

Fibers Released from Cigarette Filters: An Additional Health Risk to the Smoker?¹

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ABSTRACT

Tests of 12 popular brands of cigarettes manufactured by 6 companies from the United States have shown that fibers were released from the filters and that there exists probable cause to suggest that fibers are inhaled and/or ingested. Filter fibers, made of cellulose acetate, were implanted in mice for 6 months. The fibers withstood degradation and retained the tobacco-brown color and bright fluorescence of the tobacco tar that had been adsorbed from cigarette smoke. With a confocal laser scanning microscope, we have observed cigarette filter fibers in lung tissue from patients with lung cancer and who were known to be habitual smokers. These findings raise the question as to whether fibers released from cigarettes further jeopardize the health of smokers and document the need to test components of cigarette filters for toxicity and tumorigenicity.

INTRODUCTION

The filter cigarette was not a dominant factor in the marketplace before the 1950s when it was thought to be "a novelty item directed mainly at the women's market" (1) and commanded less than 1% of sales (1-4). At that time, the typical smoker preferred a 70-mm nonfilter cigarette (1). In response to emerging health concerns (5-7) and the first report in 1964 by the Surgeon General on smoking and health (8), acceptance of filter cigarettes increased rapidly (1, 4, 7, 9). By 1983, approximately 95% of the cigarettes sold in the United States contained filters (1-4); this high percentage has been sustained to the present (9).

The purpose of the cigarette filter has been described in foreign and domestic patents (10-12). A patent awarded in 1956 in the United States to Knudson (10) stated that the cigarette filter was designed for: "the removal of any desired proportion of the tars and nicotine present in tobacco smoke which account for its irritating properties and potential toxicity . . . and the remarkable nature of my invention that I can in fact achieve almost complete removal of the stated substances and even within the limits imposed by practical factors such as the necessity for maintaining a free draw. . . ." However, the author notes that "Actually, of course, complete removal of these substances is not desirable due to considerations of taste and flavor. Moreover, in the event all of the tars and nicotine are removed, no 'smoke' is produced, i.e., the smoker draws into his mouth only colorless and highly unpalatable combustion gases."

The technology of making cigarette filters and the characteristics of the filter fibers have also been described in patents (10-12), and this subject has been summarized in a monograph (1). Filters of almost all cigarettes consist of fibers that are made of cellulose acetate, are coated with the plasticizer triacetin to bind individual fibrils, and contain the amorphous microparticulate (granule size, $\leq 1.0 \mu\text{m}$) pigment TiO_2 to provide a milk-white appearance (1, 4, 10-12). The standard filter contains approximately 16,000 fibers (fiber diameter, $\sim 20\text{--}50 \mu\text{m}$) (1, 4, 11). Filter fibers have a unique Y shape that has been engineered to maximize the surface area for tobacco tar

adsorption (1, 4). When viewed with a white light microscope, the cellulose acetate fibers appear to have an internal channel-like structure. This pattern is due to the image of one arm of the "Y" that is visible in the translucent fiber. Most other synthetic fibers are round, ovoid, or serrated (13, 14), and we know of no other synthetic or natural fiber that has the same Y shape as that of the cigarette filter fiber. The Y shape, TiO_2 , and other features that are readily visible have enabled us to distinguish, microscopically, cigarette filter fibers from other synthetic as well as natural fibers.

We report here that fibers are released from cigarette filters. This finding raises questions concerning the health risk of filter fibers that may be inhaled or ingested by the millions of people worldwide who smoke filter cigarettes.

MATERIALS AND METHODS

Cigarettes Analyzed. Cigarettes used were purchased from local vendors. The cigarettes included 20 different popular brands, and these brands were selected to represent the products of 6 different manufacturers in the United States. Smoked cigarettes were provided by adult volunteers or were obtained with the use of a mechanical smoker.

Cigarette Filter Fiber Identification. Fibers from smoked and non-smoked cigarettes were examined with a conventional fluorescence microscope that had been configured to provide mercury arc illumination, with filter configurations optimal for FITC and TRITC,³ and to produce white light illumination (Reichert-Jung; Cambridge Instruments, Inc., Buffalo, NY).

Human lung specimens were also examined with a Nikon Optiphot microscope that had been interfaced with a MRC 600 argon laser microscope (Bio-Rad Microscience Division, Cambridge, MA). The details of this technology were reported elsewhere (15).

Fibers were defined as a particle with a length:width ratio (i.e., aspect ratio) $\geq 3:1$. Particles with an aspect ratio of less than 3:1 are defined as structures.

To delineate cigarette filter fibers from other fibers, we established the following criteria: (a) a central channel-like motif that reflects one arm of the Y-shaped fiber; (b) TiO_2 particle pattern; (c) fiber diameter; (d) arm diameter; (e) translucence; (f) smooth fiber surface; and (g) bright fluorescence in the TRITC and FITC filter configuration of filter fibers from smoked, but not from non-smoked, cigarettes.

Evaluation of Filter Fiber Release. A study was conducted using cigarettes of 12 different brands to ascertain whether fibers were released from cigarette filters. Different tests performed in this study included the following analyses in which filter fibers were identified and enumerated with the use of a stereo-zoom microscope: for wrapper examination, filter fibers trapped between the cellophane wrapper and the unopened pack of cigarettes were counted; for residue observation, after the cigarettes were carefully removed from a pack, the residue (i.e., tobacco flakes and debris) at the bottom of the pack was poured onto a black paper and the number of filter fibers was counted; in the tap test, a cigarette was placed in a plastic tube (diameter, 13 mm) and dropped 3.5 cm onto a black paper. Thereafter, the number of filter fibers released was assessed; the drop test was similar to the tap test, but the cigarette was released from a height of 15 cm; in the tongue test, the filter end of a cigarette was touched to the tongue of a volunteer, and then a clean microscope slide was pressed onto the same site. Thereafter, the number of fibers transferred from the tongue to the slide were delineated. To facilitate screening different brands of filter cigarettes, a tissue test was established to replace the tongue test. In the tissue test, the filter end of a cigarette was

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³ The abbreviations used are: TRITC, tetramethylrhodamine 5-isothiocyanate; CLSM, confocal laser scanning microscope; PAH, polycyclic aromatic hydrocarbons; M ϕ , macrophage.

touched to the surface of a piece of bovine liver, and the number of filter fibers that had been released was counted.

Fiber Degradation and Tar Retention Assessed in Mice. Filter fibers from smoked, nonsmoked, or a mixture of both types of cigarettes were implanted i.p. or s.c. into mice. On different days thereafter, the fibers were recovered and analyzed.

Fibers in Human Lung Specimens. Patients were identified who were to undergo a lobectomy or pneumonectomy for removal of a lung cancer. Human lung tissue from the surgical specimens was obtained with written informed consent under approved investigative protocols. Freshly collected lung specimens that had not been fixed, sectioned, or stained were mounted in a viewing chamber and examined with white light, polarizing, fluorescent, and confocal microscopes. Kodak Ektachrome film was used for photographic documentation and to record split-screen images of white and argon light views obtained with a CLSM of cigarette filter fibers. A more complete description of these methods has been described elsewhere (15, 16).

RESULTS

Filter Fibers Identified within and upon Cigarette Packs. An examination of 20 different brands of filter cigarettes revealed that the filters consisted of a homogenous bundle of cellulose acetate fibers; no other types of fibers were present. Moreover, the fibers from the filters of various cigarettes were morphologically indistinguishable. From this group of 20 brands, 12 brands were selected for further study.

In all instances ($n = 24$ packs; 12 different brands), we observed filter fibers located between the cellophane wrapper and the unopened pack (9.83 ± 8.0 , (SD); range, 3–32) and in the pack residue (17.9 ± 8.4 ; range, 6–30) (Table 1).

Tests Defining the Release of Filter Fibers. Filter fibers were discharged from all cigarettes that had been tapped (3.44 ± 2.4 ; range, 1–9; $n = 60$ cigarettes) or dropped (7.34 ± 4.0 ; range, 3–15) (Table 1).

Other tests were conducted to determine whether filter fibers were released if touched to the tongue as may occur during smoking. A procedure was established in which the filter end of a cigarette was touched to the tip of the tongue; immediately thereafter, a microscope slide was touched to this same site. In all instances, the microscope slide contained cigarette filter fibers. In subsequent experiments, we observed that a larger number of fibers were recovered from the tongue using clear, polypropylene package-sealing tape than could be obtained with a microscope slide.

To extend our findings of fibers released from cigarette filters in the tongue test and to facilitate counting the fibers, subsequent experiments were conducted in which the filter end of the cigarette was touched to the surface of bovine liver. In all instances, fibers were detached from cigarette filters (14.0 ± 3.4 ; range, 9–19; $n = 60$ cigarettes) (Table 1). In tests of both smoked and nonsmoked cigarettes, we also noted that additional fibers were released when the same filter had been touched to either the tongue or tissue a second and third time.

Fibers were observed protruding from cigarette filters. Fig. 1A illustrates displaced filter fibers of a cigarette that had been removed

carefully from a pack that had been opened in the laboratory. Fibers were also released from cigarettes that had been smoked mechanically (Fig. 1B).

Filter Fibers of Smoked Cigarettes Fluoresce. Fibers of filters from smoked and nonsmoked cigarettes could be distinguished easily. Fibers of filters from nonsmoked cigarettes were translucent and clean (Fig. 1C). Fibers of filters from smoked cigarettes were also translucent; however, these fibers had a light brown residue caused by tobacco tar that had been adsorbed by the filter (Fig. 1C). Tobacco tar, which is the particulate (*i.e.*, nongas) phase of cigarette smoke (1, 8, 9), adsorbed onto filter fibers is more easily recognized microscopically when one examines a bundle of fibers. The tobacco brown of the adsorbed tar is readily apparent with the naked eye in a comparison of intact filters from a smoked and a nonsmoked cigarette.

Tobacco tar trapped on the surface of an individual filter fiber was manifested more vividly by viewing the fibers with a fluorescence microscope. Fibers of filters from nonsmoked cigarettes displayed very little or no fluorescence (Fig. 1D). In contrast, fibers of filters from cigarettes that had been smoked fluoresced brilliantly (Fig. 1D). The intense fluorescence of the adsorbed tobacco tar was observed for fibers that were viewed with either a FITC [fibers appeared green (Fig. 1D)] or TRITC [fibers appeared red (not shown)] filter configuration. Moreover, the intense fluorescence was also observed for fibers from low-tar cigarettes and cigarettes that had been smoked partially.

It is well known that the fluorochromes FITC and TRITC, used commonly for labeling antibodies and other agents, are photobleached quickly. In contrast, the fluorescence of tobacco tar on the filter fibers was not photobleached. The resistance to photobleaching was demonstrated by exposing a small segment of the filter fiber for a prolonged time (>15 min) to the argon laser of a CLSM or to the mercury arc illumination of a fluorescence microscope.

The fluorescence of fibers from smoked cigarettes was caused by adsorbed tobacco tar. This was demonstrated by eluting the adsorbed tobacco tar from filter fibers with methanol or other solvents. After the tobacco tar was washed off, the fiber retained its characteristic morphology but did not fluoresce.

Filter Fibers Resist Degradation and Retain Tobacco Tar. Having observed that fibers were released from cigarette filters, we conducted tests to determine whether the fibers resisted degradation and retained the adsorbed tobacco tar.

In all instances, filter fibers that had been implanted i.p. or s.c. became encapsulated (Fig. 2A). Histological examinations of the capsule (Fig. 2B) showed that the implanted fibers had become surrounded and enmeshed in tissue containing collagen, fibroblasts, and Mφ (Fig. 2B; harvest day 183). The high-power view of Fig. 2B also illustrates the Y shape of the filter fibers as well as the TiO₂ pigment.

Fibers implanted i.p. or s.c. in mice showed no evidence of degradation (Fig. 2, B–D). In addition, the fibers retained their tobacco-brown color (Fig. 2C). The absence of fiber degradation and retention of tobacco tar were recorded for groups of mice ($n = 6$) in which the

Table 1 Cigarette filter fibers observed in cigarette pack wrapping and pack residue and released in tap, drop, and tissue tests

Cigarette		Cigarette filter fibers released				
Manufacturer ^a	Brands ^a	Wrapped ^b	Residue ^b	Tap ^c	Drop ^c	Tissue ^c
1–VI	A–L	9.83 ± 8.0^d 3–32 ^e	17.9 ± 8.4 6–30	3.44 ± 2.4 1–9	7.34 ± 4.0 3–15	14.0 ± 3.4 9–19

^a $N = 12$ brands total; 2 brands from each of 6 different manufacturers in the United States.

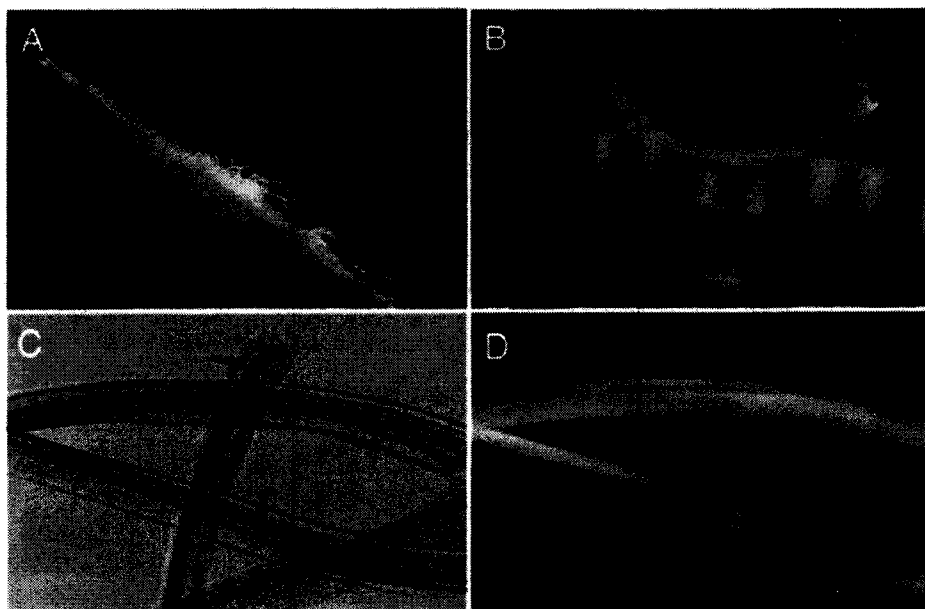
^b $N = 24$ packs (12 brands).

^c $N = 60$ cigarettes (12 brands).

^d Mean $\pm$ SD.

^e Range.

Fig. 1. Morphology and fluorescence of cigarette filter fibers. A, fibers protruding from a cigarette filter (filter diameter, 8 mm); B, a filter fiber, coated with tobacco tar, that had been released from a cigarette that had been smoked mechanically. The displaced fiber was captured with a fine-mesh screen and was viewed with a fluorescence microscope equipped with a FITC filter configuration. $\times 100$; C, a view with a white light microscope of four cigarette filter fibers. Two of the fibers were from a nonsmoked cigarette and two of the fibers were from a smoked cigarette. Arrows identify the appearance of the channel-like motif in the center of the fibers; this structure reflects the unique Y-shape morphology of the translucent fiber. Also shown are the pepper-like grains of the TiO_2 pigment that is added to the cellulose acetate polymer to give the filter fiber a white appearance. $\times 200$; D, the same microscope field as that of C but observed with a fluorescence microscope with a FITC filter configuration. The two fibers from the smoked cigarette display a high level of fluorescence (green) that emanates from tobacco tar that has been adsorbed onto the filter fibers from cigarette smoke. In contrast, the fibers from the nonsmoked cigarette do not fluoresce and, thus, are not visible $\times 200$.



fibers were harvested after 57 and 183 days. The bright fluorescence of adsorbed tobacco tar was observed with either a FITC (Fig. 2D) or TRITC (not shown) configuration.

Other experimental groups consisted of mice that had received a mixture of fibers from smoked and nonsmoked cigarettes. Fibers that had been retrieved 6 months later from the mice could be distinguished easily by fluorescence microscopy.

Cigarette Filter Fibers Observed in Human Lung Tissue. Specimens of lung tissue that had been freshly collected and that had not been fixed, sectioned, or stained were examined with a CLSM to

identify cigarette filter fibers. A criterion was established (see "Materials and Methods") whereby cigarette filter fibers were distinguished from other fiber types.

Shown in Fig. 3 are split-screen images obtained with a CLSM of cigarette filter fibers present in fresh human lung tissue. Fig. 3A is a white light and fluorescent light, low-power view of a cigarette filter fiber in a fresh human lung specimen. Fig. 3B is a similar view of another fiber, but this fiber is shown at a higher magnification so as to illustrate features characteristic of a cigarette filter fiber.

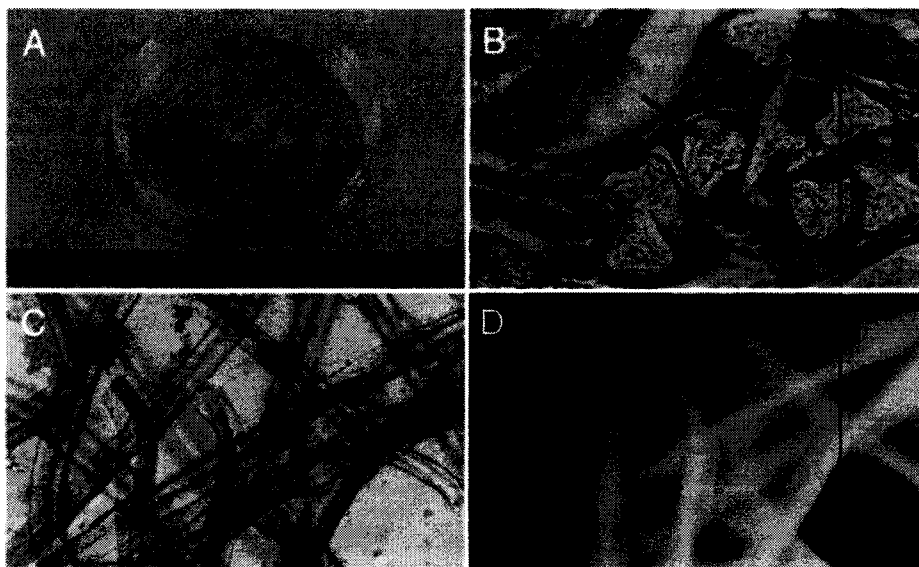


Fig. 2. Filter fibers of smoked cigarettes that had been implanted into mice. A, a view of filter fibers that had been placed into the peritoneum of a mouse and harvested after 57 days. The filter fibers had become encapsulated. Arrow, capsule located on a bed of fat (*mm* scale); B, section ($10\ \mu\text{m}$ thick) of a wax block histological preparation of encapsulated cigarette filter fibers harvested after 183 days. In all instances, fibers that had been implanted into the peritoneum or s.c. ($n = 6$ mice) became encapsulated, showed no evidence of degradation, and retained the adsorbed tobacco tar. The arrow identifies one of eight filter fibers, that have been transversely cross-sectioned. This view illustrates the unique Y-shape morphology of cigarette filter fibers. The TiO_2 pigment of the filter fibers is also illustrated; the pigment appears as amorphous black specks within the fiber. There was no evidence of fiber degradation. The capsule was similar to that shown in A. The filter fibers had been entwined in a heterogeneous tissue that contained fibroblasts. H & E, $\times 200$; C, a view with a white light microscope of cigarette filter fibers that had been isolated with forceps from the tissue capsule. There was no evidence of fiber degradation. Also, the fibers were tobacco-brown, and there was no perceptible reduction in the amount of adsorbed tobacco tar. $\times 200$; D, the same microscope field as that of C but observed with a fluorescence microscope with a FITC filter configuration. The high level of fluorescence further documented the retention *in vivo* of the tobacco tar that had been adsorbed onto the fibers during smoking. $\times 200$.

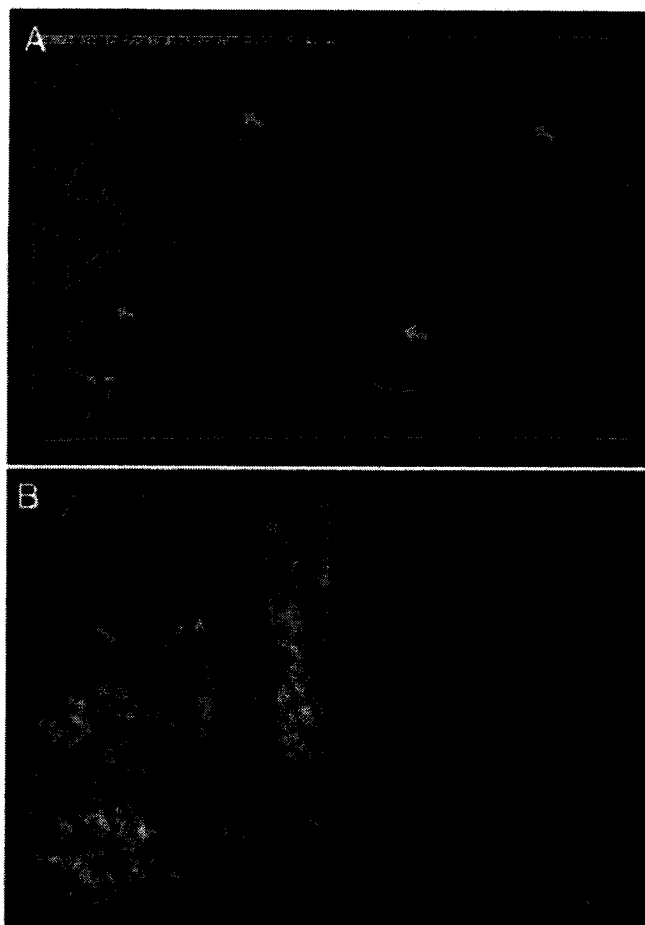


Fig. 3. Cigarette filter fibers present in human lung tissue are illustrated in split-screen images obtained with an argon laser scanning microscope. A, a low-power view obtained with an argon laser of a cigarette filter fiber in a fresh, nonfixed, and unstained lung tissue (left). One arm of the Y-shaped, translucent cigarette filter fiber appears as a channel-like structure (two arrows). A single, confocal, optical section (thickness, 5 μ m) of the lung tissue (right) illustrates the high level of fluorescence (FITC configuration) of the fiber at left. Fiber diameter, 32 μ m (see scale bar); B, a high-power picture acquired with an argon laser of a lung tissue specimen exhibiting more fully the unique features of an inhaled cigarette filter fiber (left). The channel-like structure of the Y-shaped cigarette fibers is apparent (bar, 6 μ m). Arrow, prominent TiO₂ granules. A single optical section (2 μ m) of the tissue obtained with the microscope in the confocal mode (right). This view shows the bright fluorescence of the cigarette filter fiber (FITC configuration). Fiber diameter, 20 μ m (see scale bar).

DISCUSSION

In a previous study, we examined freshly excised human lung tissue with the intent of defining the most suitable method of isolating M ϕ (17). The goal of this study was to identify the expression of surface membrane cytokine receptors and to formulate a mixture of human recombinant cytokines that could be delivered as an aerosol to achieve the *in situ*, site-specific activation of human lung M ϕ (18). In these experiments, a fresh, nonfixed, and unstained lung specimen was placed in a viewing chamber and examined with a fluorescence microscope. A fluorescence microscope was chosen to screen different lung specimens because it has been known for many years that lung M ϕ of habitual smokers display a high level of fluorescence; we (17) and others (19) have attributed the fluorescence primarily to ingested tobacco tar. Our inspection of fresh human lung tissue revealed the presence of fluorescent fibers. This serendipitous observation prompted us to inquire as to whether these fibers were inhaled cigarette filter fibers and inspired us to undertake the study reported herein.

We have demonstrated that fibers are released from the filters of popular American cigarettes. In these experiments, we used cigarettes from packs that had been opened carefully in our laboratory. Larger numbers of fibers would be expected to be released by cigarettes that had been distressed; e.g., when a cigarette pack is dropped, crushed, or damaged in some other manner as may occur during daily activities.

We have observed filter fibers between the cellophane wrapper and the unopened pack. This would suggest that cellulose acetate fibers are present as airborne contaminants in the high-speed filter cigarette making (>10,000/min) and cigarette packaging operation. Filter fibers were also discovered in the residue of all packs examined. Presumably, these fibers were released from the cigarettes during packaging or shipping. Our tests also revealed that filter fibers were dislodged when the cigarettes were tapped or dropped.

We have shown that cigarette filter fibers became detached when the filter was touched to the human tongue or bovine liver. In related experiments, cigarettes with recessed filters were also evaluated in the tongue and tissue tests. The tipping paper of the recessed filter prevented the fiber bundle from touching the tongue and tissue, and no fibers were released. Thus, the recessed filter provided a safeguard against contact-associated fiber release.

Having established that cigarette filter fibers are likely to be inhaled or ingested, experiments with mice were undertaken to define whether the fibers were degraded *in vivo*. No degradation was detectable. The absence of cellulose acetate fiber deterioration *in vivo* was not unexpected, and we know of no mechanism(s) whereby these acetylated polysaccharide fibers would be biodegraded under physiological conditions.

We also noted that the filter fibers that had been implanted in mice for 6 months exhibited their characteristic tobacco-brown color and bright fluorescence, thus illustrating that tobacco tar had been retained on the filter fiber.

The presence of fluorescent PAH in tobacco tar has been well documented (9, 20–24). About a dozen PAH have been identified in cigarette smoke (20–24), and several of these PAH [e.g., 3,4-benzo(a)pyrene] have been shown to be human carcinogens (9, 20–24).

Other investigators have documented the adsorption of PAH and tobacco-specific N-nitrosamines as well as different heavy metals to cellulose acetate cigarette filter fibers (9, 22).

We have observed cigarette filter fibers in human lung specimens. We acknowledge, nevertheless, that microscopic screening of lung specimens for inhaled fibers is labor intensive and unsuitable for quantitative analyses. To this end, additional techniques must be established for the identification and enumeration of different synthetic and natural fibers. A method that we are exploring is one in which a 0.5-g human lung specimen is digested and the fibers present in the residue are collected onto a micropore filter. Thereafter, the classification and unequivocal identification of various fibers may be achieved with combined microscopic and spectrophotometric analyses such as those of established protocols that are used by forensic pathologists (13, 14).⁴ Delineation of the health risks will require correlating fiber burden with the pathological findings, clinical observations, and medical, occupational, and behavioral history of the patient.

The following multicomponent hypothesis has been defined: (a) filter fibers are released from cigarettes and are ingested and/or

⁴ J. L. Pauly, H. M. Jezewski, M. I. Rodriguez, E. L. Hurley, and R. J. Streck. Inhaled natural and synthetic fibers identified in fresh, non-fixed, and non-stained human lung specimens, submitted for publication.

inhaled; (b) fibers that have been inhaled resist degradation and may be sequestered in the lung of smokers for a prolonged time, possibly for life; (c) fibers may accumulate in large numbers, particularly in the lungs of habitual smokers whose clearance mechanism has been impaired by smoking; (d) inhaled cigarette fibers may induce acute and/or chronic inflammation; (e) different chemicals in the tar that had been adsorbed onto the fibers (e.g., PAH, tobacco-specific *N*-nitrosamines, heavy metals, phenols, etc.) are released, possibly at variable rates, into the adjacent microenvironment, and (f) the slow release of carcinogens and tumor promoters may induce and/or accelerate malignant transformation; moreover, the nondegradable fiber and the discharge of various tar-associated toxins and heavy metals may provoke chronic inflammation.

Filter cigarettes have evolved through several steps (1). The first was probably the use of tipping papers that had been selected to prevent the cigarette from sticking to the lip of the smoker. The second step was the addition of a stiff paper tube at the end of the cigarette; this tube acted as a built-on holder and prevented sticking. A third step was the insertion of a small wad of cotton fiber in the paper tube placed up against the tobacco column. This tuft of fiber performed the further function of retaining any loose particles of tobacco that might enter the mouth of the smoker and may have had some filter effect. Paper and cotton filters have also been used; these preceded the introduction of the cellulose acetate filters. The smoker has preferred the taste of acetate-filtered smoke and the neat appearance of the typical acetate filter tip (1).

Many other changes have occurred in both the composition and design of the cigarette (1, 25). A partial listing includes variation in tobacco type, blend, and processing; reduction in tar and nicotine delivery; and the incorporation of reconstituted tobacco, expanded tobacco, as well as different chemical "additives." Likewise, the design of the cigarette has changed (e.g., paper porosity, side ventilation, column length and diameter, and charcoal filter). These changes have been shown to alter smoking behavior (9). Taking into account these variables as well as the complex nature of cigarette smoke, it would seem difficult to assess accurately health benefits derived from the cigarette filter.

An extensive search of the literature has identified only two reports that relate to our study.

The first report (26) is a 1958 publication of a study, sponsored by a tobacco company in the United States, in which light and transmission electron microscopes were used to visualize the physical organization and content of cigarette smoke deposits of filter and nonfiltered cigarettes that had been smoked mechanically and in a way which attempted to approximate the manner in which the smoke deposits come in contact with the surface of the respiratory tract of the smoker. Filter fibers were released from all six of the popular-brand United States filter cigarettes that were examined; these six brands are currently marketed.

The second report (27) described a xanthogranuloma formed by a cigarette filter tip in the lung of a patient who had inhaled a cigarette filter tip 1 year previously. Pathological findings of the lower lobe lung specimen identified the cigarette filter tip. The histology revealed an inflammatory infiltrate of plasma cells, large foamy histiocytes, and lymphocytes. This case study demonstrated that the inhaled filter was not degraded, was the source of a chronic inflammatory response, and was the probable cause of the observed tumor.

In summary, we have demonstrated that: (a) filter fibers were released from cigarettes; (b) there exists probable cause to suggest that cigarette filter fibers are inhaled and/or ingested; (c) the discharged fibers were coated with tobacco tar, and it is common

knowledge that tobacco tar contains adsorbed onto filter fibers contains carcinogens [e.g., PAH and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone] and toxins; (d) cigarette filter fibers implanted in mice for a prolonged time retained their morphology and adsorbed tobacco tar and thus the cellulose acetate fibers resist biodegradation; and (e) cigarette filter fibers have been identified in human lung specimens. These findings establish the need for studies analyzing the toxicity and tumorigenicity of cigarette filter components.

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