. They include many indoor pollutants: tobacco smoke, cooking fumes, dust, and radon progeny.

The researchers conducted their studies in a filter test facility, using three instruments to measure fractional efficiency. A differential mobility particle sizer measured aerosols from 0.01 to 0.09 µm; a laser aerosol spectrometer measured sizes between 0.09 and 0.3 µm; and an Optical Particle counter measured particles up to 3 µm.

The test aerosol consisted of solid potassium chloride. The loading dust was comparable to that specified in the ASHRAE 52-76 standard, but without ASHRAE's carbon black.

The researchers found that efficiency curves were similar for many filters. Diffusional collection trapped many of the particles smaller than 0.1 µm, while interception and inertial collection trapped many particles above 1 µm. Most filters, however, were least efficient in the range between 0.1 to 0.5 µm.

One common furnace panel filter had an efficiency of less than 10% for particles between 0.02 and 1 µm. This improved with dust loading, but remained below 20% over the 0.03 to 0.3 µm range. A pleated paper filter's efficiency also increased with dust loading. A charged fiber filter showed a high initial efficiency, but that decreased with dust loading.

The researchers concluded that any accurate efficiency rating for filters needs to be expressed in terms of efficiency for specific particle sizes.

TITLE: **Fractional Aerosol Filtration Efficiency of Air Cleaners**, *Proceedings of Indoor Air '93*, Vol. 6, p. 369.

PRINCIPAL AUTHOR: James T. Hanley, Research Triangle Institute, P.O. Box 12194, Research Triangle Park, NC 27709, USA; (919) 541-8050.

MMMF Levels in Buildings Show Correlation with SBS Symptoms

A survey of sick building syndrome (SBS) symptom complaints in nine US buildings with air conditioning failed to show a positive correlation between airborne pollutants and the symptoms. However, researchers from Cornell University in the US detected a correlation between the symptoms and man-made mineral fiber (MMMF) counts in settled dust.

Investigators studying sick building complaints have often had difficulty relating the symptoms to measured amounts of commonly associated pollutants in the building air (see previous article on "lost" TVOC). Some researchers have found that symptoms do correlate with total suspended particulates and organic dust.

The researchers sampled each building in the winter/spring season over two consecutive workdays. The study included structures with both variable air volume (VAV) or constant air volume (CAV) ventilation. Most sampling took place during normal work hours, except for the MMMF sampling, which took place during evening hours because of the noise caused by the pumps.

The study measured a number of pollutants including formaldehyde, respirable suspended particles (RSP), ultraviolet particulate matter, settled dust, and airborne MMMF.

Building occupants completed a self-reporting questionnaire on perceptions of ambient conditions, occupational factors, and work-related SBS symptoms. Researchers considered symptoms work-related only if they improved on days away from work.

To test correlation between symptoms and pollutants, researchers counted the number of work-related symptoms per person and computed the building sickness score (BSS) as the average number of symptoms per worker.

They discovered no correlation between the BSS and indoor pollutants, temperature, humidity, or lighting. However, they did find a significant correlation between the BSS and the density of MMMF in the settled dust. Airborne MMMF and the MMMF count in the settled dust didn't show the same correlation.

The researchers noted that one building, in which settled MMMF was the most abundant, had the greatest influence on the total results. The researchers concluded that while MMMF might may not be the sole cause of SBS, MMMF in settled dust may have a threshold effect.

They suggested that two factors may come into play. One is the increasing use of acoustic ceiling tiles, which may be a source of MMMF in the office environment. The other factor is that office cleaning could have an influence on SBS symptoms, with extensive cleaning reducing the number of symptoms reported.

TITLE: **Effects of Man-Made Mineral Fibers in Settled Dust on Sick Building Syndrome in Air Conditioned Offices**, *Proceedings of Indoor Air '93*, Vol. 1, p. 291.

PRINCIPAL AUTHOR: Alan Hedge, Department of Design and Environmental Analysis, Cornell University, Ithaca, NY, USA.

Early Results Promising in Using Sensor Array to Evaluate Air

Some IAQ researchers have employed trained panels of judges to evaluate air quality in buildings. While this provides a desirable human element, it presents several disadvantages, not the least of which is that monitoring IAQ acceptability continuously is difficult, if not impossible, with human "sensors."

Researchers from Johnson Controls, Inc., in the US, have tried using a gas sensor array to mimic the work of a trained panel. Early results, despite some shortcomings, show considerable promise in tracking the scores given to the air by a trained panel of judges.

The effort has several goals for such a sensing system:

- Human equivalent response for odors, unhealthful but nonodorous compounds, and irritants;
- Ability to perform real-time measurements without saturation;
- Stable and accurate operation without frequent calibration;
- Portability; and
- Small size and low cost.

This particular research used 11 judges chosen from 25 candidates on the basis of performance. Panel members trained using known decipol levels by specific concentrations of acetone. During training the mean error for the panel was 1.9 decipol and the standard deviation of error was 1.7 decipol.

The sensor array consisted of a temperature sensor, eight tin-oxide gas sensors, and 11 optical filters in a photoacoustic infrared gas detection instrument. The tin-oxide sensors were rated for detecting ethanol, hydrogen sulfide, ammonia, cooking gases, organic vapors, combustible gases, air quality, and carbon monoxide.

The optical filters were calibrated for water vapor, carbon dioxide, acetone, ethanol, toluene, propane, ammonia, vinyl chloride, chloroform, benzene, and formaldehyde.

The researchers carried out evaluations over several days in a large facility which consists of six interconnected buildings.

After some preliminary pattern recognition analysis, researchers eliminated some sensors from the array. Among these were several that provided no new information for pattern recognition. The tin-oxide sensors for organic vapors, ammonia, air quality, and cooking gases appeared in the final array.

Researchers used four methods of pattern recognition analysis: artificial neural networks, direct cosine method, Euclidian distance measure, and Tanimoto similarity measure. When sensor array results were compared to the votes of the trained panel, the best pattern recognition technique was Euclidian with an average mean error of 2.2. The best technique for standard deviation of error was the artificial neural network.

The researchers note the shortcomings of the technique and the small number of samples involved. However, they feel the initial results are promising and indicate the need for more testing.

TITLE: **A Gas Sensor Array for Measurement of Indoor Air Pollution — Preliminary Results**, *Proceedings of Indoor Air '93*, Vol. 5, p. 27.

PRINCIPAL AUTHOR: Jarrell Wenger, Controls Group Research, Johnson Controls, Inc., P.O. Box 423, Milwaukee, WI 53201 USA; Fax: (414) 274-5810.

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Germans Label MMMF Carcinogenic; US Health Agency Backs Off

Three German government agencies, operating as an informal working group, said in September that various man-made mineral fibers (MMMF) are either carcinogenic or probably carcinogenic. The classification, announced in the popular media in Germany, has created intense public pressure on the German government to set some regulations.

Earlier this year, the US Department of Health and Human Services (HHS), responding to pressure from the US insulation industry, further delayed an already overdue report from the National Toxicology Program (NTP) that would classify fiberglass as carcinogenic. In an unprecedented move, HHS has ordered the NTP to go back to the beginning and review all the scientific data leading up to the proposed classification.

The German action came from a joint effort by the Bundesgesundheitsamt, the federal public health agency; the Bundesanstalt für Arebeitsschutz, the German equivalent of the US Occupational Safety and Health Administration; and the Umweltbundesamt (UBA), the environmental protection agency.

MAK Commission Proposal

Dr. Holger Brackeman of the UBA press office told ***IAQU*** that the working group was formed after a 1991 proposal by the Maximale Arbeitsplatz Konzentrations Kommission (MAK Commission) to list certain fibers as carcinogens. The MAK Commission issues guidance on toxicological and carcinogenic levels for workplaces.

Brackeman said the MAK Commission, following the working group's announcement, went ahead with the carcinogen designations it had proposed in 1991.

Neither MAK findings nor the ruling by the three-agency working group serve as regulations, but the actions have spurred the public to request further action. The working group's findings appeared in television broadcasts early in September and, despite the group's caution that citizens not overreact, many people expressed concern about mineral fiber insulation in their homes.

The three government agencies will now hold a conference involving all federal agencies to review the action and offer possible solutions.

IN THIS ISSUE

US Industry Statement on Proposed MMMF Ruling by NTP

The following is excerpted from the Insulation Bulletin, published by the North American Insulation Manufacturers Association.

The National Toxicology Program (NTP) has said that its proposal to list glass wool as a substance "which may reasonably be anticipated to be a carcinogen" was based upon the 1988 classification by the International Academy for Research on Cancer (IARC) of glass wool as a "2B" or "possibly carcinogenic" to humans. The IARC 2B classification was primarily based upon studies in which massive quantities of glass fibers were surgically implanted or injected into the lungs and abdomens of rodents, bypassing the animals' normal bodily defense mechanism.

The significance of the proposed NTP listing should not be misunderstood. Although NTP's proposed "reasonably anticipated" listing may sound worse than the IARC's "possibly" rating, the NTP proposal is not based upon any new scientific information. In fact, the listing proposal fails to reflect the most current scientific studies (including a state-of-the-art animal inhalation study completed in 1992 by the Research and Consulting Company of Geneva, Switzerland). Instead, NTP's proposal is based on the same artificial injection/implantation studies that were the basis of the 1988 IARC ruling.

Moreover, the proposed listing should not be looked upon as an assessment of risk to humans.... In a recent letter to the North American Manufacturers Association (NAIMA), the head of NTP explained, "The basic purpose of the 'reasonably anticipated' category in the report is to provide a listing of substances that may possibly be carcinogenic as the first step in hazard identification. The inclusion of these substances is to begin a process of wider scientific review and analysis....

...NAIMA and its member companies have strongly opposed the proposed listing for several reasons ... the NTP rules are scientifically obsolete...[and] are outside the scientific mainstream and inconsistent with the positions taken by other government agencies such as the EPA, as well as the National Academy of Sciences.

Because of the widespread public concern, the conference will most likely be held by the end of November, according to Brackemann.

In addition, the UBA will consider possible substitutes for the fibers in question and will ask the fiber industry to develop mineral fibers that are less stable in the body than present fibers and have different critical dimensions, a factor that is considered important in determining a fiber's carcinogenicity.

Action in the US

A similar ruling in the US has been stalled by the HHS decision to delay once again the publication of the 1992 annual report on carcinogens from the National Toxicology Program.

Dr. James Fouts of the US National Institute for Environmental Health and Safety (NIEHS), senior science adviser to the NTP, told ***IAQU*** that the NTP proposed in 1989 to list fiberglass in the annual report on carcinogens. It was to be listed in the report that was due out in early 1992, but the industry protested, claiming its own research showed that the NTP's data were faulty.

This delayed the report last year, and another petition this year led HHS to order a review of all research on the matter. Much of the data on carcinogenic potential of various materials comes from the International Academy of Research on Cancer in Lyons, France.

Fouts said his group would complete its work on the review by the end of the year, but that a timetable for further action by the NTP is "anybody's guess."

In Germany, the insulation trade group has asked the Ministry of Labor — which must issue any regulations on the matter — not to adopt the MAK Commission's conclusions.

Studies in Dispute

At the heart of the dispute is controversy over the types of studies that have been done to determine the potential carcinogenicity of mineral fibers. Scientists basically use two types of experiments for this purpose: inhalation studies, in which rats are exposed to airborne fibers, and injection studies, in which the fibers are injected into the animals' bodies.

Most of the results showing carcinogenicity have come from the injection studies, leading the fiber industry to complain that this is not

German Position Paper on Man-Made Mineral Fibers

The following are excerpts from the statement issued by the three German agencies forming the informal working group to study the possible health effects of man-made mineral fibers. The agencies included are the Bundesgesundheitsamt, the federal public health agency; the Bundesanstalt für Arbeitsschutz, the German equivalent of the US OSHA; and the Umweltbundesamt, the environmental protection agency.

The accumulated research on fiber-forming particulates shows that the carcinogenic potential of these fibers is difficult to demonstrate in inhalation experiments. This is probably attributable to the fact that in inhalation experiments, fiber fragments do not always reach the lung tissue in significant numbers.

... From a practical standpoint, it may be important to distinguish the carcinogenic potential of different fiber types according to their geometric structure or persistence, but for the purpose of classifying the fibers as carcinogens, the potential for carcinogenicity alone is sufficient to set standards.

Conclusions that can be made from research:

- Refractory ceramic fibers: Unequivocally carcinogenic through inhalation in several species forming lung tumors, as well as mesotheliomas and fibromas.
- Glass wool fibers: Positive in injection studies; marginally positive in three-dose inhalation test for lung tumors. No evidence of mesotheliomas or fibromas. There is sufficient evidence to suggest human exposure to glass wool fibers can cause cancer.
- Slag wool/mineral wool fibers: Insufficient evidence to classify as a carcinogen, but still suspect.
- Rock wool fibers: Positive in injection tests. There is sufficient evidence to suggest that human exposure can cause cancer.
- Microscopic fiber glass fibers: Positive in injection studies and after intratracheal introduction. There is sufficient evidence to suggest that microscopic fiberglass fibers can cause cancer.

Experimental evidence suggests that refractory ceramic fibers are even more carcinogenic than asbestos fibers on account of their greater length. Evidence on the other man-made mineral fibers (MMMF) suggests that they may be as carcinogenic as asbestos, but are probably less so. The key issue in determining risk may be the probability of exposure.

The greatest potential for exposure is in workplaces in which these fibers are being manufactured or used for the manufacture of products such as insulation.

The greatest chance for exposure for the general public is through fiber-containing insulation or from sound-proofing materials in suspended ceilings. Because of their direct contact with indoor air, these building materials have the greatest potential of shedding particulates to which humans could be exposed.

The concentration of ambient MMMF product fibers during the use of mineral wool products in buildings:

- Is generally not increased when the insulation is installed according to building codes;
- Is generally significantly increased when the MMMF products have contact with indoor air during air exchange — particularly with suspended ceiling materials; and
- Is continuously and significantly elevated up to levels of several thousand fibers per cubic meter during construction or restoration activities that disrupt existing MMMF products.

... In contrast to the opinions of many experts, lay people tend to overestimate the cancer risk of typical insulation fibers. They cannot make accurate risk assessments that take into account other risks that people accept or are forced to take on a regular basis. The working group is concerned that the general public will mistakenly overestimate the cancer risk of MMMF and will be plagued by irrational fears.

NEWS AND ANALYSIS

Germans Continue MMMF Studies, Remove Environmental Approval

German environmental agencies sponsored a two-day hearing in December on the carcinogenic potential of man-made mineral fibers (MMMF), setting the stage for an April meeting at which a policy-making commission will consider setting guidelines for human exposure.

In the meantime, one German agency has removed its environmental seal, the "Blue Angel," from glass fiber products produced by three manufacturers. The agency had granted the seals not because it had ruled on the safety of the glass fibers, but because the products were made mostly from recycled materials. The removal of the "Blue Angel" is unprecedented.

German Environment Minister Klaus Töpfer invited international experts to participate in the December 9-10 meeting in Berlin. Representatives of the Bundesgesundheitsamt, the federal public health agency; the Bundesanstalt für Arbeitsschutz, the German equivalent of the US Occupational Safety and Health Administration; and the Umweltbundesamt (UBA), the German environmental protection agency, joined in reviewing the testimony of the expert witnesses in order to make recommendations for setting guidelines and policy.

In April, the MAK-Kommission (which issues guidelines on carcinogenic levels) will consider the recommendations, when it holds a special session to set TRK (Technischen Richtkonzentrationen) values, the technical guidance values for confirmed human carcinogens, for MMMF. The German delegation to the EC-Commission has offered to provide the working group's report and the opinions of the MAK-Kommission for use in setting EC-wide recommendations or policy on MMMF exposure.

Töpfer says that regardless of whether MMMF fits the criteria of a known human carcinogen, users of MMMF-containing products need to be protected from potential risk. He has therefore established an MMMF working group at the public health agency. The working group includes representatives from the Institut für Wasser-, Boden-, und Lufthygiene des Bundesgesundheitsamt (Institute for Water, Ground, and Air Hygiene of the public health agency), the Umweltbundesamt, and the Bundesanstalt für Arbeitsschutz, as well as scientists from the Medizinischen Instituts für Umwelthygiene (the Medical Institute for Environmental Hygiene) in Düsseldorf, and the Instituts für Toxicologie der Fraunhofer-Gesellschaft (the Institute for Toxicology of the Fraunhofer Society) in Hannover. Thus far, the working group has downplayed the health risk for users of MMMF products, stating that:

- There is no urgency in setting any prohibition for the use of MMMF. The greatest danger exists for workers involved in the manufacture of MMMF products, for whom it might be necessary to lower TRK values.
- The risk from MMMF exposure in indoor air from MMMF insulation materials is minimal provided the insulation is properly installed and maintained. Exposure levels are for the most part well within guideline values.
- The airborne fiber concentrations can be significantly elevated when MMMF insulation materials are installed in such a way that it contacts indoor air during air exchanges, for example by contact with suspended ceiling tiles. The only other situation of potentially elevated levels noted by the working group occurred during construction and installation of MMMF-containing building materials.

Töpfer said, "I am satisfied with the progress of the hearings to this date, because here we have a truly scientifically-based discussion in a professional atmosphere. To this point it appears that with properly installed and maintained MMMF insulation materials there is no need for remedial actions. I am convinced that we will soon have a widely-accepted scientifically-based opinion on the use of MMMF materials."

The Umweltbundesamt did not, however, wait for the outcome of the multi-agency hearings or MAK-Kommission rulings in deciding to remove the "Blue Angel" environmental seals from glass fiber products of three different German manufacturers in mid-December: Detlef Rave GmbH and Co., Hamburg; Gutzweig und Haftmann, Ladenburg; and Dämmstoffe Helt, Wesel

The environmental protection agency declared that in light of the health risk associated with these products it goes against the Blue Angel environmental principles for such products to bear the agency's endorsement. The Umweltbun-

the way humans encounter the fibers. The industry points out that inhalation studies — which parallel human exposure — have failed to produce any elevated occurrence of tumors in laboratory rats.

Those who give credence to the injection studies, on the other hand, say that rats differ significantly from humans. For example, rats' lung volume is extremely small, meaning that they have far less opportunity to breathe fibers than do humans under similar circumstances.

Another factor, they claim, is that rats can't breathe through their mouths, as many humans do. The rats' defense mechanisms in the nasal passages may prevent inhalation of sufficient fibers to produce the tumor response. However, humans, especially children in general and adults in cases of physical exertion, often breathe through the mouth, bypassing the defenses in the nasal passages that might trap airborne fibers.

Discussion

Where does all this leave IAQ professionals — and consumers — who are concerned about fibers? First, they need to understand that neither the actions taken by the German government agencies nor those proposed by the NTP are regulatory.

Second, while certain fibers may possess carcinogenic qualities, more important are the conditions under which this carcinogenicity exists and what the risk is relative to other risks people take on a regular basis — or relative to the risks of the alternatives.

For More Information

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PRACTICAL RESEARCH BRIEFS

Paper Questions Value of European Ventilation Guidelines

An original paper appearing in the most recent issue of *Indoor Environment* (1993:(2) 143-148) questions the ventilation guidelines issued last year by the Commission of the European Communities (CEC) (see ***IAQU***, October 1992).

The authors of the article, including Miloslav Jokl of the Technical University of Prague, Czech Republic, argue that the sensory perception standards called for in the CEC approach are intuitively attractive, but sufficiently flawed to render the method ineffective. Jokl and his co-authors, George Leslie of the Imperial College of Science, London, United Kingdom, and L. S. Levy of the University of Birmingham, United Kingdom, instead point to the current ASHRAE Standard 62-1989 as a more reliable approach.

The European guidelines rely on a perceived evaluation method in which a panel judges the air quality. The building pollution load is measured in terms of olfs. (An olf is the pollution load caused by one average person at rest.) The outdoor air quality and building air quality are expressed in terms of decipols. (A decipol is the quality of the air polluted by one olf and ventilated with 10 liters per second (l/s) of fresh air.)

Air Quality Formulas

In the CEC guidelines, a set of formulas, using perceived quality of the air and ventilation effectiveness, produce a ventilation rate to provide for human comfort. Designers theoretically would employ another set of equations, using known pollutants within the space, to arrive at a ventilation rate for health. The designers would be required to use the higher of the two rates.

Also, the designer would use different equations depending on whether the goal is to satisfy 70%, 80%, or 90% of the occupants.

In the recent paper, the authors first object that the method relies on a host of assumptions, rather than real data about materials used in the building. The subjective evaluation of air quality would have to wait until the building was built, furnished, and occupied. This would defeat the purpose of using the evaluation in the design of a ventilation system.

inclusions about the ability of the materials to support growth.

Price told ***IAQU*** that he "has nothing against fiberglass insulation," but that we need better methods for cleaning and maintaining it.

IAQU asked Price about what pollution load if any may come from the addition of the antimicrobial. He responded that tests conducted by his firm in seeking US Environmental Protection Agency (EPA) approval for the product showed no downstream offgassing of compounds from the substance. He said the emissions of the product were below the limit of detection.

Filter Study

In his presentation at the Tampa conference, Price described a second phase of the research involving the ability of new and used low-efficiency filters to support fungal growth. The research also examined the antimicrobial's ability to inhibit that growth.

In this portion of the study, the researchers conducted *in situ* experiments on filters located in rooftop air handling units (AHUs) in an office complex in the southeastern US. These five-ton units had air flow rates of 2,000 cubic feet per minute.

The filters consisted of low-density prefilter type media, prefilter roughing media, and polyurethane foam sandwiched between two polypropylene scrim layers. Researchers treated some of the filters with the antimicrobial product.

Treated and untreated filters remained in the AHUs for 28-30 days, during which ambient temperatures ranged from 20°-38°C (68°-100°F). Relative humidities varied from the 58% to 100%.

Following each exposure, researchers removed the filters from the AHUs and submitted them for analysis. They cultured some sections in petri dishes and placed another set in a nonchallenge chamber with relative humidity above 95% and temperatures of 22°C and 34°C (72°F and 93°F). Another set was cultured in agar.

Unused control samples were placed in an environmental challenge chamber for 28 days and researchers examined sections of them under light microscopy.

The researchers found viable fungal propagules in new untreated filter media, but not in the treated media. They found that both treated and untreated filters in the AHUs contained fungal growth, but the treated filters — although they appeared more soiled — had markedly lower fungal counts.

Discussion

The fact that both filter media and insulation products — once exposed to dirt and moisture — can support microbial growth comes as no surprise. This research shows not only the value of a particular antimicrobial treatment, but indicates a pattern of fungal growth that speaks directly to the manufacturing process and installation of these materials.

Table 1 — Fungal Growth on Insulation Products

Sample	Days in Chamber		
	<30	30-90	90-270
Samples in challenge chamber	Positive readings/Number tested		
Duct Liner 1	22/22	22/22	22/22
Duct Liner 2	4/26	14/26	20/26
Duct Board	0/14	1/14	9/14
Treated Duct Liner	2/13	3/13	6/13
Samples in nonchallenge chamber			
Duct Liner 1	0/8	1/8	8/8
Duct Liner 2	0/6	0/6	2/6
Duct Board	0/8	0/8	Not done
Treated Duct Liner	0/2	0/2	2/2

Source: Daniel L. Price