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Industrial Hygiene Survey Report
Worker Exposures During Sugar Cane Harvesting
Florida Sugar Cane League
Clewiston, Florida

Survey Conducted by:
Mark Boeniger
Bruce Hills

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Mark Boeniger

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Literature was reviewed which dealt with commercially important plant species which contain amorphous silica. Specifically, results were presented of a field survey of sugar cane field workers in Florida. Determinations were made of the airborne concentration of amorphous silica fibers to which these workers were exposed. The airborne fibers ranged in size from 3.5 to 65 micrometers long with an average diameter of 0.6 micrometers. The concentration of these fibers in the air was as high as 300,000 fibers per cubic meter during cane cutting activities. Polyaromatic hydrocarbon concentrations were detected in the burnt leaf, but the concentrations in air were well below the limit of detection. The author recommends that comprehensive monitoring be considered for exposure to biogenic fibers among field workers, as well as refinery workers. The author also suggests that exposure to biogenic silicates in other industries which involve processing of agricultural commodities should be investigated. Solubility and persistence of these particular fibers in biological fluids should be considered.

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Purpose of Survey:	To perform a survey of sugar cane operations during harvesting in Florida to obtain preliminary data on the potential for exposure to biogenic silica fibers, polyaromatic hydrocarbons, and total dust.
Employer representative contacted:	Joseph Orsenigo, Ph.D, Vice-President - Research, Florida Sugar Cane League
Employee Representatives Contacted:	John Wilkie, Local Coordinator, West Indies Central Labour Organization, South Bay, Florida H. F. Edwards, Chief Liaison Officer, West Indies Central Labour Organization, Washington, D.C.
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ABSTRACT

The literature has suggested that many commercially important plant species contain amorphous silica. This report provides a summary of that literature as well as the findings from a field survey in Florida of sugar cane field workers where airborne concentrations of amorphous silica fibers were determined. In addition to the fiber analysis, concentrations of polynuclear aromatic hydrocarbons (PAHs) and total airborne dust were also determined.

It was confirmed that biogenic amorphous silica fibers exist in the mature sugar cane leaf and that these fibers become airborne during the manual harvesting of the cane after the leaf is burned. Airborne amorphous silica fibers were found that were 3.5 to 65 um long (mean = 12 um) with an average diameter of 0.6 um. Air concentrations were calculated to be as high as 300,000 fibers per cubic meter of air during cane cutting. Some PAH compounds were found to be present in the burnt leaf but the concentrations were below the limits of detection in the air. The health significance of these findings to sugar cane workers as well as to other agricultural workers are discussed.

INTRODUCTION

A number of different plant species have been shown to normally contain substantial amounts of silicon in the form of silica (SiO_2) and complex silicates. Biogenic silica is insoluble, amorphous, and has therefore been described as opaline silica (1). Knowledge of the existence of these bodies was first gathered by Russian botanists in the early 1800's (2).

The presence of plant silica has been most studied in food crops and its presence is thought to be biologically important. In dry plant matter, SiO_2 concentrations have been measured at up to 12% by weight in rice (3), 3.4% to 5.6% in wheat (4), up to 16.6% in corn (5), and 1% to 11% in oats (6). Prairie grass has been found to average about 3% silica by dry weight with a range of 1% to 7.7% (7). Non-food plant species that have been found to contain biogenic silica include oak, sugar maple, and red pine (8). It is not surprising then that sugar cane also has been shown to contain biogenic silica (1,9-12).

The most prevalent belief regarding the mechanism of deposition of silica in sugar cane tissue is that soluble monosilicic acid (H_4SiO_4) is taken up from the soil by the plant and is primarily deposited in the plant epidermal cells (1,10,12). In some species the deposition is believed to be passive since the highest silica concentrations are typically found where the greatest rate of transpiration occurs, such as in the leaves (4,6). It also has been shown that the uptake and deposition of silica by some plants is dependent upon the amount of available or soluble silica in the soil (5,6,12). In sugar cane, Fox et. al. showed that silica appears to be deposited in the young leaves and remains constant as the leaf matures (1). However, there is some disagreement on this in that Newman (12) was only able to detect biogenic silica fibers in mature sugar cane leaves.

The morphological characteristics of biogenic opal silica have been poorly described for most plant species. Studies have shown the presence of both cubic and fiber-like opal silica in conifer needles (7) and a wide variety of ribbed and smooth-sided elongated bodies in grasses (13). Baker et. al. (14,15) in Australia, showed the existence of a variety of opal phytoliths (rock-like parts of plants) in oat chaff and in the rumen and feces of sheep that existed on this feed. Phytoliths with widths of only a few micrometers and up to 150 um long were found. Lanning, et. al., described a variety of opal phytoliths in grass, corn, wheat, and sorghum (16). The persistence of opal phytoliths found in some Australian surface soils has been estimated to be about 1,000 years (17). Recently, the presence of opaline silica fibers was shown to exist in mature sugar cane leaves collected in Trinidad (12). The fibers were 10 to 300 microns in length and an average 0.85 microns in diameter.

A number of epidemiological studies suggest a relationship between biogenic silica exposure and cancer. The evidence for these fibers being an etiological agent in cancer comes from several globally distributed sources. For instance, Das et. al., documented five cases of rare mesothelioma in sugar cane farmers in India who were not believed to ever have been exposed to asbestos (18). Rose investigated the high incidence of carcinomas of the mouth, pharynx, and esophagus in a Bantu tribe of the Transkei (Africa) and attributed the etiology to the siliceous spicules found in corn and other plants eaten by the tribe (19). In Iran, siliceous fibers that were between 50 to 150 microns long were found in flour contaminated by the seeds of some common Mediterranean grasses. These fibers were associated with the extremely high incidence of esophageal cancer found in that region (20). A similar incidence of esophageal cancer has been reported in North China where the bran of millet is eaten (21). Examination of the esophageal tumors of these cancer patients discovered that there were more than 15 times as many silica fragments in the Chinese patients as there were in the esophageal region in London patients (21). Silica fibers have been also detected in the stomach tumors of patients in Japan where this disease is very common (22). In the United States, Rothschild and Mulvey interviewed the next of kin of 284 persons who had died of lung cancer during 1971 to 1977 in southern Louisiana. Of the deceased, 38 percent had been employed for at least 6 months as sugar cane farm workers compared to 20 percent in the matched controls. Employment in other industries did not appear to account for the elevated number of lung cancer cases seen among the farmers. After adjustment for smoking, the relative risk estimate of lung cancer mortality for sugar cane farm workers was 2.4 (95% confidence limits, 1.7 to 3.6). Two of the deceased sugar cane farmers were found at autopsy to have had mesotheliomas (23). A more detailed review of these studies and others has recently been completed elsewhere (24).

Exploring their suspicions about biogenic silica fibers, Bhatt and co-workers demonstrated that the fibers derived from the grass seeds contaminating the diet in Iran acted as powerful tumor "promoters" on mouse skin that was "initiated" with a polyaromatic hydrocarbon. The fibers had no tumorigenic effect when used alone (25). This study may suggest the potential importance of this combination of exposures as a hazard to the skin as well as to the respiratory system in man.

The purpose of this report is to present the results of a sampling survey of sugar cane harvesting operations performed during February, 1985, near Clewiston, Florida. Exposures of concern included inorganic fibers, polyaromatic hydrocarbons, and total dust. Personal exposure to the above compounds was assessed for workers performing various field tasks by using personal sampling equipment.

PROCESS AND WORKFORCE DESCRIPTION

The sugar cane crop is multi-seasonal, perhaps providing up to six satisfactory annual harvests from one planting. Newly planted cane takes two years to mature before harvest. In Florida, approximately 400,000 square acres of land south and east of Lake Okeechobee are planted with sugarcane. Because the soil in the area is composed almost entirely of peats and mucks, it is extremely soft and light. Until recently, all harvesting was done by hand so as not to uproot the plants, thus assuring future harvests from one planting. In recent years, about 28% of the acreage has been harvested by machine. In Florida, about 9000 field workers, mostly Jamaican nationals and other British West Indians, are employed each year during a 4 to 5 month period to hand cut the cane. The welfare of the foreign national workers is monitored by the West Indies Central Labour Organization. Additional year-round employees work all year operating mechanical field equipment and working in the sugar mills.

The following paragraph describes the overall field operations that are necessary in order to bring sugar cane to the raw sugar mills or factories in Florida. Minor variations in the basic operations are not presented. Furthermore, harvesting procedures are expected to differ somewhat in other parts of the world.

In Florida, before mature cane can be harvested it must first be burned to remove the leaves. This is typically performed by torching a 20 acre field at the perimeter on all four sides. Usually, between four to six workers comprise a burning team. Burning is performed during the dry season and the fields will burn completely in about 20 minutes. Only the dry leaf is removed by the burning process while the stalk is unscathed. One to two days following burning, a harvest crew arrives to cut the standing cane and stack it in rows along the field for mechanical pickup. Sixty to 120 workers will cut one field, starting at one end and working across the field. The cane is cut by hand using a heavy blade cane knife that is about 15 inches long. The cut cane that is gathered by mechanical pickup is first loaded into four-ton carts. At transfer stations the field carts are unloaded into larger truck semi-trailers or into rail cars. At the transfer station, a line of full four-ton carts is driven up onto an elevated platform where they are tipped by a loading jackman, and the cane is dumped onto a conveyor belt that is operated by another worker. The cane in the large truck trailer or rail cars is then sent to a raw sugar mill for processing into domestic sugar.

METHODS

Air Samples

Air samples were collected for the determination of three potential exposures that were of concern. In addition to the obvious interest in biogenic fibers, gravimetric samples were also taken to use as a basis from which to assess the degree of general dustiness in the fields. Air samples for polynuclear aromatic hydrocarbons (PAHs) were also collected since these compounds might be formed during the burning of the sugar cane leaf. Only a minimal number of samples were collected during this preliminary evaluation. Small numbers of samples were chosen since the PAH and fiber analyses are both difficult and expensive to perform and it was believed that only a small number of samples would be needed to qualitatively determine exposure. Workers were selected based upon their willingness to cooperate with this study. Assistance from the Florida Sugar Cane League was instrumental in locating nearby field operations and in obtaining cooperative workers.

A dual sample collection system was constructed for collecting air samples for total weight and fibers by using a rubber Y connector to which two limiting orifices were inserted. A filter cassette for collecting total airborne dust and one for collecting and analyzing fibers were attached to the connector. A rubber sampling tube was used to attach the dual-sample collector to a single personal sampling pump attached to the worker's belt. The air flow rate through each filter was checked before and after each field sample was collected.

Gravimetric total dust samples were collected and analyzed according to NIOSH method 0500 (26). Samples were collected on pre-weighed PVC filters through which air was drawn at a known rate of about 1 to 1.3 liters per minute (Lpm).

Air samples for inorganic fiber analysis were collected on 25mm Nuclepore® polycarbonate filters with a pore size of 0.4 micrometers. The sample air flow rate was 0.6 to 2.1 Lpm. The filters were contained in a polystyrene cassette with a 50-mm extension cowl (27). These filters were collected within 1 inch of the gravimetric samples.

Initially, seven of the polycarbonate filter samples were analyzed using scanning electron microscopy (SEM) and electron-probe X-ray micro-analysis. Each filter was inspected over an area of 20 fields at 1000X magnification in an area near the center of each filter. The area inspected (approximately 0.244 mm^2) represented 0.000634 of the total filter surface.

All twenty-five of the polycarbonate filters were analyzed using transmission electron microscopy (TEM) via a modified version of the procedure outlined in EPA Publication No. 600/2-77-178 (28). One-fourth of each filter was sectioned from the rest of the filter and was tacked to a glass microscope slide with double stick tape and carbon-coated in a vacuum evaporator. From the carbon-coated filter section was cut a piece approximately 4 mm^2 which was placed on a 200 mesh carbon-coated grid supported by a stack of glass microscope slides wrapped in filter paper in a chloroform bath. The grids were allowed to remain in the chloroform bath for 48 hours. The latter process completely dissolved the filter prior to analysis.

Filters that had previously been analyzed using scanning electron microscopy were removed from the SEM stub so that they could also be analyzed using TEM. A section approximately 4 mm^2 was cut from each filter and exposed to chloroform as described above.

At least 100 grid openings (equivalent to 20,000 fields) having a total area of at least 0.706 mm^2 were examined on each filter section. The analysis was performed on a JEOL 100B TEM at 10,000 times magnification with an accelerating voltage of 100 kilo-volts and a filament current of 90 microamperes. X-ray spectra were collected for 10 seconds at a take-off angle of 39 degrees. Photomicrographs were taken at varying magnifications for 3 seconds with an exposure sensitivity setting of 5. Diffraction patterns were obtained for the fibers that were seen.

Air samples obtained for analysis of 16 specific polyaromatic hydrocarbons were collected by drawing air at a flow rate of 2 Lpm through a sampling train consisting of a 37-mm PTFE-laminated membrane filter followed by a washed XAD-2 sorbent tube. Sampling and analysis was performed according to NIOSH method 5506 (29). The specific compounds that were included in the analysis are listed in Table 1.

Bulk Leaf Analysis

In addition to the air samples, bulk leaf ash was collected from a recently burned field and analyzed for 16 specific PAH compounds. This ash was analyzed by extracting approximately 250 milligrams of the sample with cyclohexane. The limits of instrumental detection were 2 ug/sample for each compound.

Finally, unburnt leaf samples from ten sugar cane varieties and one soil sample were collected and prepared for inorganic fiber analysis. The leaf samples generally consisted of mature, dry material. One of the leaf samples was taken from sawgrass that was growing on the edge of one of the cane fields. The sugar cane leaf samples were collected from various varieties, clones, or cultivars that are grown in Florida. A soil sample, collected in a cleared sugar cane field, was also submitted for analysis. A burnt ash sample taken from a sugar cane field, which was also submitted for PAH analysis, was analyzed for fibers.

The bulk leaf samples were prepared by cutting the leaf into pieces approximately 3 mm x 3 mm and dried in an oven at 110°C. Enough material was placed into a 50 mL beaker to cover the bottom with approximately two to three layers of the leaf pieces (approximately 0.25 gram). The pieces were then ashed in a low temperature plasma asher (LTA) until only a fine white ash remained (approximate weight, 0.015 grams). The ash was subsequently ultrasonicated in 20 mL of ethyl alcohol and three capillary tubes of the resulting suspension were evaporated onto 200 mesh carbon-coated copper grids and examined on a Phillips 420 scanning transmission electron microscope with an accelerating voltage of 100 KEV. One hundred fields having an area of 7.06×10^{-3} mm^2 each were examined on each preparation at 5000X magnification. X-ray spectra were collected for 30 seconds at a take-off angle of 20 degrees. Diffraction patterns were obtained for the fibrous components.

RESULTS

Air Samples

The gravimetric sampling results are reported in Table 2. Personal breathing zone air concentrations are reported for the burning unit and harvesting workers as well as the results of upwind and downwind stationary samples. Most of the burning unit samples produced analytical results which were above the range of six blank samples (range -0.01 to 0.04 mg weight change per sample; mean 0.01 mg). However, some of the burning unit samples had low gravimetric loadings. This might be expected since the sample period, which lasted the length of a single burn, was only 33 to 72 minutes.

Generally, the gravimetric samples indicate that airborne concentrations of total dust upwind of the burn are lower than the concentrations measured downwind and lower than the personal samples. Three upwind sample concentrations showed non-detectable, 0.3, 0.5 and 0.5 mg/m^3 of total dust. Downwind stationary sample concentrations were 0.4, 0.8, and 1.8 mg/m^3. Personal samples taken on six burning unit workers ranged from non-detectable to 5.2 mg/m^3, with a mean of 2.1 mg/m^3.

During the cutting operations, personal exposures to total dust among seven workers ranged from 0.1 to 1.3 mg/m^3 (mean = 0.6 mg/m^3). A sample collected on a conveyor operator at a transfer station indicated a 5-hour time-weighted air concentration of 2.6 mg/m^3 while the air concentration for a loading jackman was measured at 0.8 mg/m^3 during this same period.

The results of the analysis of the filter samples for fibers are reported in Table 3. The results are presented in the same order as were the gravimetric samples to which the fiber samplers were paired. Inorganic fibers, as confirmed by using an energy dispersive X-ray analyzer, were found in a few of the samples that were collected on workers involved with burning as well as cane cutting and material transport. The calculated number of inorganic fibers per cubic meter of air was 15,000 and 58,000 for two of nine samples collected in the burn areas. In the cutting operations, three of the seven samples collected contained inorganic fibers. The air concentrations were calculated as being equivalent to 60,000 to 300,000 fibers per cubic meter of air. An additional personal sample of a loading jackman contained fibers which would correspond to a concentration of about 9,000 fibers per cubic meter of air. Many of the fibers from each sample contained elements in addition to silicon while some fibers contained no silicon.

Table 4 specifically describes the elemental composition of 30 inorganic fibers that were seen in air sample F9. This analysis was performed using SEM and electron-probe X-ray micro-analysis. The analysis showed that most of the inorganic fibers contained primarily silicon. Calcium and magnesium were also often found, but to a lesser degree. Only one of the fibers observed within the scanning area contained only silicon. The fiber lengths ranged from 3.5 to 65 micrometers (um) long with a mean of 12 um (median = 6 um). The width ranged from 0.3 to 1.5 um with a mean of 0.6 um.

Additional fiber analysis of the air filter samples was performed using TEM with X-ray diffraction. Approximately 56 percent of the inorganic fibers found on sample F8 contained silicon only or silicon plus lesser amounts of calcium, potassium, or magnesium. Figure 1 presents four photomicrographs of some of the fibers seen on sample F8. Photomicrographs 1 thru 3 contain fibers that are composed entirely of silicon while the fiber in photomicrograph 4 contains silicon, calcium, and magnesium. All diffraction patterns obtained during the analysis indicated that the silicon was amorphous. The X-ray spectra that accompanied the fibers are also shown in Figure 1.

Also shown as Figure 2 is a scatter diagram of the size distribution of fibers for filter sample F8. The sizes of 36 fibers were plotted by diameter and length. Most of the fibers were less than 1 um in diameter and 2 to 10 um long.

Eighteen air samples were submitted for PAH analysis. Included in the samples were three from upwind and downwind stationary sites, eight from burning unit workers, and seven collected during cane cutting. Acetonitrile was chosen as the best solvent for extraction of the filters. The instrumental limits of detection for each of the 16 PAH standard compounds were between 0.3 and 0.5 ug/samples. Because the gravimetric loading on each sample was low, none of the PAH compounds included in the analysis were detected in any of the filter samples, nor were any of the analytes detected in the sorbent tubes.

Bulk Samples

Bulk fiber analysis results are reported in Table 5. Reported in the first column are the identities of each sample. The sugar cane samples are listed by their designated variety, clones, or cultivar number. In the second column the number of pure silica fibers are reported. When some of the fibers also contained magnesium and/or calcium, the number of such fibers is reported within parentheses. All of the silicon fibers displayed noncrystalline diffraction patterns. The lower and upper size range of the fiber diameters and lengths are provided in the right-hand side of the table. As can be seen, the fiber diameters in the sugar cane range from 0.1 to 1.75 um and the lengths varied from 3 to 50 um. Based upon the sample dilutions made during preparation, it was calculated that the number of silica fibers per gram of dry unburned leaf could be obtained by multiplying the results reported in Table 5 by 320,000. Photomicrographs of some of the fibers seen in the bulk sample analysis are presented in Figure 3. These fibers are characteristically similar to the fibers found on the air filter samples shown in Figure 1.

The bulk ash field sample contained about as many silicon fibers as the LTA samples, as might be expected. The soil sample was found to contain silicon fibers but fewer than expected. It is suspected that the soil is a long-term depository of silicon fibers that have originated in the sugar cane plant. The sample collected was taken only for the purpose of demonstrating the existence of silicon fibers in the sugar cane leaf and in the soil. To quantitatively evaluate the soil concentration of inorganic fibers, more samples need to be collected.

Of the 16 compounds sought in the analysis of the bulk ash sample collected from a burnt field, only fluorene (26 ug/g), phenanthrene (15 ug/g), and anthracene (13 ug/g) were detected.

DISCUSSION

Generally, there are four basic job categories involved in field operations; equipment operators, burning unit workers, cane cutters, and supervisors. Several workers from the first three categories were monitored for airborne exposures to total dust, polyaromatic hydrocarbons, and fibers.

While machine operators, cane cutters, and burning unit workers may all be potentially exposed to dust, soot, and smoke, the magnitude of exposures might be expected to vary considerably depending upon weather conditions and the location of the worker. Any exposure monitoring data that is collected outdoors is subject to these conditions. The present study was conducted after several months of drought of a degree that was quite unusual for this area. This area had also recently experienced unusual frost conditions which had stressed the mature cane. Therefore, it is currently uncertain how past weather conditions may have influenced the results reported here or how the present findings would differ if the survey had been conducted following more normal conditions.

Newman (12) found a greater number of siliceous fibers in the sugar cane leaf grown in Trinidad than were presently found in the leaf from Florida. Since others have shown that the availability of soluble soil nutrients affect the elemental content of the plant, one might suspect that the soil difference in Trinidad and Florida may account for the difference in the number of siliceous fibers. The Florida everglades area soil is comprised primarily of peat which may be deficient in soluble monosilicic acid. The volcanic island of Trinidad, on the other hand, would be expected to contain a higher proportion of silica. We did find a much higher silica fiber count in wild sawgrass and the possibility also exists that the leaf sample Newman obtained in Trinidad was mistaken for, but not actually obtained from sugar cane. However, expert evaluations by a botanist of the leaf makes this latter possibility unlikely.

The fiber counts and size distributions reported here should not be considered quantitatively accurate. Potentially serious quantitative variance of the fiber counts has recently been reported for air samples collected on nuclepore filters (30). Problems have been attributed to static electric interference during sampling (31-33) and dislodging of fibers during transport and analysis (34). In spite of these problems which can greatly reduce the actual number of fibers seen on a filter, substantial numbers of inorganic fibers were detected on some of the air samples.

The health effects of inhaling the amorphous siliceous fibers described here are unknown. However, the similarity of these fibers with other fibers which are known to cause serious health effects is reason for concern. Recently, ceramic fibers that are made from aluminum-silicate minerals were found to cause abdominal tumors and mesotheliomas in rats exposed via intrapleural injection (35). In 1984, NIOSH stated in regards to asbestos that there is no safe concentration of exposure to asbestos (36). Considering the infeasibility of reducing all exposure to zero and the imprecision of the air measuring techniques, NIOSH recommended that exposure to asbestos fibers greater than 5 micrometers in length not exceed 100,000 fibers per cubic meter of air (36).

Total dust exposure was determined to be below all established limits for nuisance dust. Samples that were collected on burning unit workers were generally of a short duration and the workers try to avoid heavy exposure to smoke. Cane cutters usually begin work soon after dawn to avoid the heat. Typically, nights are accompanied by heavy dews which dampen the cane that was burned on the previous day. The above factors may help to reduce overall exposure to total dust and could account for the low concentrations found in this investigation.

The low gravimetric loading on the sample filters collected here also precluded the chance of detecting polyaromatic hydrocarbons in the air. However, detecting only three of the 16 PAH compounds during the analysis of a bulk ashed-leaf sample from the field suggests that the other PAH compounds may not be formed during the burning process. However, as demonstrated by Bhatt, et. al.,(25) exposure to PAH's as well as silica fibers can act synergistically to cause cancer. Our analysis of only 16 PAH compounds is very selective considering that potentially hundreds of PAH compounds could form. Only some of these compounds have been shown to cause cancer directly while others may promote the effects of direct carcinogens. The cane cutting operation is extremely dirty work because of the frequent contact the workers have with the cane. Even if respiratory exposure to the fibers and PAH compounds is minimal, this does not preclude the possibility that a hazard to the skin may exist.

CONCLUSIONS

The literature suggests that biogenic silicate fibers may constitute a health risk when ingested, inhaled, or rubbed onto the skin. This survey of sugar cane harvesting operations in Florida is a very preliminary investigation of the potential for workers' exposure to these fibers. However, inorganic fibers of biogenic origin were found in mature sugar cane leaf as well as in air samples collected on workers in the sugar cane fields. Many of these fibers consisted solely of amorphous silicon. Also suspected was that polyaromatic hydrocarbon compounds could form during the burning process. Several of these compounds were found in the burned leaf. Exposure of field workers to silicate fibers as well as to polyaromatic hydrocarbon compounds may constitute a potential health risk which warrants epidemiological study.

RECOMMENDATIONS

Since the present study has demonstrated an apparent potential for worker exposure to silicate fibers during various operations involved with sugar cane harvesting, comprehensive monitoring of exposure to biogenic fibers among field workers, as well as refinery workers could be performed to obtain representative and quantitative information on the extent of exposure. Further study could be performed in Florida and elsewhere where sugar cane is grown. In other industries which involve processing agricultural commodities, the potential for exposure to biogenic silicates and the morphology of the silicates could be determined. The question of the solubility and persistence of these particular fibers in biological fluids should be addressed in laboratory studies.

Epidemiological investigations of agricultural workers should consider the potential exposure to biogenic silicates when trying to identify the etiology of effects. An epidemiological study of the West Indies workers described here may be appropriate and scientifically enlightening in terms of better understanding the role of inorganic fibers in the etiology of disease. Detailed work history records and medical history records on this cohort are believed to exist.

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Table 1

Polyaromatic Hydrocarbons Included in the Analysis
and the Limits of Detection

Analyte	LOD[A] (ug/sample)
Acenaphthylene	0.3
Acenaphthene	0.3
Fluorene	0.3
Phenanthrene	0.5
Fluoranthene	0.5
Anthracene	0.3
Pyrene	0.3
Benz(a)anthracene	0.3
Chrysene	0.3
Benzo(e)pyrene	0.3
Benzo(b)fluoranthene	0.3
Benzo(k)fluoranthene	0.3
Benzo(a)pyrene	0.3
Dibenz(a,h)anthracene	0.5
Benz(g,h,i)perylene	0.5
Indeno(1,2,3-cd)pyrene	0.5

A. limit of detection

Table 2
Gravimetric Air Sampling Results
Sugar Cane Field Harvest Operations
Taken in Florida During February, 1985

Location & Date	Sample Number	Sample Volume (m3)	Analytical Result (mg)	Air Concen. (mg/m3)	Location/Description
Burning 2/26/85	4201	0.06	0.02	0.3	Area sample taken upwind of 1st burn
	4203	0.07	0.03	0.5	Area sample taken upwind of 2nd burn
	4210	0.08	0.06	0.8	Area sample taken downwind of 2nd burn
	4209	0.07	ND[A]	-	Area sample 100 yds. upwind of burn
	4211	0.05	0.08	1.8	On water wagon near burn
	4212	0.04	0.02	0.5	Attached to water wagon upwind of burn
	4204	0.05	0.02	0.4	On water wagon downwind of burn
	4193	0.04	0.06	1.7	Burner
	4207	0.05	0.14	2.7	Burner
	4190	0.05	0.01	0.2	Burner
	4198	0.05	0.25	5.2	Burner yardsman
	937	0.08	0.08	1.0	Burner
	4186	0.06	0.10	1.7	Burner
Cutting Operations 2/27/85					
	4205	0.17	0.02	0.1	Cane Cutter
	4189	0.22	0.22	1.0	Cane Cutter
	4185	0.41	0.27	0.7	Cane Cutter
	4208	0.42	0.55	1.3	Cane Cutter
	4192	0.44	0.33	0.8	Cane Cutter
	4200	0.47	0.15	0.3	Cane Cutter
	4206	0.35	0.32	0.9	Cane Cutter
Area Samples 2/27/85	4188	0.35	0.91	2.6	Conveyor operator at truck station
	no sample	-	-	-	Attached to cane conveyor
	no sample	-	-	-	Downwind of cut fields
	no sample	-	-	-	Upwind of Cut Field
	4192	0.44	0.33	0.8	Jackman at truck loading platform

A Sensitivity to 0.01 mg/sample.

Table 3
Inorganic Fiber Results
Sugar Cane Field Operations

Location & Date	Sample Number	Sample Volume (m3)	Analytical Result	Air Conc. (mg/m3)	Location Description
Burning Operation					
2/26/85	F17	.041	ND		Area sample taken upwind of 1st burn
	F22	.032	ND		Area sample taken downwind of 1st burn
	F16	.021	ND		Area sample taken downwind of 2nd burn
	F4	.055	ND		Area sample 100 yds. upwind of 2nd burn
	no sample taken				On water wagon near burn
	F7	.032	ND		Attached to water wagon downwind of burn
	F12	.031	4	58,000	On water wagon downwind of burn
	F11	.030	ND		Burner
	F24	.032	1	15,300	Burner
	F26	.029	ND		Burner
	F25	.031	ND		Burner yardsman
	F5	.047	ND		Burner
	F13	.039	ND		Burner
Cutting Operations					
2/27/85	F1	.099	ND		Cane Cutter
	F20	.111	ND		Cane Cutter
	F8	.314	38	60,000	Cane Cutter
	F27	.282	60	300,000	Cane Cutter
	F2	.443	ND		Cane Cutter
	F23	.251	ND		Cane Cutter
	F9	.320	30	133,000	Cane Cutter
Area Samples					
2/27/85	F19	.597	ND		Conveyor Operator at truck station
	F10	.865	ND		Attached to cane conveyor
	F6	.219	ND		Downwind of cut fields
	F15	.814	2	980	Upwind of cut field
	F18	.866	19	9,300	Attacked near Jackman at loading platform

Table 4

Specific Fiber Identification
for Filter Sample F9

Elemental Composition	Number of Fibers[A]
Si only	1
Si and Ca	11
Si, Ca and Mg	6
Si, Ca and S	3
Si, Ca and K	2
Si, Ca, Mg and P	2
Si, Ca, Mg, K, and S	2
Si, Ca, Mg and Cl	1
Si, Ca, Mg and K	1
Si, Ca, Mg, K, Cl and S	1
	30

A. An area of 0.244 mm2 was examined by taking 20 1000X magification fields.

Table 5
TEM Count of Silicon Fibers in Ashed Materials

Sample Type and Number	No. Fibers Detected	Size Range (um) Diameter	Length
Mature Sugar Cane Leaf			
CP 65-357	3	0.1 - 1.5	16 - 44
CL 54-378	7 (3)	0.3 - 1	3 - 17
CP 63-588	3 (1)	0.4 - 1	4 - 50
CL 59-1052	1	1	7
CP 70-1133	11 (2)	0.1 - 1.75	3 - 22
CP 72-1210	4	0.3 - 1	5 - 44
CP 70-1527	9	0.3 - 1.75	3 - 40
CP 75-1632	3 (1)	0.3 - 1.25	3 - 14
CP 74-2005	8 (1)	0.3 - 3	5 - 30
Sawgrass	76 (10)	0.3 - 1.75	6 - 60
Field Ash	9	0.3 - 2	6 - 56
Soil	3	0.3 - 0.6	2.5 - 6

The numbers in parenthesis in column 2 indicate that of the number of fibers reported, this many contained small amounts of magnesium and/or calcium, in addition to silicon.

100 fields were examined in each sample that equalled an area of 0.706 mm2.

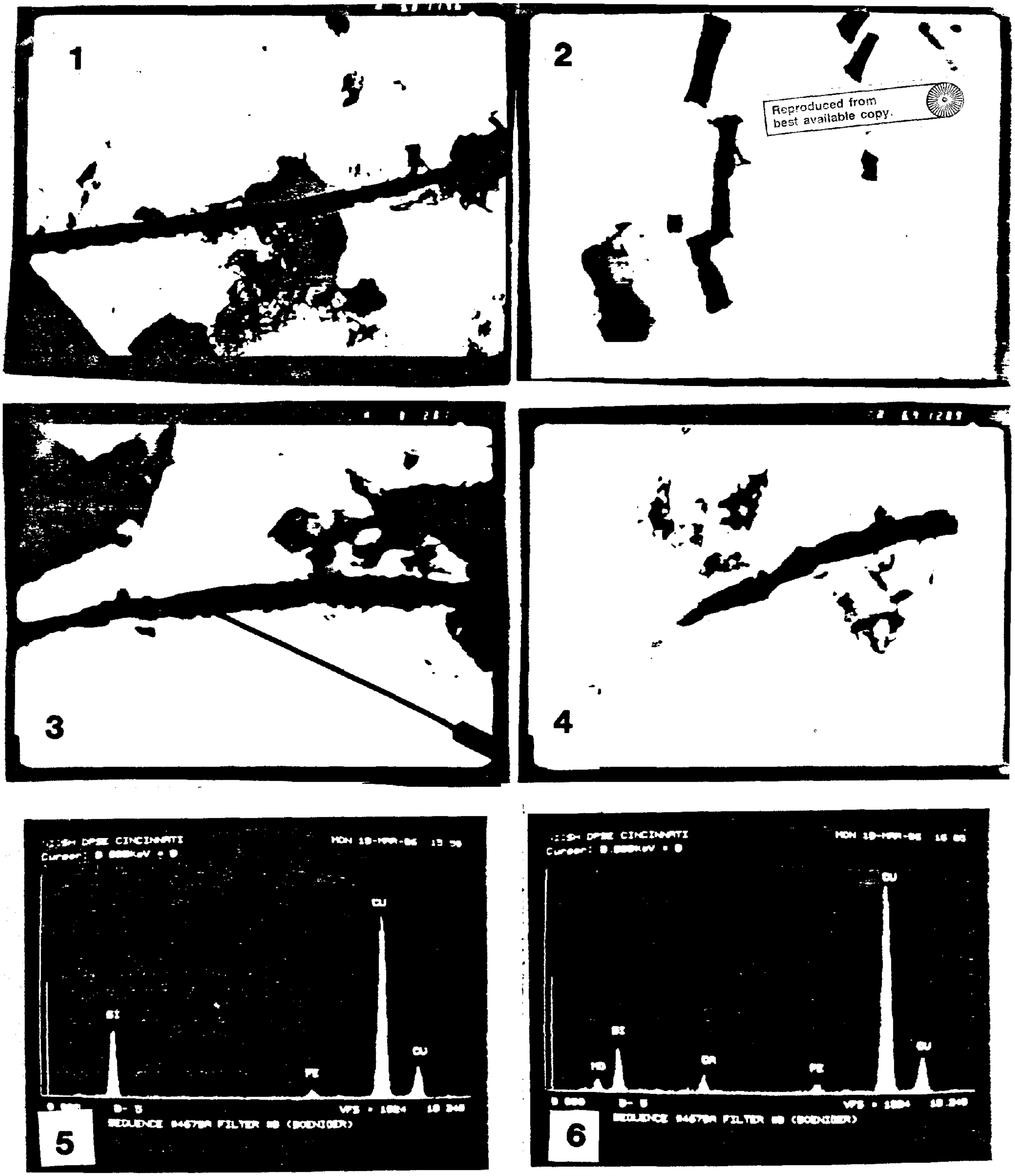

Figure 1--Photomicrographs of Siliceous Fibers Found on Filter Sample F8. Items 1-3 show fiber types that contain silicon as seen in the accompanying X-ray spectra, item 5. Item 4 shows a fiber composed of a silicate containing some magnesium and calcium, as indicated in item 6. The X-ray spectra shown in item 5 and 6 for Fe and Cu are artifacts of the instrument.

Figure 2

Inorganic Fiber Distribution in Filter Sample F8

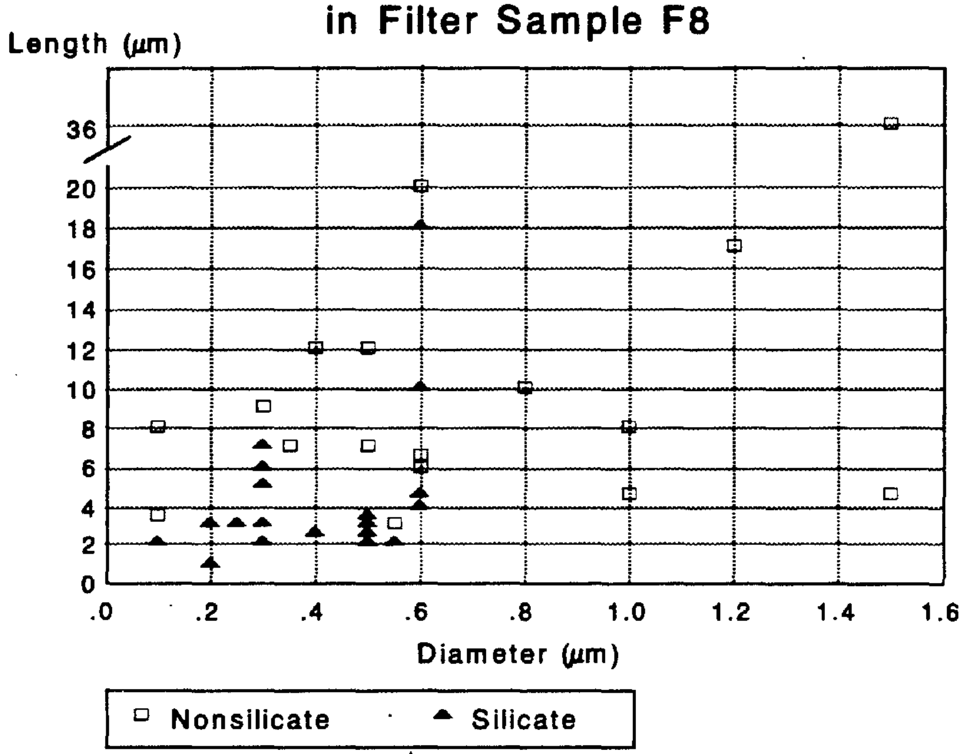

Figure 3 - Photomicrographs of Silica Fibers found in Ashed Materials.
Fiber #17 was 1um x 30 um and found in ash after burning a cane field.
Fiber #18 was 1um x 28 um and found in ash after burning a cane field.
Fiber # 25 was 2 x 28 um and found after mature cane leaf was ashed in the laboratory in a plasma low temperature asher.
Fiber #26 was 0.6 x 15 um and also found after cane leaf was ashed in the laboratory.