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INDUSTRIAL HYGIENE FOUNDATION OF AMERICA, Inc.

HEALTH ASPECTS OF FIBROUS GLASS

A Detailed Summary

Medical Series, Bulletin No. 16-69

5231 Centre Avenue
Pittsburgh, Pennsylvania 15232
1969

TABLE OF CONTENTS

Introduction 1

Manufacture 2

Toxicological Information 4

Environmental Measurements 9

Binders 10

Discussion. 11

Recommendations 11

References 12

INTRODUCTION

Fibrous glass as it is known today has been produced since the 1930's.[1] The earliest fibers were very coarse, consequently quite irritating to the skin. For this reason, coupled with the fact that fibrous glass lint could be seen floating in air, the original manufacturer became concerned about possible respiratory effects of the material. This concern led to animal and clinical studies in the early forties. As a result of these studies, it was concluded that there were no permanent adverse health effects from fibrous glass, chiefly because the dusts were too large to be respirable.[2]

In the mid-fifties preliminary intratracheal and inhalation studies were conducted to resolve the question of possible pulmonary damage from glass wool fibers small enough to be respired. Unfortunately, these studies, which were inconclusive, lacked controls.[3]

Additionally, isolated case reports appeared in the literature which tended to implicate fibrous glass in a variety of pulmonary conditions, none of which were well documented;[4] however, despite such reports, a review[5] of the world literature in 1967 on the health effects of fibrous glass concluded that fibrous glass is "a relatively inert material with no fibrogenic or other significant toxic properties."

In 1963 the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limits Committee was presented a suggested value of 2 mg/m³ based on a report in the European literature, but no good substantiating documentation was available. It was recognized by the Committee that there was need for additional toxicological information, both animal and human, to allow setting of a valid threshold limit for fibrous glass. As an interim procedure, however, the Committee used the number 5 mg/m^3, based on possible adverse effects of chrome and other additives (subject to completion of toxicological studies being conducted within IHF).[4] Several fibrous glass manufacturers supported and cooperated in clinical and epidemiological research studies needed to gain objective information on the health effects of fibrous glass. The results of these experimental and human studies form the basis of this report.

An additional biostatistical cohort study being conducted by the United States Public Health Service, which will require additional time to complete, will effectively supplement these comprehensive studies undertaken to assist in the setting of a threshold standard on fibrous glass.

MANUFACTURE

Fibrous glass is produced in two forms—as a wool-type product primarily for thermal and acoustical insulation and as a textile fiber for fabrics and strength-giving reinforcements.

The methods of producing "wools" and textile fibrous glass are different. "Wool" products may be formed in one of three ways: (1) a steam blowing, (2) a flame blowing, or (3) a centrifugal process. Over the last fifteen years the steam blown process has largely been replaced by the centrifugal process.

This has resulted from a higher per cent of fibers being grouped more closely about the mean diameter, and the reduction in the average fiber diameter. The average diameter of fibers produced by the centrifugal process is now about 6-7μ. The flame blown process was introduced in 1944. This produces a fiber with an average diameter of 3μ with a range from the submicronic to about 5μ. It is primarily used in thin wall insulation applications where high thermal effectiveness based on weight performance is desired. These materials represent less than 1% of the fibrous glass insulation market.

Processes which produce textiles include continuous strand forming, staple fiber forming and continuous strand mat forming. In continuous filament-forming, numerous continuous filaments of glass are drawn from the platinum bushing and collected together into a strand which is wound onto a "take-up" package. These strands are then twisted and plied into yarn. The average range of fiber diameters varies from 3.5μ to 15μ. The 3.5μ average diameter (Beta) fibers make up less than 1% of the textile fibers produced. The bulk of the textile fibers are 9μ in average diameter.

The staple forming operation is an air-blown-drum collected process which produces a staple fiber 4-8 inches in length. These are collected into strands or bulk fiber used in filtration and electrical insulation. It is produced in very small quantities. The average fiber diameter is 9μ.

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The fibers for continuous strand mat are formed by the continuous strand process except that instead of pulling the strand by a "take-up" package, the continuous filament is laid transversely across a conveyer. This process produces a fiber diameter of 16μ. The mat is used chiefly for automotive reinforced plastics applications.

TOXICOLOGICAL INFORMATION

In 1968, the Industrial Hygiene Foundation (IHF) published a review of information on health effects of fibrous glass in order to provide general guidance to the field.[6] The "asbestos body" question (discussed in several recent articles by IHF's Dr. Paul Gross,[7] U. S. Public Health Service's Dr. Lewis J. Cralley,[8] Cambridge University's Dr. John M. G. Davis[9]) had been the basis for two false rumors: first, that the public at large was in imminent danger of the pathogenic effects from asbestos fibers in air of the general community, due to brake drum dust;[10] and second, that, because it had been shown to produce such bodies experimentally, long term exposure to fibrous glass must share the ability of asbestos to produce serious harm to the lungs not only in exposed employees of industry but in the public as well.[11] A number of attempts have been made to correct these two false rumors which are based on unsupported assumptions. The most recent of these was an article by Gaensler[12] in the New England Journal of Medicine which cites data on 17 human ferruginous bodies presented at a Mellon Institute seminar sponsored by IHF on November 22, 1968. These data, which have since been expanded to include 28 such bodies (obtained from a similar number of autopsied persons with no known occupational exposure to asbestos), showed that in every instance chrysotile asbestos, the type which constitutes about 90% of all asbestos used in the United States, could be definitely excluded by electron diffraction. In addition, as pointed out in an article recently submitted for publication, the crystalline electron diffraction pattern present in each case in this sample also specifically excluded glass fiber as the central core.[13]

False rumors are thus in the process of being squelched with regard to predictions of epidemics of asbestos related lung disease and cancer in the general population. Having dealt with this most serious public health rumor, which had also become a matter of controversy in jurisdictional disputes between labor unions, let us review systematically the present status of our knowledge of toxicologic data concerning fibrous glass, along lines suggested by the ACGIH Threshold Limit Committee[14] under general headings of Experimental Animal Data and Data From Human Subjects.

Experimental Animal Data. An experimental study which appeared in 1960 by Dr. Paul Gross[15] on the pulmonary effects of glass dust alone (of respirable size) showed this dust to be biologically inert; however, the dust was in flake form, i.e, its diameters were roughly equal, but the flakes were very thin. Glass dust length must be three or more times the ~~width~~ to merit the term "fiber," so the question remained whether the same material in fiber form would also be inert. Prior to his death, Gardner[2] in 1940 found it impossible to produce pulmonary damage from exposure to glass wool dust, although maximum inhalation exposures possible were used. He had concluded that the dust available to him was largely non-respirable. It remained for Dr. Gross to perform experiments with glass fibers of respirable diameter (1μ).

Dr. Gross presented his findings at the IHF Seminar on Fibrous Dusts at Mellon Institute of Carnegie-Mellon University in 1968,[16] and these will be presented in detail at the 1969 meeting of the International Congress on Occupational Health in Tokyo. He reported that animals exposed to plain glass fiber, and glass fibers coated with either a wool or a textile type binder, all gave evidence of the reaction characteristic of a biologically "inert" dust. While the inhalation study is still in progress, over 18 months have now elapsed without development of a single case of fibrosis or lung cancer, and, furthermore, animals injected with fibrous glass intratracheally in preliminary studies that had lived 2 years have failed to show any such evidence. (This is considered significant since under similar conditions the same animal species (rats) produced both fibrosis and lung cancers as early as 16 months from beginning of their exposure to hammer-milled chrysotile.)

Emphysema after experimental exposure to fibrous glass has been reported but the term as used by the authors does not designate the centrilobular and panlobular types, which are the only ones associated with symptoms of chronic obstructive bronchopulmonary disease in man. Instead, the authors refer to a transitory effect from which the animals recovered.[17] There is thus no good evidence of true experimental emphysema production from fibrous glass.

Studies specifically designed to determine if fibrous glass dust will cause or aggravate pulmonary emphysema are still in progress within IHF's research laboratory; however, the results of studies with other non-fibrous inert dusts suggest such to be improbable.

Data From Human Subjects. As may be expected, occasional (usually isolated cases) have occurred, and some of these have appeared in the literature, concerning illness associated with past exposure to fibrous glass dust.[4, 18, 19]

None of these have withstood critical diagnostic evaluation, and the authors have usually confined their comments to questions concerning possible significance and in most cases have called attention to the danger inherent in concluding that since larger glass fibers may be observed with the naked eye in lungs and sputa of individuals recently exposed to heavy concentrations of dustiness, therefore, any disease found to be present must have resulted from such exposure.

Clinical epidemiological studies of employees of the largest and oldest fibrous glass producing plant have been performed by a number of scientists and physicians. Wright's[20] findings on review of chest radiographs of approximately 1400 employees (some of whom had been employed upwards of 25 years) was reported as being completely negative for any fibrous glass effect on the lungs observable by X-ray.

Findings have been reported[20] of another epidemiological study conducted by the Industrial Hygiene Foundation with the help of Drs. Antonio Ciocco, Philip E. Enterline, H. M. D. Utidjian and Benjamin J. Lambiotte. After categorizing the total past exposure of all male plant employees into one of three groups, i.e., lightest, medium and heaviest dust exposure over their entire period of employment at the plant, groups of 30 men were selected (by random means) in each of three age groups, i.e., less than 30, 30-49, and greater than 50 years. Studies of the health of these men were next performed by means of (1) a questionnaire which was a slightly modified version of the British Medical Research Council's Chronic Bronchitis questionnaire (patterned closely after that used by Drs. R. R. MacDonald and Margaret R. Becklake in their studies of Canadian asbestos miners), and (2) an evaluation of lung function by means of ventilatory measurements, i.e., total vital capacity. These data were presented by Dr. Utidjian, representing Dr. Ciocco, at the IHF Fibrous Dust Seminar in 1968, with the conclusions that they showed no clear relationships between degree of exposure as defined in the study and any of the disease parameters studied. Advancing age alone does appear to be related to chest illness, or symptoms and impairment of ventilatory capacity which is, of course, predictable. Time had not permitted further analysis of pulmonary function tests, but subsequent analysis of Timed (lst sec.) Vital Capacity still fails to show any grouping of abnormalities in relation to degree of exposure.[22] Maximum mid-expiratory flow rates have not yet been calculated, but these should logically be comparable to the timed vital capacity findings which were, as indicated, essentially negative. Thorough medical and pulmonary physiological laboratory evaluations of smaller samples (i.e., half) of two groups, representing the oldest, <u>most</u> heavily exposed and the oldest <u>least</u> heavily exposed individuals are now in progress in the cardiopulmonary laboratory of a well equipped regional hospital, and results of these will be forthcoming some time later. Their purpose is to quantitate any changes of significance in an additional measurable parameter, pulmonary diffusion, which are not excluded by tests of ventilatory function.

Another important human study is the pathological appearance of lungs of long-termed employees of the industry coming to autopsy for any reasons, when these become available. A study of 10 such lungs has failed to show any evidence of fibrosis, cancer or other changes attributable to fibrous glass.[23]

During their initial exposure, some individuals contacting glass fiber of greater than 5μ diameter sustain transitory (24-hour) irritation. Where there is continued exposure, this effect usually lasts somewhat longer (two to three days). Present knowledge points to a mechanical etiology for this phenomenon, which is not related quantitatively to air concentrations of the glass fibers, but to gross amounts of glass fiber deposited on the skin from handling of fiber glass materials.[24]

ENVIRONMENTAL MEASUREMENTS

Reports of in-plant attempts on the part of the Kettering Laboratory,[25] the U. S. Public Health Service and others to quantitate glass fiber of respirable size in plants manufacturing fibrous glass, have shown that there are very low levels of glass fiber in the workers' breathing zone. While respirable glass fibers have always been present in the plant air, there has been no apparent trend for these to increase in recent years—according to Konzen.[1]

All tests on ventilating ducts made of or lined with fiber glass of which we are aware have failed to show measurable erosion or air contamination even after 12 years or more of use.[26]

Dusts encountered by insulation workers are of varied composition and require consideration independent of their glass fiber content. They are not, therefore, suitable for coverage here.

BINDERS (INCLUDING WOOL BINDERS AND TEXTILE SIZING WHEN USED AS A BINDER)

For purposes of threshold standards setting, it was considered necessary to discuss binder and size compositions which reflect all components of those used by the major manufacturers of both wool and textile products. It is the employees of such plants who will receive the greatest and longest exposure and it was considered important not to overlook any additive, such as chrome, which has known pathogenic (carcinogenic) potential. Even though the 1966 documentation of the threshold limit proposed for fibrous glass refers to chrome, chrome additives have been supplanted almost entirely by other more useful and versatile substances documented in detailed reports received by IHF from manufacturers of fibrous glass.[24, 27] There is relatively a greater weight and volume of binder in insulation type products as compared with those sizings used in textiles, and there has been little or no change in the basic make-up of the phenol-formaldehyde resin binders in the past 30 years.

The model phenol-formaldehyde binders and starch sizes used in IHF's studies, therefore, are considered truly representative of those in actual use in industry. Epoxy sizes are also widely used but the diameter of fiber is so large that it is considered not respirable.

It should be recognized that others in industry purchase textile yarns for incorporation into plastic materials of an infinite variety. No attempt has been made to anticipate the nature of such exposures—they constitute a mixed type exposure and should be dealt with in accordance with ACGIH Threshold Limits Committee recommendations for mixtures of dusts.

DISCUSSION

A prime basis of the 5 mg/m^3 value threshold limit suggested by the ACGIH in 1963 appears to have been concern for the chrome content in the textile sizes. The wool binders never have contained chrome; and while chrome containing sizes once represented a significant percentage of the textile-type sizes, these have been in process of being phased out for almost 10 years. At present, from data which has been received by IHF from the leading manufacturers of fibrous glass, only 2-3% of the total textile production has chrome additives and these for specialty applications.

RECOMMENDATIONS

A tentative threshold limit was assigned to fibrous glass by the Threshold Limit's Committee in 1963 based on knowledge then available to it.

A prime basis of the 5 mg/m^3 value suggested at that time appears to have been the concern of the Committee for the chrome content in the textile sizes, which in light of present knowledge, discussed herein, appears unjustified.

As well controlled data are now available from human as well as animal studies to demonstrate that there is no adverse health effect from exposure to fibrous glass of respirable size, it is recommended that the threshold be raised to that of an inert dust.

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