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GLASS FIBER EMISSIONS FROM HVAC DUCTWORK: A REVIEW OF THE LITERATURE

J.E. Woods[1], and A.K. Goodwin[2]

[1] College of Architecture and Urban Studies, Virginia Polytechnic Institute and State University (Currently at HP-Woods Research Institute), USA
[2] Formerly at College of Architecture and Urban Studies, Virginia Polytechnic Institute and State University, USA

ABSTRACT

Recent concerns have been expressed with regard to emissions of glass fibers from heating, ventilation, and air conditioning (HVAC) systems. In this literature review, over 350 citations were found, of which 10 reported original measurements of glass fiber concentrations associated with the presence of fibrous glass duct lining or duct board, and two yielded sufficient data from which emission rates could be calculated. This review indicates that fibrous glass duct lining and duct board can provide thermal and acoustical benefits while maintaining exposure to glass fibers in occupied spaces at or near background or outdoor air concentrations only if care is provided to maintain these materials in clean and dry conditions throughout the construction and operational phases of the facility.

INTRODUCTION

For over 40 years fibrous glass duct lining and duct board have been used in heating, ventilation, and air conditioning (HVAC) systems for thermal and acoustic insulation. However, concerns are now being expressed that HVAC systems can become sources of indoor contaminants. Among these concerns are the emissions of glass fibers from the duct lining or duct board systems and the influence that the properties of the insulation materials have on the transfer rate of contaminants through the components of HVAC systems. The objective of this paper is to summarize the current state of published information pertaining to the emissions of glass fibers from fibrous glass duct board systems and sheet metal ducts internally lined with fibrous glass duct liners.

METHODS

This literature review focuses on three issues: 1) What is known about the use and effectiveness of fibrous glass duct lining and duct board for thermal and acoustical control? 2) What is known about the intrinsic and extrinsic emissions of glass fibers from duct board and internal duct lining in HVAC ductwork? 3) How are these emissions influenced by desing and opeational factors? 4) What is known about human response to extrinsic and intrinsic emissions with and without influence by other factors?

A preliminary search of literature was conducted to identify keywords and to develop a literature classification scheme. The keywords and literature classification scheme were then used to conduct an extensive search of several library databases. This search yielded over 350 citations, of which 65 pertaining to the critical issues were analyzed in more detail. More complete details on the literature search procedures, have been reported elsewhere (1).

RESULTS

Purpose and constraints of fibrous glass duct board and duct lining

It is apparent from the literature that the combined thermal *and* acoustical performance of internal duct lining and duct board can offer technical and economic incentives for their selection over external duct insulation. Thus, thermal and acoustical properties of these materials were found to be well documented. Conversely, the effects of moisture and contaminants on these materials apparently are considered as system constraints, and the properties associated with them are not as well documented in the literature.

Unlike the moisture constraint, which has been recognized to adversely affect thermal *and* acoustical performance of fibrous glass insulation, the contaminant constraint apparently is not considered as a factor that affects this performance. Rather, it is primarily recognized as a factor that can affect occupant health. This distinction between moisture and contaminant constraints was reflected in this literature review, as the handbooks and product literature provided some quantitative guidance on moisture control, but no such engineering guidance was found for contaminant control.

Types and characteristics of fibrous glass material

Properties and characteristics of the fibrous glass material intrinsic in duct board and duct lining are primarily associated with a fiber classified as *glass wool*. It is one of five types of *man-made vitreous silicate fibers* (i.e., MMVF) which are a specific subset of a class of particulates known as *fibers* (2). The complex mixture of MMVF used in building materials and products presents a difficult challenge in assessing the relative contribution of duct board and duct lining to the total concentration of glass wool, and other MMVF, that might be found in occupied spaces.

This literature review indicated that glass wool can be characterized with an average fiber diameter that ranges from 1 to 10 μm and a variability of the diameters of 50%, a fiber length usually much greater than 250 μm, only a trace of non-fiber particulate or "shot," a "chemical durability" of approximately 0.4 years, a relatively high composition of sodium and boric oxides (i.e., Na_2O and B_2O_3), and the presence of binders. These characteristics may then be used to distinguish glass wool from, for example, rock and slag wools which may have similar binders and fiber diameters but differ in fiber length (e.g., several centimeters), percent of shot (e.g., 20-50%), chemical durability (e.g., 1.2-2.0 years), and relatively high compositions of calcium, magnesium, aluminum and iron oxides (i.e., CaO, MgO, Al_2O_3 and Fe_2O_3).

Glass fiber concentrations

Of the 10 articles that reported original, quantitative data on concentrations of glass fibers related to the presence of fibrous glass duct lining or duct board, five were field studies (3-7), and five were laboratory studies (8-12). In all ten of these studies, volumetric air samples were obtained and fibers were counted through either optical or electron microscopy. However, the characterization of the ductwork (e.g., sizes, configurations, ages, and quality of maintenance), the selection of sample sites, and the methods of obtaining samples, preparing them for analysis, identifying and characterizing the fibers, and counting them varied significantly.

The results reported by Gamboa (10) and Tolvanen (12) were obtained in a test duct section and a test chamber, respectively, with similar air velocities across the glass fiber materials. A comparison between these studies indicated that the measured ranges differed by two orders of magnitude (i.e., 3-500 fibers/m^3), but within each of these studies, the differences in ranges for the various materials tested were negligible. The "scale" effect between the small chamber used by Tolvanen and the larger UL 181-type test duct used by Gamboa is a likely explanation of the significant differences between these studies.

In two field studies reported by Balzar (3,4), glass fibers were found to comprise nearly 50% of the total fibers measured in the outdoor air, ductwork, and occupied spaces; the ranges of concentrations of glass fibers and other fibers in the ductwork were narrower and the values smaller than in either outdoor air or occupied spaces; but ranges and values differed from those in the laboratory studies (9,10,12) by several orders of magnitude. Although Balzar's results did not isolate glass wool from glass fiber, they add further evidence that fiber reduction in the HVAC systems (i.e., filtration or settling in the ductwork) is a significant confounder to the understanding of intrinsic glass fiber (i.e., primarily glass wool) emissions from fibrous glass duct board or duct liner.

The results from the field studies of Gaudichet and Schneider (6,7) add another important perspective to the issue of glass fiber emissions from ductwork compared to other sources. Although the morphology of fibers was characterized as MMMF rather than MMVF, these studies introduced the important differentiation of *respirable* verses *non-respirable* fibers emitted by the materials in ductwork. The similarity of the ranges and values of respirable MMMF found in the occupied spaces (6,7) and those of glass fibers reported from within test ductwork (10) indicate that the settling rates of respirable fibers (i.e., MMVF or MMMF) may be smaller than those of total glass fibers.

A comparison of measured MMMF and MMVF concentrations in outdoor air (3,4,6,13,14), within HVAC ductwork containing glass fiber material (3,4,10,12), and in occupied spaces (3,4,6,7,14) indicates that the ranges of MMVF and MMMF concentrations measured within HVAC ductwork closely matched the ranges measured in outdoor air (i.e., 10^{-1} to 10^{4} fibers/m^3). With the exception of one Balzar study in which occupational samples were obtained during the installation and application of fibrous glass insulating materials (3), the ranges of MMMF and MMVF concentrations measured in occupied spaces also closely matched those obtained in outdoor air and in the HVAC systems.

Glass fiber emissions

Of the ten citations that provided original measurements of glass fiber concentrations related to the presence of fibrous glass duct board or duct lining, none reported on *emission rates*, either as direct measurements or as calculated values. However, sufficient data were found in two of these citations (10,11) from which emission rates of *glass fibers* could be calculated, but in neither of these studies was the morphology of the glass fibers fully described. The time-averaged emission factors derived from Gamboa's data for 24-hour test periods, obtained immediately after duct installation, tend to cluster around log 5 (fibers/hr-m^2), whereas those derived from Hays' data, 120-hour hours after installation, varied from - log 2 to + log 3, with a mean value of + log 2. The importance of this comparison is more obvious when the emission factors for duct board are compared at the same air velocity (i.e, 12.2 m/s). In this case, when the single value of the emission factor, derived from Gamboa's 24-hour test, is compared to the mean value derived from Hays' 120-hour tests, a reduction of log 2 is apparent in approximately 100 hours. Assuming this trend is valid, initial decay rates for emissions of glass fibers from duct board and duct liner may be significant, and may be quantifiable using known methods (15).

Influencing factors

Emissions during construction and installation of fibrous glass duct board may be initially high but rapidly decay. Emission factors of new, carefully constructed fibrous glass ductwork may decay by two or more log orders in less than 120 hours. This finding is supported by a laboratory study (9) in which the majority of measured fibers were emitted during the first 100 hours of the 1000-hour test periods. In Cholak's field study of six existing buildings (5), glass fibers were found in "settled dust samples" that likely "had their origin during periods in which the fibrous-glass ducts were first installed." In Schneider's field study of 11 randomly chosen schools (7), the concentration of glass fibers in one school was measured as 950 fiber/m^3 one day after MMMF had been handled, but the concentration fell to 60 fiber/m^3 after thorough cleaning. Also, in one study by Balzar in which occupational samples were obtained during the installation and application of fibrous glass insulating materials (3), glass fiber concentrations were measured at +log 3 higher than in the occupied spaces during his other study (4) or in the ductwork of either study.

The quality of ductwork construction is also likely to influence the initial and long-term emission rates of glass fibers. A comparison of the data reported by Gamboa (10) indicates an apparent 28% smaller initial glass fiber emission rate for fibrous glass duct lining with treated rather than untreated edges. Also, as indicated in Schneider's field study (7), one school, whose age was unreported but had "ventilation ducts made of uncoated MMMF," had a 3-day average concentration of 120 fiber/m^3, which was significantly above the maximum reported for nine other schools (i.e., 87 fiber/m^3). Thus, glass fiber emissions during construction and installation of fiber glass duct board or duct lining should be carefully controlled.

The literature is not clear as to whether emission rates of glass fibers decay to low-level positive or negative values, or vary, during operations of HVAC systems that are not known to be dirty or contaminated. Moreover, in none of the studies reviewed were the temperature and humidity conditions of the air reported. The literature was clear, however, that without effective care and maintenance, HVAC systems can become dirty and contaminated. Not only can glass fibers accumulate on the fibrous glass duct board and duct lining (3,4,5,7), other fibers, particulates, microbial matter, and water are likely to adhere to these materials if the air entering the ductwork is not clean or thermally treated (16,17). Three studies provided particularly important evidence that ineffective care and

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maintenance can cause fibrous glass duct board systems and duct linings to become wet and contaminated which increases the probability that glass fibers and other contaminants can be emitted from these materials (12,16,17).

CONCLUSIONS

Three conclusions have been drawn from this review. First, the use of fibrous glass duct lining and duct board systems can provide the intended thermal and acoustical benefits while maintaining occupant exposure to glass fibers at or near background or outdoor air concentrations. Second, if care is not provided to maintain these materials in clean and dry conditions throughout the construction and operational phases of the facility, not only will the thermal and acoustical properties be compromised, the probability of glass fiber emissions from these materials may increase. Finally, well-controlled field and laboratory studies are needed to adequately characterize and to accurately quantify emissions rates of glass fibers from fibrous glass duct liners and duct boards.

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