ABSTRACT

PATRICIA S. WEGGEL. Review of Asbestos Abatement Programs for Universities or Large Multifunctional Institutions. (Under the Direction of Professor David Fraser)

As of 1985, institutions operated by state and local governments are required by OSHA/EPA to protect their employees from hazardous asbestos exposures. This study examines asbestos abatement programs of three universities to determine whether they a) comply with federal and state laws; b) are effective in providing a safe and healthy working and living environment, and c) are managed in an effective manner. Two hundred fifty-nine air samples were analyzed to characterize airborne asbestos concentrations during asbestos management and abatement activities. The arithmetic mean concentration during asbestos removal, 3.04 fibers per cubic centimeter air, exceeded the legal permissible exposure limit of .2 f/cc. Although university asbestos abatement programs generally met minimum legal requirements, improvement was necessary in support programs for medical monitoring and respirators. Management improvements include 1) the enforcment of policies regarding asbestos abatement work practices and personal protection; 2) the expedition of funds for the removal of asbestos in potentially hazardous locations; and, 3) the evaluation of the decision-making process to remvove asbestos.

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# INTRODUCTION

# INTRODUCTION

Asbestos is a group of natural, fibrous serpentine and amphibole silicates used extensively in industry and construction since the beginning of the century. Although asbestos types vary significantly in physical description, all are composed of fire-proof, chemically stable, and strong fiber bundles useful for soundproofing, insulation, and decoration.

Extensive epidemiology studies and animal toxicology experiments (McDonald and McDonald, 1978; Gardner, 1942; Yazicioglu, et al, 1980; Whitwell, Scott, and Grimshaw, 1977), indicate that airborne asbestos fibers are dangerous to health and life. Ryckman, Ryckman, and Peters (1983) estimate that over 15% of all cancer deaths during the next 25 years will be linked to asbestos exposure. The risk to health increases as the bonding material deteriorates and the asbestos fibers become airborne.

The issue of abatement is controversial. Asbestos removal and abatement policies depend on perception of health risks, costs and availability of abatement and replacement resources, and political climate. The decision to use asbestos depends on the exchange between individual risks and community safety. Although installing and removing asbestos causes potentially dangerous asbestos exposures, bonded asbestos insulates and retards fire. Since the commitment to produce and promote commercial asbestos products began years ago, the current asbestos abatement strategy is to cost-effectively minimize exposures from deteriorating sources. The history of asbestos includes the simultaneous promotion of the use of asbestos and the discovery of asbestos toxicity. An historical background provides an understanding of the magnitude of the asbestos abatement problem and the evolution of the economic and legal issues. Knowledge of asbestos toxicity and fiber toxicity develops a foundation to assess the risks of abatement options.

## A. HISTORICAL BACKGROUND OF ASBESTOS

Asbestos is not new to society. Anthophyllite asbestos fibers have been found in pots dating back to 2500 B.C. (Seaton, 1984). Ancients recognized that the natural fibers could be spun into yarns and cloths with high tensile strength and durability as well as fire resistance. Societies of the Roman empire and the orient wove reusable asbestos funeral pyre shrouds and lamp wicks. Pliny in 50 A.D. observed that the weavers of the wicks for the lamps of the vestal virgins wore masks to avoid inhaling the dust (Hunter, 1969). Perhaps the most entertaining anecdote involves the use of an asbestos table cloth at Charlemagne's banquets. After feasting, the Emperor impressed his guests by dramatically tossing his asbestos table cloth into burning flames. Upon removal, his guests found the table cloth not only unscorched by fire, but magically clean. Although asbestos products are anecdotally referred to by historical figures such as Herodotus, Strabo, Plutarch, and Marco Polo (Cooke, 1927), it was the industrial revolution and the development of thermodynamics and heat distribution principles that initiated the widespread development of asbestos products.

1. Commercialization and Promotion. The widespread use of asbestos began at about the turn of the 19th century with the industrial revolution and the extensive advancements in steam engines, boilers, and friction machines. Companies such as Johns-Manville Corporation realized immense profits from insulation products made from large resources of cheap chrysotile and amosite mined and imported from Canada and South Africa (Brodeur, 1985, Parts I-IV). Chrysotile and amosite became the most common types

of asbestos in the U.S. between the 1940s and 1970s. After World War II, asbestos insulation manufacturers promoted and extended the use of asbestos beyond the industrial and military sectors into the construction industry. Because of this, asbestos now exists in materials such as wallboards, insulation, soundproofing, structural reinforcement, ceiling and wall tiles, and decorations. It is especially common in pipe and boiler insulation; in wartime, post-war, and multi-family housing; and in public and recreational buildings. Asbestos materials are incorporated in buildings where fire safety is a key concern.

2. Discovery of Health Hazards. In 1900, a London physician, Dr. H. Montague Murray, raised the issue of asbestos-related mortality (Murray, 1907; also discussed in Merewether, 1956 and Seaton, 1984). He performed a post-mortem examination of a 30 year old man who had been the last survivor of ten men working in the carding room of an asbestos-textile factory. With asbestos fibers found in his lungs, Dr. Murray diagnosed the man as suffering from pulmonary fibrosis and, in 1907, he reported a case of pulmonary fibrosis to a British governmental committee on compensation for industrial diseases. The first study of mortality among asbestos weaving mill workers, however, appeared in the French literature in 1906 (Auribault, 1906).

As a result of sporadic cases of fatal pulmonary fibrosis among asbestos-workers, Merewether and Price of Great Britain' Home Office conducted an official inquiry into the asbestos manufacturing industries and the effects of asbestos on the lungs (Merewether, 1930). In 1930 and 1931, the study resulted in the recognition of asbestosis as a compensatable disease and in requirements for both exhaust ventilation and dust suppression in asbestos factories and periodic medical examinations for workers (Workmen's Compensation (Silicosis and Asbestosis ) Act of 1930). Although British studies continued to demonstrate a correlation between asbestosis or asbestos exposure and lung cancer, studies by R. Doll in the 1950s and 1960s showed that the improvements made in industrial hygiene resulting from the 1930/1931 British asbestos regulations accompanied a reduction in risk of asbestosis and cancers (Doll, 1955).

3. Compensation. From the 1930s through the 1960s, studies such as Wood and Gloyne (1934); Merewether (1930 and 1947); Doll (1955); and Selikoff, Churg, and Hammond (1964 and 1968) showed excess cancer deaths of those occupationally exposed to asbestos. The most famous of these were Selikoff's mortality studies of 632 New York asbestos insulation workers (Selikoff, Churg, and Hammond, 1964). Selikoff found an excess of 99 mortalities due to bronchial cancers and, in part, gastrointestinal cancers. Despite these studies, the hazards of asbestos were overlooked by industry and the U.S. governement until 1961, when the Claude J. Tomplait sought compensation from the Texas Industrial Accident Board (Tomplait v. Texas Industrial Accident Board, Case W-67299, Dec. 11, 1961) for his asbestos related lung disease. Being denied workers compensation, Tomplait through his lawyer, Ward Stephenson, brought an unsuccessful suit against asbestos manufacturers and distributors. On October 20, 1969, in the federal district court in Beaumont, Stevenson filed a product-liability suit on behalf of Tomplait's co-worker, Clarence Borel (Clarence Borel v. Fibreboard , 493 F.2d, 1076 (5th Cir 1973)). The plaintiff claimed that the defendants knew of asbestos toxicity and were negligent in their failure to warn the users of the product hazards. Although Borel and Stephenson both died before the conclusion of the lengthy trial and successful appeal, the litigation both exposed an apparant cover-up of asbestos health hazards by the asbestos industry and set precedence for subsequent lawsuits.

On August 26, 1982, Johns-Manville Corporation, the world's largest asbestos company, with over 25,000 employees and 50 factories and mines, filed for "reorganization and protection" under Chapter 11 of the Federal Bankruptcy Code. Johns-Manville hopes to halt thousands of lawsuits brought against it by workers who claim to have developed lung cancer and other diseases as a result of the company's failure to warn them of the dangers involved in handling Manville's insulation products. Because the workers were unable to collect from Johns-Manville for extensive medical costs and wage loss, they are now bringing law suits against employers of asbestos insulators as well as those managers of asbestos laden buildings.

4. Governmental Intervention. During the 1970s, the federal government prohibited the use of most spray-on asbestos materials. The Environmental Protection Agency (EPA) is trying to phase out all non-essential uses of asbestos materials and has initiated asbestos abatement programs for all primary and secondary schools (40 CFR § 61.150 and 34 CFR § 230.1). The EPA, the Occupational Safety and Health Administration (OSHA), and the states regulate the release of asbestos into the environment and protect workers from occupational exposure. Both EPA and OSHA limit occupational exposure through work practices and personal protective equipment. States such as North Carolina now include asbestos-related diseases in worker's compensation.

## B. HEALTH RISKS

Epidemiological studies by researchers such as Selikoff, Churg, and Hammond (1964 and 1968); Wagner , Sleggs, and Marchand (1960), and Whitwell, Scott, and Grimshaw (1977) link airborne asbestos to asbestosis, mesotheliomia, and pulmonary and gastrointestinal cancers. Many occupational epidemiological studies, as referenced throughout this paper, focus on the exposures and morbidity or mortality of miners and insulators. There is a paucity of studies, however, concerning craftpeople such as pipe fitters/coverers, carpenters, plumbers and electricians, and power plant personnel, who are routinely exposed to presumably low concentrations of asbestos. Data from the EPA (48 Fed. Reg. 51096-51097, 1983), indicate that approximately 7815 construction workers will die from a career exposure (45 years) of up to 0.5 fibers per cubic centimeter air (f/cc). An additional 2461 deaths are estimated for exposures between 0.5 and 2 f/cc. Table I summarizes the total estimated cancer deaths per 100,000 persons occupationally exposed to asbestos. The total deaths are displayed as a function of years and levels of asbestos exposures.

## Table I

### ESTIMATED ASBESTOS RELATED CANCER MORTALITY PER 100,000 BY NUMBER OF YEARS EXPOSED AND EXPOSURE LEVEL

| ASBESTOS FIBER CONCENTRATION (F/CC) | LUNG | MESOTHE-LIOMA | GASTRO-INTESTINAL[1] | TOTAL DEATHS |
|---|---|---|---|---|
| | | 1 Year Exposure | | |
| **0.1** | 7.2 | 6.9 | 0.7 | **14.8** |
| **0.2** | 14.1 | 13.8 | 1.4 | **29.6** |
| **0.5** | 36.1 | 34.6 | 3.6 | **74.3** |
| **2.0** | 144. | 138. | 14.4 | **296.4** |
| **4.0** | 288. | 275. | 28.8 | **591.8** |
| **5.0** | 360. | 344. | 36.0 | **740.0** |
| **10.0** | 715. | 684. | 71.5 | **1470.5** |
| | | 20 Year Exposure | | |
| **0.1** | 139. | 73. | 13.9 | **225.9** |
| **0.2** | 278. | 146. | 27.8 | **451.8** |
| **0.5** | 692. | 362. | 69.2 | **1123.2** |
| **2.0** | 2713. | 1408. | 271.3 | **4392.3** |
| **4.0** | 5209. | 2706. | 527.8 | **8511.8** |
| **5.0** | 6509. | 3317. | 650.9 | **10476.9** |
| **10.0** | 12177. | 6024. | 1217.7 | **13996.7** |
| | | 45 Year Exposure | | |
| **0.1** | 231. | 82. | 23.1 | **336.1** |
| **0.2** | 460. | 164. | 46.0 | **670.0** |
| **0.5** | 1143. | 407. | 114.3 | **1664.3** |
| **2.0** | 4416. | 1554. | 441.6 | **6411.6** |
| **4.0** | 8841. | 2924. | 844.1 | **12209.1** |
| **5.0** | 10318. | 3547. | 1031.8 | **14896.8** |
| **10.0** | 18515. | 6141. | 1851.5 | **26507.5** |

1. Assumes exposure begins at age 25. Risks are calculated using U.S. male lung cancer background rates for 1977.

Source: Federal Register/ Vol.48. No. 215/ Friday, Nov. 4, 1983/ p. 51129.

Along with the worker's sensitivity and lifestyle, the dose of asbestos, the duration of exposure, and the physical characteristics of the airborne asbestos are the major toxicity factors of asbestos diseases. The most toxic fibers are small, durable, and barbed-wire shaped (Leineweber, 1981). Crocidolite is considered the most hazardous of the common types of asbestos in inducing mesothelimia, an asbestos-related pleural cancer, followed by amosite and then chrysotile (McDonald and McDonald, 1978; McDonald et al, 1980). The risk of asbestos-related diseases is expected to increase during the 1980s due to relatively high exposures from the removal of asbestos and the deterioration of aging bonded asbestos (Newhouse and Berry, 1976).

It is generally understood that cancer is intiatied by environmental (chemical, physical, or biological) substances that effect the genes that control cell division (Trosko and Chia-Cheng Chang, 1978). Because cells have defense mechanisms to repel or repair cell damage, an organism may escape adverse effects from small doses of toxic substances. It is, therefore, possible that just one unit of a substance has a small probability of successfully mutating a gene to initiate or promote a cancer. Since asbestos fibers are ubiquitous in the environment and even one fiber has a potential to cause cancer, theoretically, everyone is at some risk.

The issue of asbestos health risks is further complicated by the epidemiological evidence of a strong synergistic association of smoking and asbestos exposures with pulmonary cancers (48 Fed Reg. 51096-50100, 1983 and Ki Poong Lee, 1985). It is unclear whether there is a synergistic association between cigarette smoking and asbestosis, a fibrotic lung disease which may incapacitate the lungs (through the formation of scar-like tissue and the loss of flexibility) for years without directly causing mortality. The only major asbestos-related pulmonary disease that is not associated with smoking is mesotheliomia, a rare pleural cancer that results from low or high asbestos exposure levels, progresses quickly, and is always fatal (usually within one year from diagnosis).

"Appendix A: Health Effects" details the asbestos-related diseases and the basic concepts of fiber toxicology. Knowledge about the diseases, associated risk factors, and basic concepts of fiber toxicology is essential to sound managerial judgments regarding 1) the necessity of asbestos abatement procedures; and, 2) the selection of employees involved in asbestos-related maintenance or removal.

## C. ASBESTOS ABATEMENT PROGRAMS FOR INSTITUTIONAL FACILITIES

The federal government regulates asbestos in almost all sectors of society. It requires asbestos abatement programs for federal institutions, such as the military, veterans hospitals, and EPA, through programs and policies (U.S. Veterans Adm., 1985, EPA Part 1 &2, 1979, U.S. Navy, 1981). Federal regulations minimize asbestos exposures to persons in grade schools, the environment, and workers employed in the private sector. Federal regulation requires both primary and secondary schools to inspect and maintain records of friable asbestos (47 Fed. Reg. 23360,1982). It requires that the existence of asbestos must be reported to either the parents or the organization that represents the parents (e.g. the Parent -Teachers Association). Although removal is at the discretion of the schools and parents, the EPA established guidelines to assist schools in complying with the inspection/reporting requirements. EPA also requires detailed asbestos abatement practices during building demolition and renovation (49 Fed. Reg. 13658,1984). OSHA limits asbestos exposures and outlines extensive abatement regulations aimed at protecting most private manufacturing and commercial employees. (29 CFR § 1910.1001).

Until recently, few federal asbestos regulations applied to private or state institutions. Following EPA and OSHA exposure limits and protection guidelines was a matter of ethics and liability. In 1985, however, under union pressure, EPA adopted asbestos exposure regulations for occupational protection of employees of state and local governments (Chemical and Engineering News, July 1985). These little publicized rules

(40 CFR 763.120-124) are enforced by EPA in all states in which it retains enforcement power. Some state agencies with environmental or occupational safety authority also enforce the ruling.

The author found no studies that review the asbestos abatement programs at state and local governmental institutions, which as of 1985 must comply with occupational asbestos-related regulations. Specific examples of institutions that may need to create or upgrade programs are research institutes, health care facilities, and educational centers. "Asbestos-containing materials have been used in 20-50% of the institutions in this country for ceiling, boiler and pipe insulation, acoustical treatment, and fireproofing. The location and amounts of asbestos in institutions is virtually unassessed. The EPA estimates that between 100 and 6,800 people may be expected to die prematurely of cancers due to non-peak asbestos exposure at the prevailing levels in schools" (Ryckman, Ryckman, and Peters, 1983). The total impact on health may be considerably higher due to higher than normal exposures created by maintenance, renovation, and student recreational activities.

## D. ASSESSMENT AND IDENTIFICATION OF ASBESTOS MATERIALS

Asbestos is seldom labeled and is generally incorporated into the difficult to access construction areas: in attics and boiler rooms; in or on ceilings, plaster walls and tile mixtures; and on pipes hidden from view. Commonly, asbestos materials are present on pipes suspended above false ceilings that are used as the ventilation plenums. Assessment strategies include the review of building and renovation plans (which unrealistically assumes that architecture drafts are accurate and updated) as well as walk-through surveys. The comprehensive strategies include review of plans, inspection, sampling, and record-keeping. The initial assessment can be expensive and time consuming. The goal of asbestos assessments is to pinpoint imminently dangerous locations and begin a long term management of the problem. It does not presume removal of asbestos materials.

It is difficult to visually identify asbestos materials. Materials such as cellulose, mineral wools, and plasters may look similar to asbestos and can mask its presence. Even with experience, mistakes occur with visual inspection. For conclusive identification, samples must be stained and examined by phase contrast optical microscopy or electron microscopy (e.g. NIOSH P&CAM 239, 1977 and Asbestos International Association RTM2, 1984 ). Even these procedures can be statistically challenged because of large sampling errors ranging from differences in fiber counting to lack of homogenity in the sampled material.

# CHAPTER II

# STUDY DESIGN

## STUDY DESIGN

Because of the vast quantities of deteriorating asbestos in state and private buildings, increased federal regulation, and public pressure for a safe and healthy environment, asbestos abatement programs are necessary for many large institutions. The following study is designed to determine the status of current asbestos abatement policies in large institutions and to make recommendations to improve the policies and practices.

### A. STATEMENT OF THE PROBLEM

Institutional buildings constucted or renovated between 1940's and the 1970's often contain vast amounts of either loose (friable) or bonded asbestos materials. Although useful as insulation, fire and noise protection, and decoration, bonded asbestos products eventually become damaged and the bonding material deteriorates. As the bonding material deteriorates, asbestos fibers may become airborne. It is the airborne fibers that are potentially hazardous. The complex asbestos issue boils down to a few facts:

1) Over 30,000,000 tons of asbestos have been used in the U.S. during this century. Two-thirds of it has been used by the construction industry for insulation or fireproofing (Ryckman, Ryckman, Peters, 1983);

2) When asbestos is damaged or its bonding agent deteriorated, asbestos fibers can become airborne;

3) Airborne asbestos contributes to morbidity and death . Although supported by extensive epidemiological and toxicological evidence (McDonald and McDonald, 1978; Gardner, 1942; Yazicioglu, et al, 1980; Whitwell, Scott, and Grimshaw, 1977; Selikoff, Hammond and Churg, 1964 and 1968) the degree of health risk is controversial;

4) The location and condition of asbestos is unassessed in most buildings. Assessment involves inspections, sampling, and reporting;

5) Asbestos abatement is the transformation of friable materials to a condition which prevents fibers from becoming airborne. Friable asbestos refers to materials that contain at least 1% of asbestos and are in a condition which is unbonded or may become unbonded. Management options include encapsulation, the creation of barriers, removal, or postponement of action for the future;

6) Decisions regarding asbestos abatement involve scientific, political, legal, and social factors;

7) Resolution of numbers 4, 5, and 6 involve a degree of training and extensive amounts of time and money.

For health, political and economic reasons, the asbestos issue impacts public institutions. Large institutions, notably educational, recreational, and health care institutions, are targeted because they affect many people and are "in the public eye." Issues can be political, records are public, and funding is competitive. Inevitably, the public becomes aware of asbestos and advocates immediate removal, a response that may or may not be reasonable from a health and safety perspective. In 1985, the EPA extended the federal OSHA regulations that protect workers who deal with asbestos to employees of state and local governments. This was prompted by a petition filed in late 1983 by the Service Employees International Union, which represents about 100,000 school workers (Chemical and Engineering News, 1985).

Concern about the deteriorating bonding of asbestos in institutional buildings may be justified. Exposures affect a multitude of individuals who are diverse in age, sensitivity, and health status. Depending on the purpose of the buildings, the exposed may be healthy workers or specifically sensitive populations. Members of institutions often have exposure risk factors more complex than the typical "healthy worker." Institutions often house and support activities for the young, ill, or handicapped.

Another unique characteristic of buildings at large institutions such as universities or hospital complexes is that individuals often live in buildings on the premises, thus being exposed to the environment for more than the typical 8 hour per day workshift assumed in the development of occupational standards. For instance, university personnel may occupy asbestos containing family post-war housing, dormitories, trailers, clinics and hospitals, and academic departments. Asbestos is a substantial problem in such diverse areas as power plants, steam tunnels, and student activity centers. Recreational and performing arts buildings usually contain asbestos fireproofing and insulation which is often damaged by recreational activities, vandalism, and normal deterioration. The problem may be serious in rooms for athletic activities (e.g. pool areas and rooms used for body conditioning and ball sports).

Finally, the problem of asbestos in large public institutions is exacerbated due to liberal use of asbestos in buildings constructed prior to 1972, high cost of abatement, and complex management channels. The federal governement relinquishes the enforcement of some environmental and/or occupational health and safety regulations to states having federally approved programs/agencies that include protective regulations and enforcement. Because the federal asbestos regulations have changed since the approval of these state programs, the applicability and enforcement of federal abatement requirements may vary considerably from state to state.

## B. THESIS OBJECTIVE

The objective of this thesis is to determine whether the asbestos abatement programs at large institutions a) comply with federal and state laws; b) are effective in providing a safe and healthy working and living environment for employees, residents, students, et cetera, and c) are managed in an effective manner.

C. CRITERIA

The following criteria were outlined as components of an adequate asbestos managment/abatement program. They are based on legal requirements and state-of-the-art considerations as detailed in Chapter IV "Program Requirements." Institutions should

1) have a policy that recognizes the potential health risks of friable asbestos and authorizes and endorse asbestos management and abatement programs. The minimal policy and programs should comply with OSHA and EPA regulations, as well as applicable state and local regulations;

2) designate and financially support (in-house or contracted) personnel responsible for

a. establishing the institutional policies and programs;
b. responding to health and safety incidents (defined as any investigation leading to the discovery of potentially friable asbestos; including situations in which asbestos abatement procedures are deemed necessary)--activities include record maintenance, inspections, and sampling;
c. recommending and initiating asbestos abatement procedures as necessary;
d. conducting the asbestos-related renovation, maintenance and demolition activities; and reporting to the EPA as required;
e. training and supervising asbestos related work activities;
f. obtaining and maintaining supplies and equipment needed asbestos abatement ;
g. communicating with contractors, governemental authorities, and in-house participants of asbestos related activities;
h. enforcement of the policies institutional policies concerning asbestos;

3) provide for

a. funding and contracting of abatement activities;
b. the disposal of asbestos waste;
c. warning signs and labels;
d. employee "hazard communication" and education;

4) have support programs as required by OSHA for:

a. training personnel in work practices and methods;
b. monitoring the working environment;
b. providing respirators and personal protection equipment;
c. medical surveillance;

5) be able to show compliance with OSHA and EPA permissible exposure limits and regulatory requirements.

In order to study the adequacy of institutional asbestos abatement programs with the above criteria, the author selected large multifunctional institutions that have extensive amounts of asbestos in conditions and locations that may pose potential health problems; constructed a data-base of airborne asbestos concentrations to estimate compliance with OSHA and EPA permissible exposure limits (PELs); and evaluated the conformance of the on-site asbestos abatement programs and practices with legal requirements and the state-of-the-art health and safety considerations. The data-base was divided and analyzed in five categories: air quality samples taken during asbestos incident investigations; during pre-removal activities; during removal, both inside and outside of the containment areas; and after the removal project is completed. The abatement policies, programs and practices were researched by reviewing records, interviewing in-house and contracted personnel, and participation in asbestos related activities.

## D. SELECTION OF THE INSTITUTION MODEL

The objective of this project is to determine the adequacy of asbestos abatement programs of large institutions. The scope of the investigation includes institutions for health care, education, and research that are operated by state or local government. Although aspects of this paper coincidently apply to nonprofit, corporate and manufacturing institutions, their programs are beyond the scope of this investigation. Since was not feasible to inspect or survey a significant random sample of programs, a few large multifunctional institutions with buildings which reasonably encompassed the activities of different types of institutions (i.e. research, education, health care, and culture and arts) were selected for study.

Universities were chosen for several reasons. They are educational facilities with a cooperative attitude with easy access to records and staff. Universities have educational, health care, and cultural/recreational components. Because of their size, diverse functions, and age and diversity of the buildings, universities have a broad range of asbestos management and abatement problems. The unique structures include hospital complexes, farms, hotels, performing arts centers and a research nuclear reactor. Almost all buildings constructed prior to 1970 contain large amounts of asbestos now in various stages of deterioration. The programs operate on competitive state budgets and without profit motivation.

E. STUDY LOCATIONS

The University of North Carolina, the University of Illinois, and the University of Michigan participated in the study. The Universities' programs exemplified large scale institutional asbestos abatement projects. Airborne asbestos concentrations were estimated from air samples taken at the universities and at three North Carolina public schools . Data taken at the public schools provided information on airborne concentrations during the removal of sprayed-on asbestos.

1. University of North Carolina. The attributes of the University of North Carolina, Chapel Hill which are relevant to asbestos abatement are:

1. The University has approximately 22,000 students (14,000 undergraduates). It was founded in the 1790's and therefore has old buildings that require renovation. There is no money appropriated for asbestos removal in the building renovation budget for next year, large asbestos removal projects are being planned for fiscal years 1987-1989. The University has 5 health care schools and operates hospitals and clinics. The hospital operates a safety office that is independent from the University's Occupational Safety and Health Office.

2. The University has a formal asbestos abatement program. It is managed by a full time asbestos coordinator at the Occupational Health and Safety Office. The coordinator acts directly with the Director of Personnel Training and Safety at the physical plant. Both conduct asbestos abatement training programs for in-house maintenance staff.

3. Most asbestos abatement projects are conducted in-house by the physical plant. Since the physical plant is limited to projects of less than $75,000, (approximately $ 1.5 million per year) large renovation projects involve asbestos removal by contracted labor. The trend for contracted removal is expected to increase because of the policy to remove asbestos during renovation. Three contracted projects have been completed to date.

4. The craft/maintenance personnel are predominantly male, are racially mixed, and are not unionized. The employees at North Carolina have strong seniority and employee turnover is low. The level of formal education varies significantly and literacy cannot be assumed.

2. University of Illinois. The attributes of the University of Illinois, Champaign-Urbana, which are relevant to asbestos abatement are:

1. The University has approximately 37,000 students (27,000 undergraduates) It was founded as a land grant institution in the mid-1800s and is characterized by farms and engineering/research. Numerous construction and renovation projects are underway because of the aggressive "Build Illinois" program and Super-Computer-Coordinated Science Building programs.

2. At the beginning of this study the University had no formal asbestos abatement program; it did, however, conduct frequent asbestos abatement activities. It had no formal employee training related to asbestos removal. This study served as the foundation for the asbestos abatement program.

3. The University contracts all projects which entail substantial asbestos removal. The current operations and maintenance policy is to undertake only those projects with less than 60 linear feet of insulation (using glove bags).

4. The University has a heterogenous maintenance/physical plant. Predominantly, the craft/maintenance employees are white males who belong to unions. Craftpeople cannot readily be dismissed from employment. The employment is generally stable with a low turnover.

5. The University invited the researcher to assess the asbestos abatement activities with the Dept. of Environmental Safety & Health and granted access to both records and data gathering equipment.

3. University of Michigan. The attributes of the University of Michigan which are relative to asbestos abatement are:

1. University of Michigan has a program which has been formally established for a longer period of time than those of the Universities of Illinois and North Carolina. It runs well established respirator and medical surveillance programs. The Department of Occupational Safety and Environmental Health contributed data regarding expenditures for asbestos protection equipment.

2. The University of Michigan has a strong student government with a history of influencing university policy through traditional means as well as lawsuits. Student groups are concerned about asbestos exposures and initiate incidents to investigate and abate exposures. Due to the controversial status of asbestos on campus the researcher was not permitted to use all of the asbestos exposure data requested.

3. The University has a coordinator of the asbestos abatement program from the Department of Occupational Safety and Environmental Health. The researcher was also permitted to interview the coordinator, review controversial incidents, and use audiovisual training materials.

4. Supplementary Exposure Data. Because of the limited exposure data available at the Universities of Illinois, North Carolina, and Michigan during the removal of friable

spray-on asbestos insulation, data was supplemented from removal projects at three nearby North Carolina schools: Ellerbe Junior High School (Richmond Co.), Guilford Middle School (Guilford Co.), and Northwest High School (Guilford Co.). Although all three Universities have extensive amounts of spray-on insulation, data on airborne concentrations are unavailable because most removal projects are either in the planning or monitoring phases.

# CHAPTER III

# METHODS

## METHODS

A safe level of exposure and compliance was determined by three methods: a literature review of asbestos-related legal requirements and state-of-the-art considerations; the collection and analysis of airborne asbestos concentrations during asbestos management/abatement activities; and an evaluation of the asbestos programs at three study locations.

### A. LITERATURE REVIEW

A literature review and legal search was conducted to investigate four areas of the asbestos issue: the historical perspective, health effects and risk factors, current practices in abatement activities, and legal or recommended exposure limits and program requirements. Sources of information include laws and regulations, scientific and professional journals, and the popular literature.

### B. AIRBORNE ASBESTOS CONCENTRATIONS: DATA COLLECTION AND ANALYSIS

The database of airborne asbestos concentrations (Appendix B) was constructed from air samples records of the University of North Carolina's Occupational Safety, and Health Office (OSHO); the University of Illinois' Division of Environmental Health and Safety (EHS); and the University of Michigan's Office of Occupational Health and Safety (OHS). Additional samples were supplied by the Health & Hygiene Inc., a Greensboro N.C. consultant for private asbestos removal contractors near the University of North Carolina. The supplemental samples were taken at primary and secondary grade schools during the removal of sprayed-on asbestos insulation. The samples were used in this study because deteriorated sprayed-on insulation exists in some locations at all three universities: removal of sprayed-on asbestos is expected at all three universities as funds become available. Although the data from the Universities of Illinois and North Carolina are comprehensive, the data from the University of Michigan is limited to two projects: the removal of asbestos insulation in the steam tunnels and the removal of asbestos in an academic building (Lorch Hall).

Most samples obtained from the Universities of Illinois and North Carolina consisted either of air quality concentrations in the student and staff occupied buildings or of airborne concentrations during asbestos-related maintenance activities by university employees. May 1985 through August 1985, the author monitored "air quality" and "pre-removal" concentrations inside and outside of several University of Illinois buildings. The author and contractors simultaneously monitored area concentrations and personnel breathing zone concentrations of both University employees and contracted labor engaged in the wet removal of asbestos from a three story dairy manufacturing building (DMB). Personal and area concentrations were monitored in one room of the building during dry removal.

1. Air Sampling Techiques. It is assumed that all data was collected using a method in accordance to either the original NIOSH P&CAM 239 Method (NIOSH, 1977) or the updated NIOSH Method 7400 (NIOSH,1984). In both methods, cellulose ester membrane filters are mounted in small sampling cassettes and are attached to personal sampling pumps (typically with a flowrate between .5 L/min and 4 L/min). Small free standing even-flow pumps (flowrates often exceeding 10 L/min) are sometimes used instead of personal sampling pumps to draw larger volumes of air for measuring area concentrations. After a given time, the cassettes are sealed until counted. Each filter is removed from the cassette and a pie-shaped portion of the filter is cut and mounted onto a

glass microscope slide. Chemicals such as dimethyl phthalate and diethyl oxalate are used during mounting to transform the white filter into a clear medium, leaving the fine asbestos fibers opaque and visible under the phase contrast microscope.

On February 15, 1984, NIOSH introduced the Method 7400 as an improvement of the P&CAM 239 Method. Because of the use of smaller filters the method has improved sensitivity, fewer problems with non-uniform fiber loading, and better counting precision than the P&CAM 239 method. The 7400 method essentially combines the best features of a method designed by the Asbestos International Association and the P&CAM 239 method. A brief comparison of the P&CAM 239 and 7400 methods is outlined in the following table.

## TABLE 2

SUMMARY OF 7400 AND P&CAM 239 SAMPLING METHODS

| | METHOD 7400 | METHOD P&CAM 239 |
|---|---|---|
| filter: | 25 mm dia.<br>.8 to 1.2 um pore size | 37 mm dia.<br>.8 um pore size |
| cassette extension cowl: | 50 mm | none |
| foil wrap cassette | yes | |
| flowrate L/min: | > or = .5 | 1.0 to 2.5 |
| air volume: | 400 to 1920 | |
| working range fibers/filter:* | 38,500 to 500,000 | 141,000 to 1,410,000 |
| detection for working range:* | .02 f/cc for 1920 L air | .1 to 60 f/cc |
| limit of detection with CV=.10:* | 2,700 f/filter | 28,000 f/filter |
| counting differences: | use of Walton-Beckett graticule (.00785 mm2/field) counting rules A; and B:<br>1. longer than 5 um;<br>2. L:W ratio at least 3:1;<br>3. less than 3 um dia.; | use of porton reticle (.003mm2/field) counting rules A:<br>1. longer than 5 um;<br>2. L:W ratio at least 5:1; |

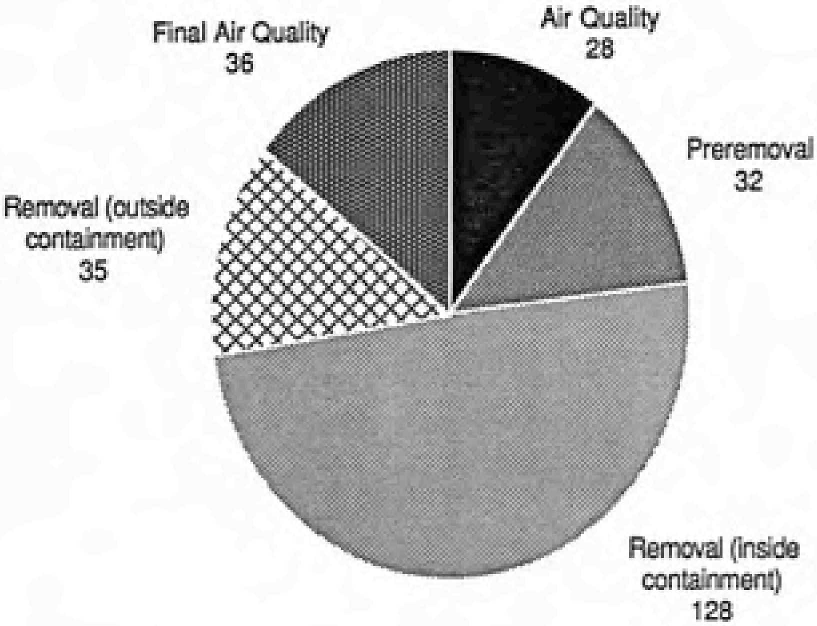
* estimates

Source: Nam Won Paik, "NIOSH Proposes New Method for Sampling and Analysis of Asbestos," Clayton Environmental Laboratory, Newsletter; based on Methods P&CAM 239 and 7400, NIOSH Manual of Analytical Methods, 1977 and 1984, Cincinnati.

2. Data Classification. The collected data was divided into five sampling classifications: samples taken during incident investigations to determine the "air quality" and the necessity of abatement procedures; samples taken just prior to abatement/removal (hereinafter "pre-removal"); samples taken within the contained work area during removal (hereinafter "removal"); samples taken outside of the work containment area during abatement activities (hereinafter "removal/outside containment"); and samples taken for "final" post-abatement air quality. Two hundred fifty-nine of the roughly three hundred collected air sample reports had sufficient information to classify into the exposure categories. Appendix B contains a complete list of the collected data. Four of these were reported as "blank" or "invalid" and approximately 15 were omitted in the statisitical analysis of the *sample* distributions because of a high lower limit of fiber detection (i.e. 0-.05 f/cc or higher). Appendix D contains a list of airborne concentrations used to describe the *sample* distributions of each exposure category. The following figure illustrates the sampling scheme and number of samples in each category.

**FIGURE 1**

ASBESTOS SAMPLING SCHEME
259 SAMPLES




3. Sorting and Standardizing the Data. After the data was classified by activities, the "blank or invalid" samples were removed from the analysis. The filters reported as "zero fiber count " were then standardized to the lowest limit of detection as reported by the company that analyzed the filter (see Appendix C) . As shown below, the overloaded filters were calculated to contain a minimum of approximately 7 f/cc.

1. The "Upper Working Range" of a filter used in the NIOSH P&CAM 239 method (Table 2) = 1,410,000 fibers;
2. the average air volume taken during the 72 personal sampling periods = 193 Liters;
3. therefore, the minimum estimated overloaded filter count is

$$\frac{1{,}410{,}000 \text{ fibers}}{193 \text{ L air}} \times \frac{1 \text{ L}}{1000 \text{ cc}} \text{ or } 7.3 \text{ f/cc}$$

Since the actual filter count could be much greater than this level, the legal ceiling limit of 10 f/cc was assigned the 6 overloaded filters.

4. Statistical Analysis. There are several statistical approaches to analyzing environmental and occupational exposure data. The most common of these are based on the assumptions that the samples are independent and distributed either normally (Roach, et al, 1967, and Kerr, 1962) or logarithmically (Breslin et al., 1967). If a large percent of samples (approximately 95%) fall below a "reliable level of detectability", the gamma distribution has been used for exposure analysis (Berry, G., and N.E. Day, 1973). It is, however, generally accepted "that occupational environmental data from both open air and confined work spaces for both short (seconds) and long (days) time periods are lognormally distributed" (NIOSH Manual, p. 122, 1977). To verify the selection of the logarithmic distribution model, the 10 categories of data were plotted as cumulative percent distributions on logrithmic probability paper . These graphs are contained throughout Chapter V, "Analysis of Airborne Concentrations."

The logarithms of the sample geometric mean (GM) and the sample geometric standard deviation (GSD) were used to determine the population arithmetic mean (AM) and the population standard deviation (SD) for each category of airborne asbestos concentrations. The AMs were then compared to the legal exposure limits.

1. GM=50%; concentration;
2. GSD=84%/50%;
3. ln (GM)= $\mu_z$ of ln(x) distribution;
4. ln (GSD)= $\sigma_z$ of ln(x) distribution;
5. AM= $\mu$ = (GM) $\exp(1/2\ \sigma_z^{\ 2})$;

Hypothesis testing, using the Student-t test (2-sided/95% confidence; Remington and Schork, 1985) was used to compare the geometric means of several exposure classes: air quality vs. pre-removal exposures; pre-removal vs. final exposures; and pre-removal vs. air quality outside of containment areas during abatement procedures.

The concentration data in the removal categories was divided and examined according to "personal" versus "area" sampling methods and according to three removal techniques : wet asbestos removal, dry asbestos removal, and dry removal of the asbestos contaminated ceiling tiles which channel air for room ventilation. Hypothesis testing using the Student-t tests were used to compare the GMs for area verses personal sampling and for wet, dry, and ceiling-tile removal techniques.

## C. PROGRAM EVALUATION METHODS

Evaluation of the existing asbestos abatement programs utilized three methods: review of the literature, written records, and policies; interviews; and involvement in training and abatement activities. The federal laws and OSHA and EPA regulations were used to outline program requirements. Additional information on methods of compliance and interpretation of the laws and regulations came from the NIOSH/ERC "Asbestos in Buildings" (1986) instructional materials. State-of-the-art safety practices and safe levels of exposures are adopted from NIOSH "Asbestos in Buildings" and " Asbestos Sampling NIOSH Course 582" (1985) instructional literature and ACGIH recommendations (ACGIH, 1984-1985).

Although written program and policy statements were used, interviews and direct involvement were the most accurate sources of updated information on actual asbestos abatement practices. All records of the health and safety offices at the Universities of Illinois and North Carolina were available for the study. Some records were obtained from the universities' departments of operations and maintenance, and engineering and planning. Some University of Illinois workers' compensation and accident records were also available. Written records were generally in the form of memos, incident reports, sampling records, policy statements, financial records, and inter-office letters. Three months of participation in abatement projects and training were essential to distinguish between actual practices and those outlined in policy statements.

To further distinguish policy statements from practice, several groups were interviewed: university craftworkers and contracted laborers; university offices of health and safety; operations and maintenance/ housing, and offices of planning; and private removal contractors and air sample test laboratories. Telephone and personal interviews with those involved in asbestos management and abatement covered six aspects of asbestos abatement programs:

1. existing policies for asbestos inspections and assessments;
2. sampling procedures;
3. nature of asbestos incidents: frequency, discovery, record-keeping and abatement decisions;
4. procedures for asbestos abatement and removal;
5. employee training and medical evaluation; and,
6. project planning and funding.

These six aspects were combined as an outline for the discussion of program review section.

# CHAPTER IV

# PROGRAM REQUIREMENTS

## PROGRAM REQUIREMENTS

To have adequate asbestos abatement programs, universities must comply with federal legal requirements incorporate state-of-the-art safety considerations. The state-of-the-art criteria encompasses the recommendations of the American Conference of Governmental Industrial Hygienists and OSHA and EPA drafted or proposed standards. The legal and recommended exposure limits are then compared with the monitored concentrations and the policies of the university asbestos management programs. This paper evaluates both written policies and the observed practices of the institutions.

Rules and regulations regarding individual states are authorized in the published annotated statutes of each state. Relevent information can be searched by various key words: e.g. abatement practices, air pollution, asbestos, asbestosis, employment, environmental protection, labor, schools, and workers compensation. Because state and local requirements impact institutions differently from state to state, state requirements will be addressed only in general terms. Examples of additional information addressing specific topics for the states of North Carolina, Illinois, and Michigan are referenced as follows:

1. Worker's Compensation: Illinois Annotated Statutes 48 § 172.41 et seq.; General Statutes of North Carolina 97 § 53 et seq.; Michigan Statutes Annotated 17 § 237 (501) et seq.
2. Asbestos in Schools: Illinois Annotated Statutes 122 § 1401 et seq;
3. Asbestos Abatement: Illinois Annotated Statutes $111^1/_2$ § 22.03
4. Environmental Protection Authority: Michigan Statutes Annotated 14 § 528 (201) et seq.
5. Occupational safety and health: Michigan Statutes Annotated 17 § 50 (1) et seq.

A. FEDERAL LEGAL REQUIREMENTS

Legal asbestos abatement requirements affecting public institutions are promulgated by either the Department of Labor's Occupational Safety and Health Administration (OSHA) or the Environmental Protection Agency (EPA). They protect both workers and the environment.

1. Environmental Protection Agency. The EPA administers the National Emissions Standard for Asbestos which includes the guidelines for asbestos emissions from demolition and renovation/remodeling projects (49 Fed. Reg. 13658-13665,1984). In addition, it regulates air cleaning, waste disposal, and new construction. The only significant air cleaning regulation requires the use of high efficiency particulate air (hepa) filters during major asbestos removal activities. University contracts for asbestos waste disposal generally provide that it is the contractors' responsibility to comply with all EPA regulations. New construction is not affected since most construction uses of friable asbestos ended in the mid-1970s. Sprayed-on applications have been prohibited since 1977 (40 CFR Part 61.150).

a. Protection for Employees of State and Local Governments. In July of 1985, the EPA adopted 40 CFR Part 763, Subpart G, "Asbestos Abatement Projects." It extends OSHA's asbestos protection rules to state and government employees who deal with asbestos (C&EN, July, 1985). The rules are virtually identical to the OSHA standards in terms of exposure limits and compliance requirements. To avoid repetition, the EPA requirements appear with the OSHA requirements in the following section. Discussion is deferred to section B of this chapter: "State-of-the-Art Developments."

b. Demolition and Planned/Emergency Renovation. The EPA (or its representative enforcement agency) requires notification of demolition and renovation projects involving significant amounts of asbestos displacement. The notification specifies the techniques used for asbestos emission control, waste disposal and cautions, and abatement procedures. Universities and other so called "operators" are required to notify the EPA ten days before scheduled removal or demolition involving asbestos of at least 80 linear meters (260 ft) on pipes or at least 15 square meters (160 $ft^2$ ) on "facility components." For removal or demolition of less than these amounts, reporting is to be conducted at least 20 days prior to the operation. For emergency operations, meaning demolition or renovation of structures which are in danger of imminent collapse or projects resulting from unforeseen events, reporting is required "as soon as possible" before the operation begins. Notification includes nine elements: name and address of operator, description of the project, estimate of the amount of friable asbestos, location of the facility, nature of the project, schedule of starting and ending dates, procedures to be used for compliance with removal regulations, the authority who ordered the demolition, and the name and location of the waste disposal site.

Most routine abatement projects at universities are small and seldom scheduled far in advance. In these cases the university is not required to adhere to any of the three previous notification timetables, or to deliniate the nine informational elements in individual reports. Instead, the University may report the additive amount of friable asbestos which can be predicted to be removed in no more than 1 year. The University then offers a general description of the nine reporting elements.

Strict adherence to the procedures outlined by the EPA rules and regulations is intended to minimize the airborne release of asbestos fibers. Asbestos material must be wetted, sealed, and contained prior to demolition or removal. No visible asbestos emissions are permitted to escape into the air. This last stipulation is ineffective because 1) it is impossible to distinguish asbestos from non-asbestos emissions; and 2) it is the invisible emissions of airborne fibers which are small enough to penetrate the respiratory tract and cause pulmonary diseases. The regulation most likely exists in this format because of the EPA's authority to regulate nuisance and fugitive dusts. EPA's dust regulations forbid visible emissions from crossing beyond the generator's property lines. Despite the shortcomings of the visible emissions provision, the EPA regulation effectively requires the controlled removal and disposal of asbestos prior to building demolition.

Friable asbestos wastes must be wet and enclosed in sealed containers for disposal. The containers must be marked (29 CFR §1910.1001):

CAUTION
Contains Asbestos
Avoid Opening or
Breaking Container
Breathing Asbestos is hazardous
to Your Health

The material must then be transported to sites which are EPA approved for asbestos disposal. The transportation and permanent storage/disposal of asbestos materials is conducted off of university property by private contractors. Therefore, responsibility for compliance with disposal regulations rests with the contractor, not the university.

c. Identification and Notification in Primary and Secondary Schools. A less obvious area of federal EPA regulation covers the operation of all primary and secondary schools. Schools, such as University High School at the University of Illinois, must adhere to the EPA's Identification and Notification regulations (40 CFR § 763). These regulations require that schools 1) inspect the premises for friable asbestos; 2) post warnings of asbestos hazards in the primary administrative and custodial offices; 3) report the existence of friable asbestos to the appropriate parent teacher association; and, 4) maintain records at the local education agency. Part four may be inapplicable because the local education agency lacks the jurisdiction over University-run schools.

2. Occupational Safety and Health Administration. Occupational Safety and Health Administration regulations apply to contracted employees even when they are working on the property of public institutions. University and state employees, however, are not

covered by these regulations unless protected by state OSHA regulations (see new EPA regulations concerning state employees in "State-of-the-Art Developments)." Enforcement of these regulations tends to be more stringent in states which have their own OSHA asbestos regulations. Until recently, incentives to comply with federal OSHA standards arose primarily from litigation and ethics, rather than federal agency enforcement.

a. Permissible Exposure Limits (PELs). The Occupational Safety and Health Administration established permissible exposure limits (PELs) which limit the concentrations of asbestos fibers to which any employee may be exposed. The 8-hour time-weighted average (TWA) airborne concentration is 2 fibers of airborne asbestos/cubic centimeters (f/cc) of air (29 CFR §1910.1001). The 15 minute peak or ceiling exposure for employees is 10 f/cc. Asbestos includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite. Asbestos fibers are defined as being longer than 5 microns in length with an aspect ratio of greater than 3 to 1. Employers must take periodic air samples to determine employee exposure. NIOSH methods 7400 or P&CAM 239 are acceptable air sampling techniques to determine the airborne fiber concentrations. If the air concentration exceeds the PELs, the employer must use safe engineering methods, sound work practices, and personal protection to reduce the employee's inhaled exposure below the PEL. When airborne concentrations exceed the PELs, engineering and work methods, rotating workshifts, and/or personal protection must be used to reduce an employee's exposure.

On November 4, 1983, OSHA established an emergency 8 hr. TWA standard of 0.5 f/cc. The emergency level was successfully disputed and, therefore, became non-binding. In June of 1986, OSHA announced the promulgation of a new permanent standard which lowers the PEL to 0.2 f/cc TWA. A 200 page discussion of the new PELs is planned to be submitted to the Federal Register in June, 1986. Although the rules are not yet in effect, they are used by the researcher in evaluating abatement policies.

b. Engineering Methods. Acceptable engineering methods include the use of engineering devices and controls that either isolate asbestos materials or ventilate, exhaust, or collect asbestos dust. Local exhaust ventilation must comply with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems (ANSI Z9.2-1971). Particular tools, such as saws, drills, and abrasive wheels, must be provided with local exhaust if their operation liberates airborne asbestos in excess of the exposure limits.

c. Work Practices. Asbestos must be removed and handled wet, insofar as practicable. Friable asbestos materials shall not be removed from transportation containers without being wet, ventilated, or enclosed so that exposures remain below the PELs. Wastes must be stored and disposed in sealed, impermeable, and labeled containers.

According to the OSHA asbestos standard, "All external surfaces in any place of employment must be cleaned and maintained free of asbestos fibers if, with their dispersion, there would be an excessive concentration" (29 CFR 1910.1001 (h)). This applies to all operations, not only asbestos abatement projects. Respirators (approved by the Bureau of Mines, the Department of the Interior, or NIOSH; see 37 Fed. Reg. 6244, 1972) and protective clothing are necessary when engineering methods and housekeeping practices are insufficient to insure that employee exposures are below the PELs. Employees engaged in removal, spraying, or demolition of pipes, structures or equipment covered with asbestos materials must be provided with respirators and protective clothing.

d. Personal Protection Equipment. The use of approved respirators or shift rotation of employees is permissible in three situations: during the time necessary to install the engineering controls and proper work practices; when the controls and engineering methods are not technically feasible to reduce exposures below the PELs; and in emergencies. Since most university abatement projects are temporary, personal protection equipment is justifiable.

1). Respirators. The use of respirators in asbestos abatement projects has extensive repercussions for institutions. Employers that require the use of respirators must have a respirator program which ensures not only the proper selection and maintenance of respirators, but also the training, and medical suitability of employees to wear respirators. This is a key point, because large institutions generally support activities besides asbestos abatement programs which necessitate the use of respirators.

The selection of respirators depends on the level of airborne exposure. The legal standards approve three categories:

1) single use or reusable air purifying respirators (APRs) are acceptable when exposure levels are reasonably not expected to exceed 10 times the PELs;
2) powered air purifying respirators are to be used when the expected exposures are between 10 and 100 times the PELs; and,
3) type C supplied-air respirators with continuous flow or pressure demand characteristics are to be used when the expected exposures exceed 100 times the PEL.

Single use respirators are discouraged by NIOSH and OSHA because it is difficult to insure an air tight seal along the face. Reusable APRs are by far the most commonly used. Although powered APRs are more expensive than the reusable or single use APRs and are relatively new to the market, they may be appropriate for people experiencing respiratory distress or heat stress while involved in abatement activities .

Under the 29 CFR §1910.134. and §1910.1001, the university must select respirators and establish a respirator program in accordance with the National Standard Practices for Respiratory Protection, ANSI Z88.2-1969. No employee can be assigned to use a respirator unless, upon his most recent examination, an examining physician determines that the employee is able to ***function normally*** wearing a respirator. The use of the respirator must not ***impair the health and safety*** of this or other employees. The minimal acceptable respirator program has 10 requirements:

1) the program must be written, including the standard operating procedures governing the selection and use of the respirators;

2) respirators shall be selected on the basis of the hazards to which the worker is exposed;

3) respirators must be properly selected; fit-testing is essential to proper selection;

4) users must be instructed and trained in respirator usage;

5) respirators must be cleaned, and disinfected as appropriate;

6) respirators must be stored in a convenient and clean location;

7) respirators must be routinely inspected and maintained;

8) surveillance of work area conditions and degree of employee exposure or stress must be maintained;

9) regular inspection and evaluation of the effectiveness of the respirator program;

10) a local physician is to determine what health and physical conditions are pertinent to the respirator program; the respirator user's medical status should be reviewed periodically (for instance, annually); and

11) *approved or accepted* respirators shall be used when they are available.

Employers must certify their employees to use respirators by fit testing and training. OSHA asserts that individuals with excessive facial hair, notably beards, may not use respirators because a tight fit may not be maintained. Similarly, contact lens wearers are also prohibited because of the danger in removing either the respirator or the lenses under adverse situations. All of the institutions surveyed tended to resist OSHA's respirator policies, because most employees only periodically use respirators and the requirements are difficult to enforce.

2). Protective Clothing. The use of coveralls or similar whole body clothing, head coverings, gloves, and foot coverings is required for those working in environments exceeding the PELs. Changing rooms with separate clothes lockers must be supplied so street clothes do not become contaminated. Laundering of contaminated clothes must be done in a manner that prevents the release of fibers over the PELs. Contaminated garments must be transported in sealed impermeable, labeled containers. The washer of the clothes must be informed about the proper laundering requirements.

e. Medical Monitoring of Employees. In addition to the medical surveillance necessitated by the use of a respirator (as discussed above), employees must undergo a medical examination within the first 30 calendar days of employment in an occupation exposed to an asbestos level of at least 1 f/cc 8-hr TWA or a peak exposure of 5 f/cc. This examination includes a minimum of:

1) a chest roentgenogram (posterior or anterior 14 X 17 inches);

2) a history to elicit symptoms of respiratory diseases; and

3) pulmonary function tests which include forced vital capacity (FVC) and forced expiratory volume at 1 second ($FEV_{1.0}$).

Thereafter, annual examinations which include the above examination criteria are required. A final examination is required within 30 calendar days of temination of employment. A *recent* examination which fulfills the above criteria may replace the appropriate initial, annual, or terminal examination. Medical records are open to the employee, the employee's representative, and OSHA/NIOSH for inspection. The records must be retained by the employer for at least 30 years.

f. Exposure Monitoring. Environmental and personal monitoring is required to determine airborne concentrations of asbestos. Initial determinations must be made, followed by periodic sampling to insure that exposure conditions have not significantly changed. In no case may the sampling period exceed 6 months.

g. Caution Signs and Warnings. Caution signs as specified in the above work practices must be displayed outside of asbestos abatement projects that may exceed the PELs. Warning labels with the same wording must be both visible and legible on all friable materials or containers of friable materials.

h. Training. Employees must be trained in asbestos abatement techniques and the proper use of respirators. Both types of training are outlined in the previous paragraphs. Employees must be specifically informed about the health hazards of asbestos, including the correlation of asbestos-related diseases with smoking.

3. Hazard Communication Laws. The effects of the federal hazard communication or "right to know" regulation on public and private institutions are subtle. The regulation requires all employers listed in Division D of the Standard Industrial Classification (SIC) Codes 20 through 39 to draft a comprehensive written hazardous chemicals/materials program. The program must include identification and hazard evaluation of chemicals produced; Material Safety Data Sheets (MSDS) which summarize physical properties, health hazards and handling precautions of hazardous substances; the labeling of all containers with hazard and emergency response information; and, the education and training of employees in the handling and work practices involving hazardous substances.

Asbestos-related testimony influenced the passage of the law and subsequent regulations in two ways (48 Fed. Reg.53280-53347, 1983). It illustrated a need for legislation designed to address hazards that cause serious morbidity and death by low level, chronic exposures with long latency periods. Asbestos related diseases among the general populous also encouraged a market-oriented response to the problem of using unlabeled products that do not contain obvious hazardous materials.

Although OSHA regulates a broad range of industries, laboratories, importers, and distributers, state instituions are not classified under SIC Codes. Therefore, the hazard regulation only indirectly impacts educational and health care institutions. Chemical manufacturers and distributors must distribute MSDS with non-consumer oriented products sold to or used by institutions. Title 40 CFR § 763, "Asbestos Abatement Projects," rather than hazard communication regulations, covers the requirements for asbestos labeling, education, and training practices at state institutions. The applicability of state employee and community right-to-know legislation, however, must be considered in each location. Illinois, Michigan, and North Carolina have all passed right-to-know legislation.

B. STATE OF THE ART DEVELOPMENTS

Legal permissible exposure levels (PELs) fail to reflect current epidemiological data and the most recent recommended threshold limit values (TLVs) of the American Conference of Governmental Industrial Hygienists (ACGIH). Recent toxicological and epidemiological findings can be used to support the proposed lowering of legal permissible exposure limits. Although the emergency rule of 0.5 f/cc in November of 1983 failed to be adopted, extensive evidence was presented demonstrating that lower levels would save lives (48 Fed. Reg. 53280-53347, 1983).

1. Recommendations of the American Conference of Governmental Industrial Hygienists. The American Conference of Governmental Industrial Hygienists consists of committees which review and interpret research on chemical substances in the work environment. Each year they reassess and publish threshold limit values (TLVs) to be adopted as safe exposure limits for an 8-hour workday. The current limit for asbestos fibers > 5 microns in length (determined by the membrane filter phase contrast method) is .2 f/cc for crocidolite, 0.5 f/cc for amosite, and 0.2 f/cc for chrysotile and other forms. These levels are much lower than the legal PEL of 2 f/cc.

2. Proposed Permissible Exposure Levels. Although OHSA's emergency standard was stayed, OSHA is currently drafting a proposal to lower the PELs. A proposed PEL standand of 0.2 f/cc TWA is expected to appear in the Federal Register approximately June 20, 1986. The proposed standard will lower the action level (usually 1/2 of the TWA) to .1 f/cc, but will not effect the ceiling limit. With evidence that lowering the PEL will save lives, OSHA maintains that the additional cost is justified. OSHA also claims that the cost

of implementing compliance measures would be minimal because existing mechanisms for training, controls, and personal protection would suffice if more broadly instituted. Because of the impending changes in the standards, this paper uses the proposed PELs and TLVs as criteria to evaluate the adequacy of institutional programs.

3. EPA'S Proposed Protection of Governmental Workers. In July of 1985, EPA proposed a rule extending OSHA's exposure limitations and methods of compliance to state and local employees (C&EN, July 1985). Title 15 U.S.C. 2605 and 2607 (c) authorizes the EPA to extend asbestos-related protection to state and local government employees. The start of action for this regulation was prompted by a petition filed in 1983 by the Service Employees International Union, which represents employees of many schools. The regulation applies to:

> all employers of State and local government employees not covered by the Asbestos Standard of the Occupational Safety and Health Administration, 29 CFR 1910.1001, or an Asbestos Standard adopted by a State as part of a State plan approved by OSHA under section 18 of the Occupational Safety and Health Act. The rule covers the employees of those employers . . . This includes but is not limited to the following examples of public entities: any State, County, City or other local governmental entity which operates or administers schools, a department of health or human services, a library, a police department , a fire department, or similar public service agencies or offices (50 Fed. Reg. 28537,1985).

The EPA currently enforces this rule in all states that are regulated by the federal rather than state EPA programs. Although EPA regulations are not applicable in states like North Carolina that have their own federally approved occupational plans and enforcement programs, many state plans have adopted similar protection policies toward state and local governmental employees (Curran, June, 1986). The proposed EPA regulation makes mandatory adherence to the requirements outlined in this thesis for most state institutions.

# CHAPTER V

# ANALYSIS OF AIRBORNE ASBESTOS CONCENTRATIONS

' ANALYSIS OF AIRBORNE ASBESTOS CONCENTRATIONS

This section characterizes 259 airborne asbestos concentrations encountered by institutional employees and inhabitants. To avoid confusion, italics will be used to distinguish the statistical *samples*., subsets taken from a population, from individual samples of filtered air. As far as possible, the statistical approaches follow the NIOSH guidelines in *The Occupational Exposure Sampling Strategy Manual* (1977). The statistical computations for hypothesis testing are outlined in Remington and Schork's *Statistics with Applications to the Biological Sciences* (1985). Because of the extreme variation at each sampling location, and the small number of samples taken during the dry and ceiling removal projects, conclusions based solely on the statistical analysis must be made with caution.

The sampling techniques and exposure ranges are first categorized into five scenarios or classifications of asbestos management/abatement activities. The geometric means (GMs) of the concentration distributions are statistically compared. The arithmatic means (AMs) are then computed and compared to the OSHA and EPA's PELs. Statistical assumptions are discussed, as well as a criticism of the sampling and counting methods.

A. <u>ANALYSIS OF THE FIVE CONCENTRATION SCENARIOS</u>

Table 3 characterizes the five categories of air samples by the number and types of samples and the variations in sampling technique. The table includes the number of analyzed samples, the number of invalid or "blank" samples, and the number of samples that could not be read due to an overloading of the filter. Some samples were omitted from the statistical analysis because of high lower limits of of fiber detection (e.g. 0-.05 f/cc and 0-.09 f/cc) . Graphs 1 through 5 depict the cumulative percent vs. asbestos concentration distributions for the "air quality," "preremoval," "removal" (inside and outside of the containment area) and "final", post abatement air quality categories.

**TABLE 3**

SUMMARY OF AIRBORNE ASBESTOS SAMPLES
OF FIVE ABATEMENT PROGRAM CATEGORIES

| ACTIVITY CLASS: | AIR quality inspections | PRE-REMOVAL exposure air samples | REMOVAL in containment area | REMOVAL outside containment area | FINAL air quality |
|---|---|---|---|---|---|
| **NO. of SAMPLES:** | | | | | |
| total samples | 28 | 32 | 128 | 35 | 36 |
| blank/invalid:* | 1 | 5 | 4 | 8 | 0 |
| overloaded:** | 0 | 0 | 6 | 0 | 0 |
| samples used in statistical analysis | 27 | 27 | 124 | 27 | 36 |
| **TECHNIQUES:** | | | | | |
| flowrates: (L/min) | 2-11.2 | .84-11.96 | .80-11.2 | 1.04-11.96 | 4-11.96 |
| sample time: (min) | 30-778 | 30-351 | 16-1210 | 30-300 | 175-300 |
| air volume: (Liters) | 60-5940 | 57-2349 | 42-4620 | 120-3300 | 240-3000 |
| no. of analysts***: | 2 | 5 | 6 | 4 | 5 |

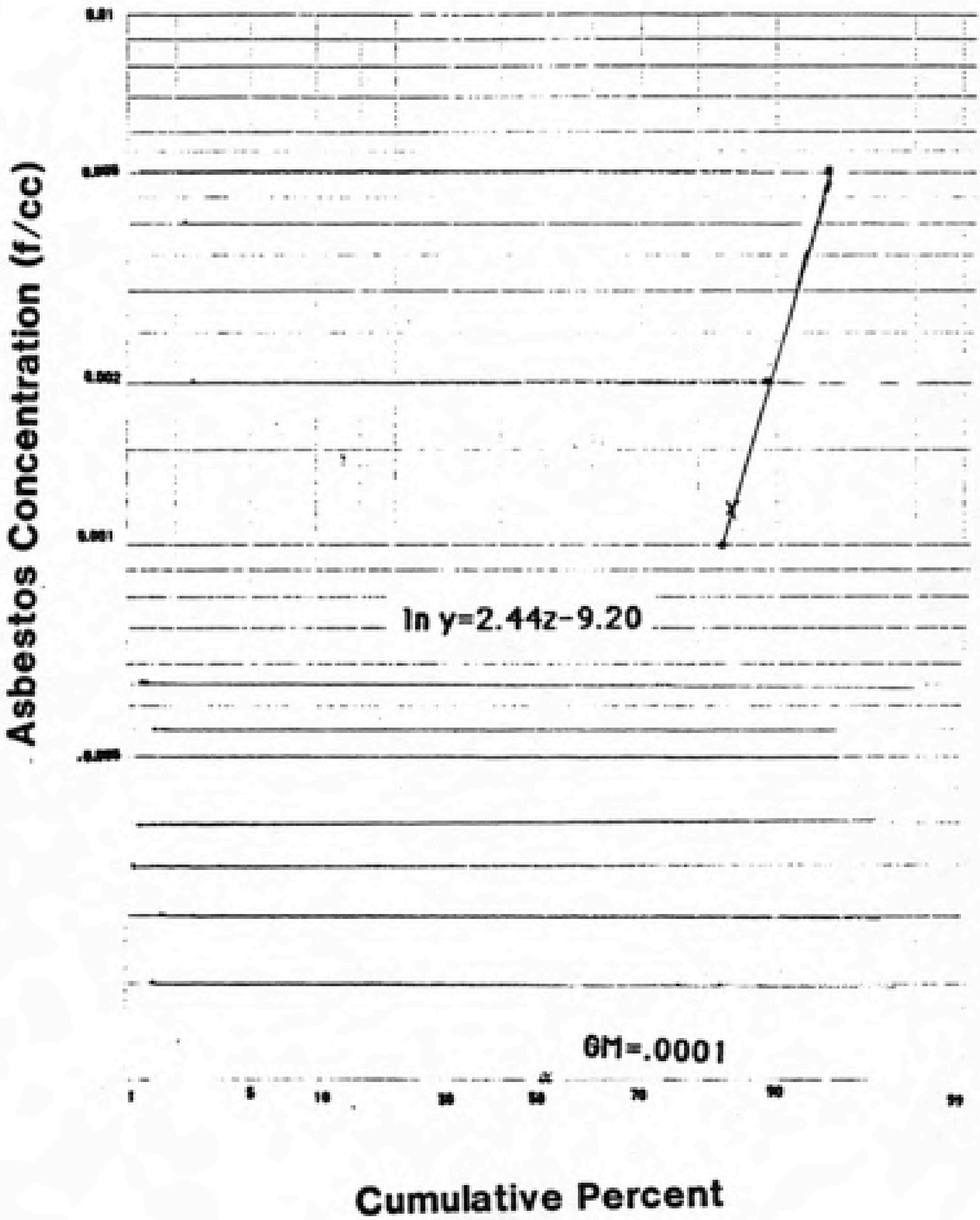
* invalid samples include the samples reported as "blank," "invalid," or discarded due to high lower limits of fiber dectection (i.e .05 f/cc or .09 f/cc)

** Overloaded samples assigned a concentration of 10 f/cc;

*** The no. of analyst implies the entities, companies or facilities that analyzed the samples.The actual no. of persons, e.g.. samplers and counters, is greater than indicated in the"no. of analyst."

# GRAPH 1

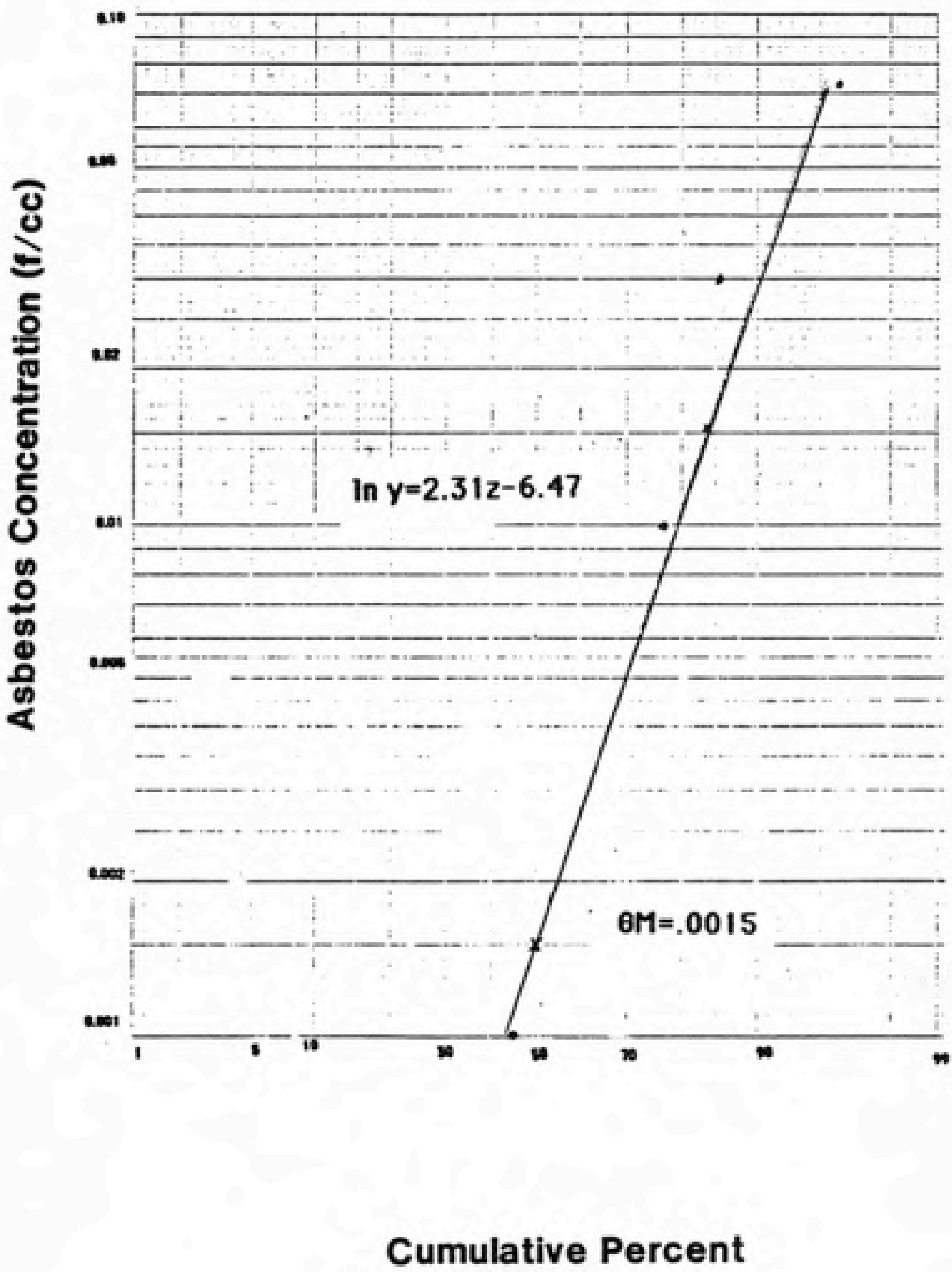
**LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc) DURING "AIR QUALITY" INVESTIGATIONS**



# GRAPH 2

LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc)

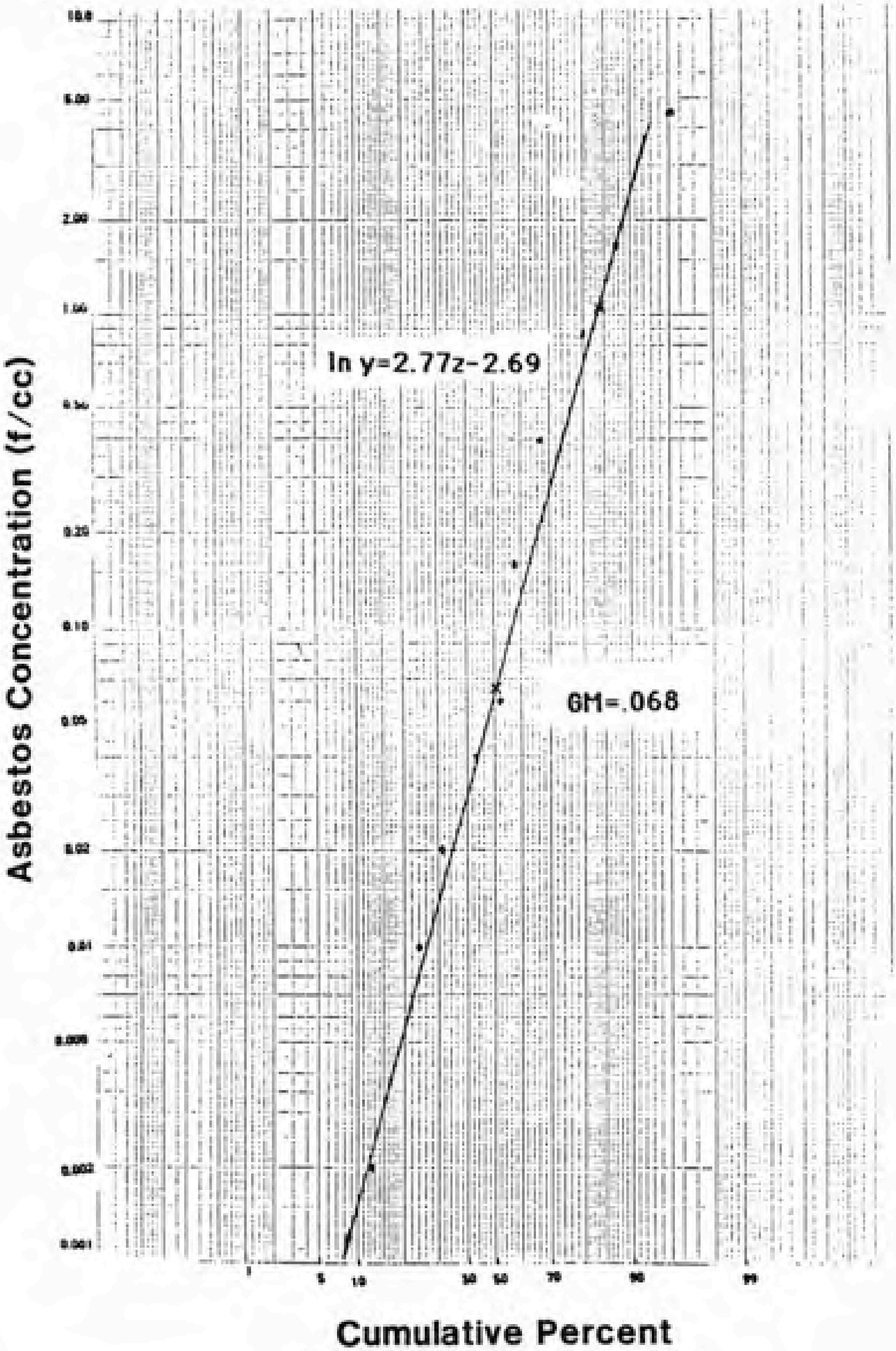
DURING "PREREMOVAL" AIR SAMPLING



# GRAPH 3

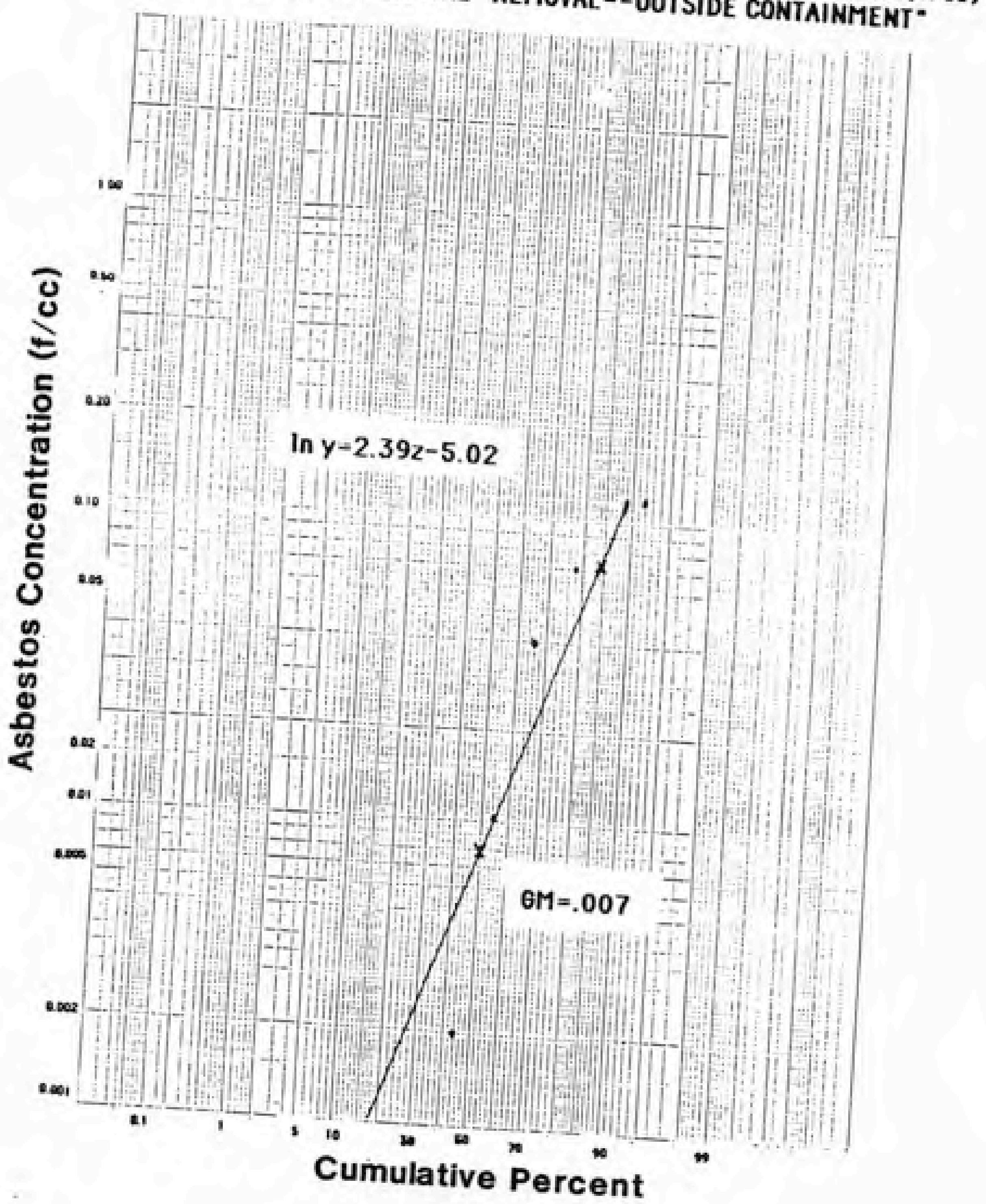
LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc)

DURING ASBESTOS "REMOVAL--INSIDE CONTAINMENT"



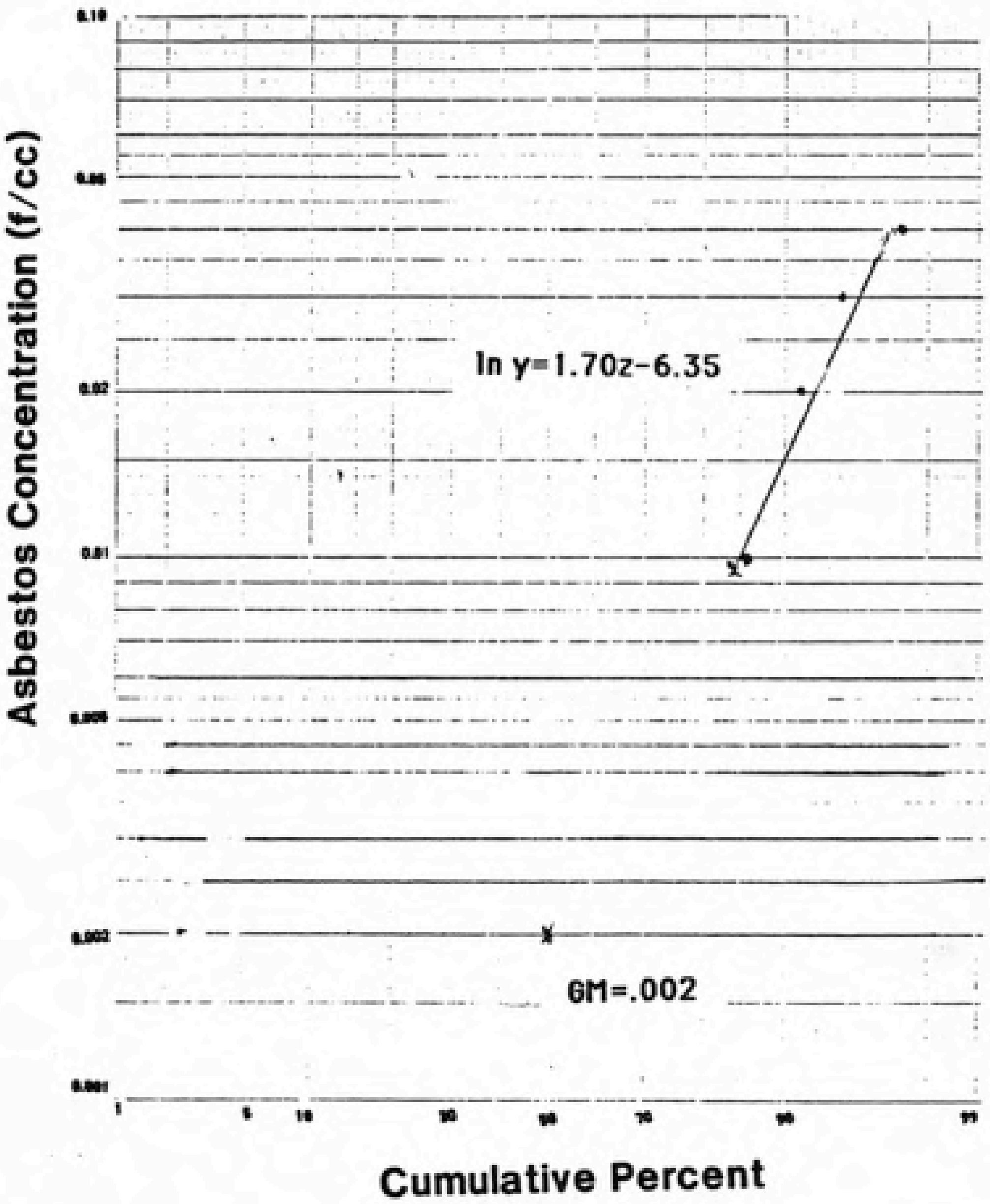
## GRAPH 4

LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc) DURING ASBESTOS REMOVAL "REMOVAL--OUTSIDE CONTAINMENT"



# GRAPH 5

**LOGNORMAL PROBABILITY GRAPHS OF "FINAL" ASBESTOS CONCENTRATIONS f/cc)--POST ABATEMENT PROCEDURES**



1. <u>Mean Concentrations.</u> Table 4 summarizes the statistical parameters of the *sample* distributions. As shown, the arithmetic mean (AM) concentration (3.10 f/cc) during asbestos removal exceeds both the 2 f/cc and the .2 f/cc OSHA permissible exposure limits (PELs). Furthermore, 51 of the 124 "removal" sample concentrations exceed the proposed PEL and 56 of the 124 samples exceed the associated .1 f/cc "action level." Also note that AM concentration (.11 f/cc) outside of the containment area exceeds the action level PEL. Three of the 27 "outside containment" sample concentrations exceed .1 f/cc. This indicates that a there is a need to review policy concerning the occupancy of areas outside of the containment areas during removal.

**TABLE 4**

STATISTICAL PARAMETERS OF ASBESTOS
CONCENTRATION DISTRIBUTIONS

| SAMPLE DISTRIBUTIONS | N | RANGE | GM | GSD* | AM |
|---|---|---|---|---|---|
| Air quality | 27 | .001-.01 | .0001 | 10.00 | 0.00 |
| Preremoval | 27 | .001-.096 | .0015 | 10.67 | 0.02 |
| Removal-in | 124 | .001-10.0 | .068 | 15.87 | 3.10 |
| Removal-out | 27 | .001-4.643 | .007 | 10.29 | 0.11 |
| Final | 36 | .001-.210 | .002 | 5.00 | 0.01 |

* Geometric Standard Deviation

A statistical comparison of the geometric means -- based on the Student t-test (2 sided; 95% confidence) and the logarithmic distribution of the data -- shows that the average pre-removal concentration (GM=.0015 f/cc) is significantly higher than the average "air quality" concentration (GM= .0001 f/cc). The data, therefore, suggests that, on the average, university personnel are successful at selecting the locations with relatively high concentrations for removal. Similar analysis, shows no evidence that the average "final" post abatement concentration (GM=.002 f/cc) is significantly lower or "safer" than the air quality (GM of.0015 f/cc) prior to removal. Although the AM outside of the contaiment area is above the OSHA action level, the Student-t test also shows no evidence that the average exposure outside of the containment area during removal is significantly higher than the exposure prior to removal.

2. Experimental and Statistical Errors. The AMs are high compared to the GM due to large GSDs. The apparantly high GSDs result in part from a broad range of experimental variance and systematic errors. There are five general sources of variance and error (Leidel, Sampling Manual, 1977):

1. random sampling device errors (i.e. pump flowrates);
2. random analytical method errors (fiber counting analysis, see Appendix C);
3. random environmental fluctuations in contaminant (between days and intra-day);
4. systematic errors in the measurement process (improper calibration, as indicated by on-site soap bubble flow calibration of sampling pumps used at the DM building/ U of I--pre-removal samples);
5. systematic changes in contaminant concentration due to employee movements (i.e. employees cooling themselves in front of exhaust fans during breaks).

Table 3 shows the ranges of 4 sampling characteristics: time, flowrates, air volumes, and number of laboratories analyzing the sample. Even more variability results from different abatement techniques, different work crews and locations, and different types of asbestos-containing materials. The broad deviations in the concentration distributions resulting from the diverse nature of the abatement activities are too complex to quantitatively enumerate. A comprehensive quantitative discussion of errors is found throughout the course notes from NIOSH Course 582 (1985) and specifically in Leidel (1979).

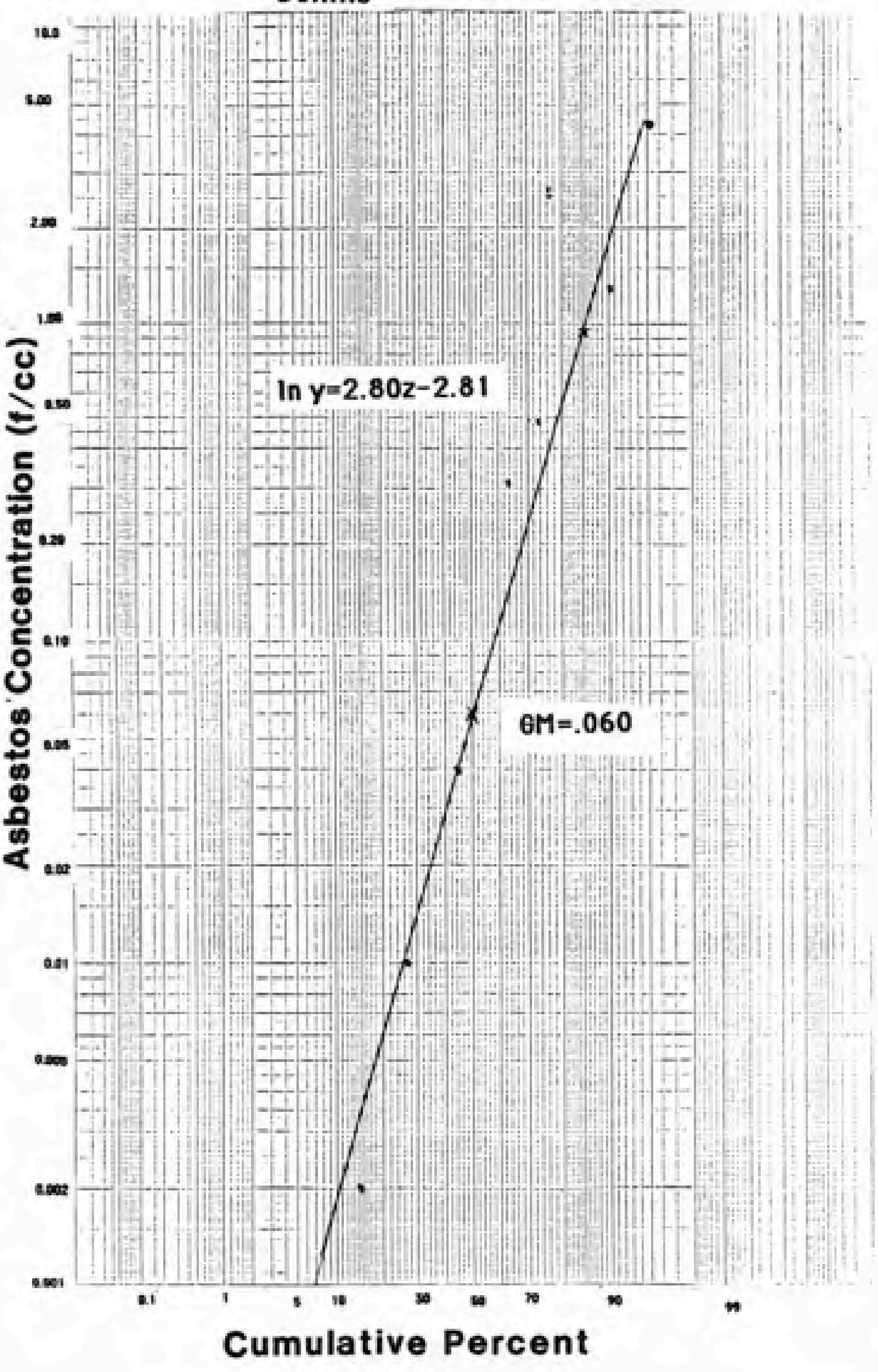
The large GSDs may result from the possibility that the *sample* distributions defined in this study are actually composites of more than one distribution. Refining the sample distribution to reduce the sampling errors and variances may reduce the discrepencies between the geometric and arithmetic means. The concentrations taken during asbestos abatement/removal procedures are divided into more refined distributions and examined in the following sections.

## B. EXAMINATION OF CONCENTRATIONS DURING ABATEMENT

Concentrations of airborne asbestos during removal were divided according to the three types of removal procedures and according to personal verses area sampling techniques. The removal procedures were dry asbestos removal, wet asbestos removal, and the removal of asbestos laden ceiling tiles. Personal air sampling is used to estimate the employees' exposure by drawing air through a cassette filter suspended in the worker's breathing zone, i.e. in the shoulder and head region. This "personal sampling" method contrasts "area sampling," which estimates the employee exposure drawing air through a cassette filter suspended randomly within the sampling area. Graphs 6, 7, and 8 depict the cumulative percent vs. asbestos concentration distributions for the wet, dry, and ceiling tile removal procedures. Table 5 summarizes the three distributions by the number and types of samples, statistical distribution parameters, and the variations in sampling technique.

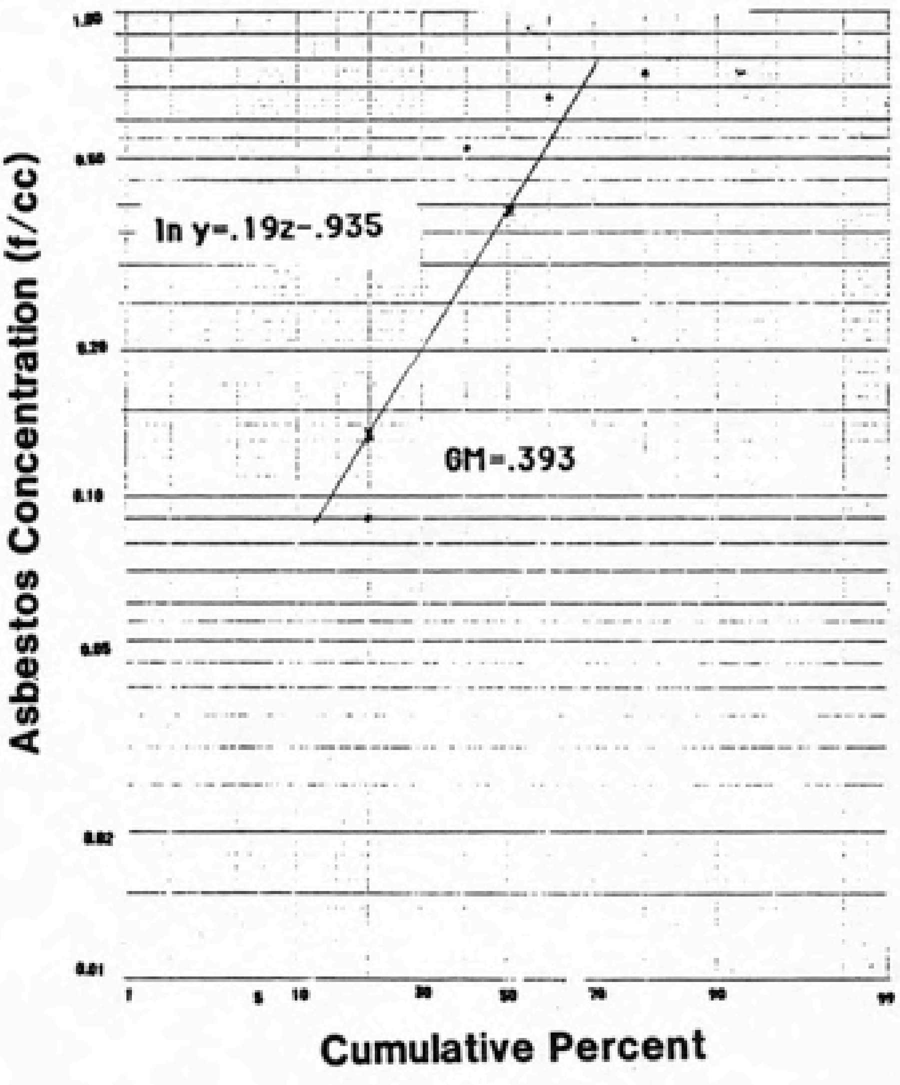
## GRAPH 6

**LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc) DURING "WET REMOVAL"**



# GRAPH 7

LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc)DURING "DRY REMOVAL"



## GRAPH 8

LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc)
DURING "CEILING TILE REMOVAL"

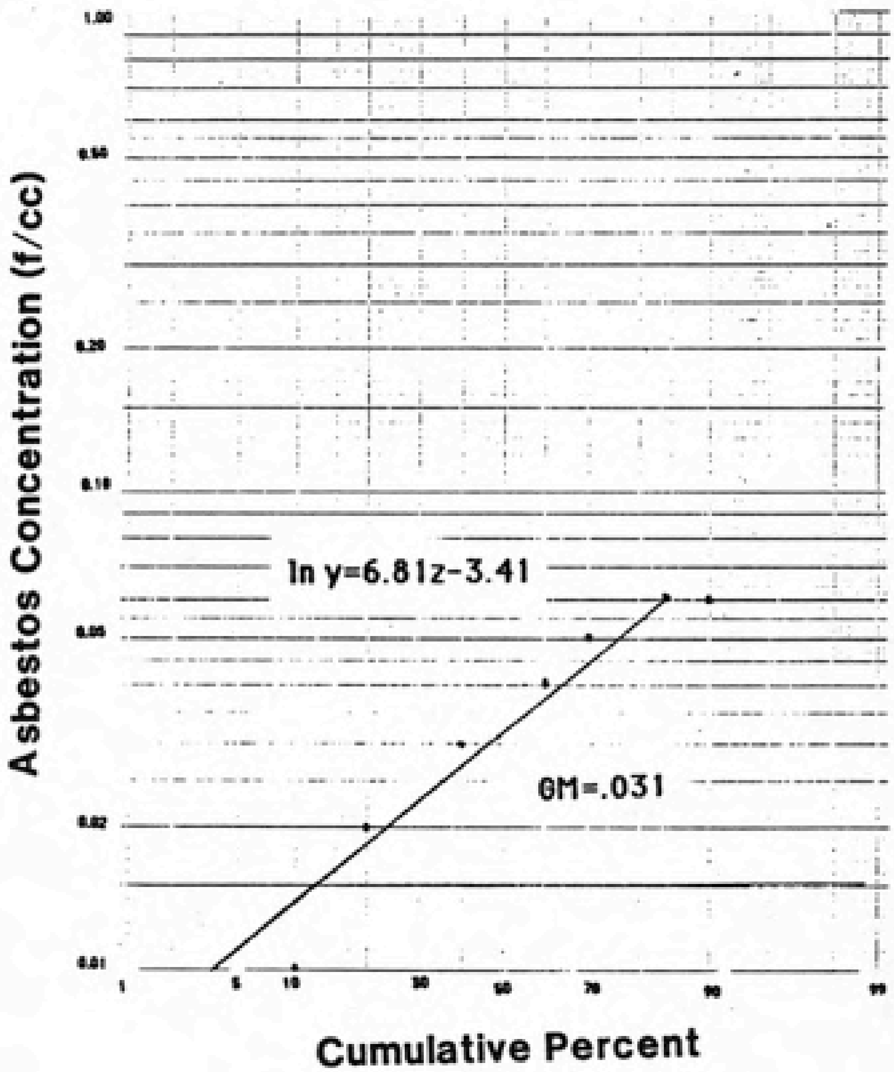


TABLE 5

COMPARISON OF
ASBESTOS EXPOSURES FOR THREE
REMOVAL TECHNIQUES

| ACTIVITY CLASS: | WET REMOVAL | DRY REMOVAL | SUSPENDED CEILING TILE REMOVAL |
|---|---|---|---|
| **No. of SAMPLES:** | | | |
| total samples | 113 | 5 | 10 |
| blank/invalid:* | 3 | 0 | 0 |
| overloaded:** | 5 | 1 | 0 |
| samples used in statistical analysis | 110 | 5 | 10 |
| **TECHNIQUES:** | | | |
| flowrates: (L/min) | .8-11.2 | 2-4 | 1.24 |
| sample time: (min) | 30-1210 | 30-116 | 16-90 |
| air volume: (Liters) | 43-46.20 | 120-330 | 42-180 |
| **STATISTICAL PARAMETERS:** | | | |
| range: | 0.001-10.00 | .09-10.00 | .01-.07 |
| GM: | .06 | .393 | .031 |
| GSD: | 16.48 | 3.27 | 1.97 |
| AM: | 3.04 | .79 | .04 |

* invalid samples include the samples reported as "blank," "invalid," or discarded due to high lower limits of fiber dectection (i.e .05 f/cc or .09 f/cc)

** Overloaded samples assigned a concentration of 10 f/cc;

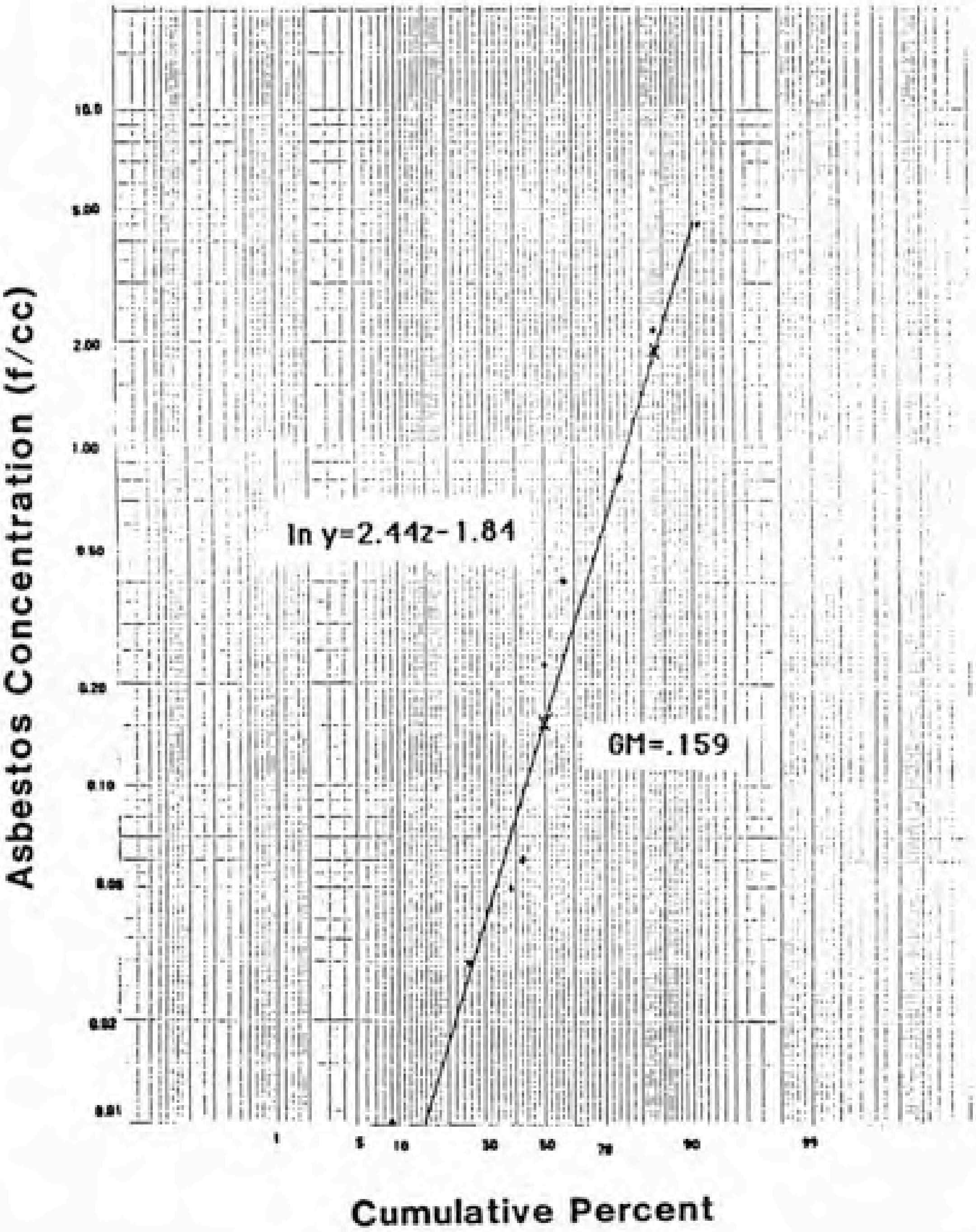
1. Comparison of Removal Techniques. An analysis of different asbestos removal techniques (Table 5) shows that the average (AM) concentration during the wet (3.04 f/cc) and dry (.79 f/cc) removal of asbestos clearly exceeds the proposed OSHA .2f/cc PEL. The GM concentration (.06 f/cc) during wet removal is significantly lower (Student-t test; 2-sided) than the GM concentration (.393 f/cc) during dry removal. Four of the five dry removal samples are above the OSHA's proposed PEL, while forty-eight of the one hundred twelve wet removal samples exceeded the proposed PEL. Although the Student-t test indicated a statistical difference between the wet and dry GMs and the dry and ceiling tile removal GMs, the test does not support a difference between the ceiling tile removal and the wet removal techniques. This may be attributed to the extremely large GSD of the wet removal distribution.

The removal or alteration of asbestos contaminated decorative or structural materials is considered a phase of asbestos abatement or removal (discussion with Pat Curran, North Carolina OSHA, May 1985). Although the suspended ceiling tiles are not directly attached to the installed asbestos, it is reasonable to assume that loose asbestos fibers have adhered to them. The monitoring of employees indicates that the AM concentration (.04 f/cc) during the removal of ceiling tiles is under the current PELs. The data does not necessitate employee protection for the removal of the suspended ceiling to comply with OSHA requirements.

2. Comparison of Personal vs. Area Sampling. Graphs 9 and10 depict the cumulative percent vs. asbestos concentration distributions for personal and area sampling methods. Table 6 summarizes the number and types of samples, the statistical distribution parameters, and the variations in sampling technique.

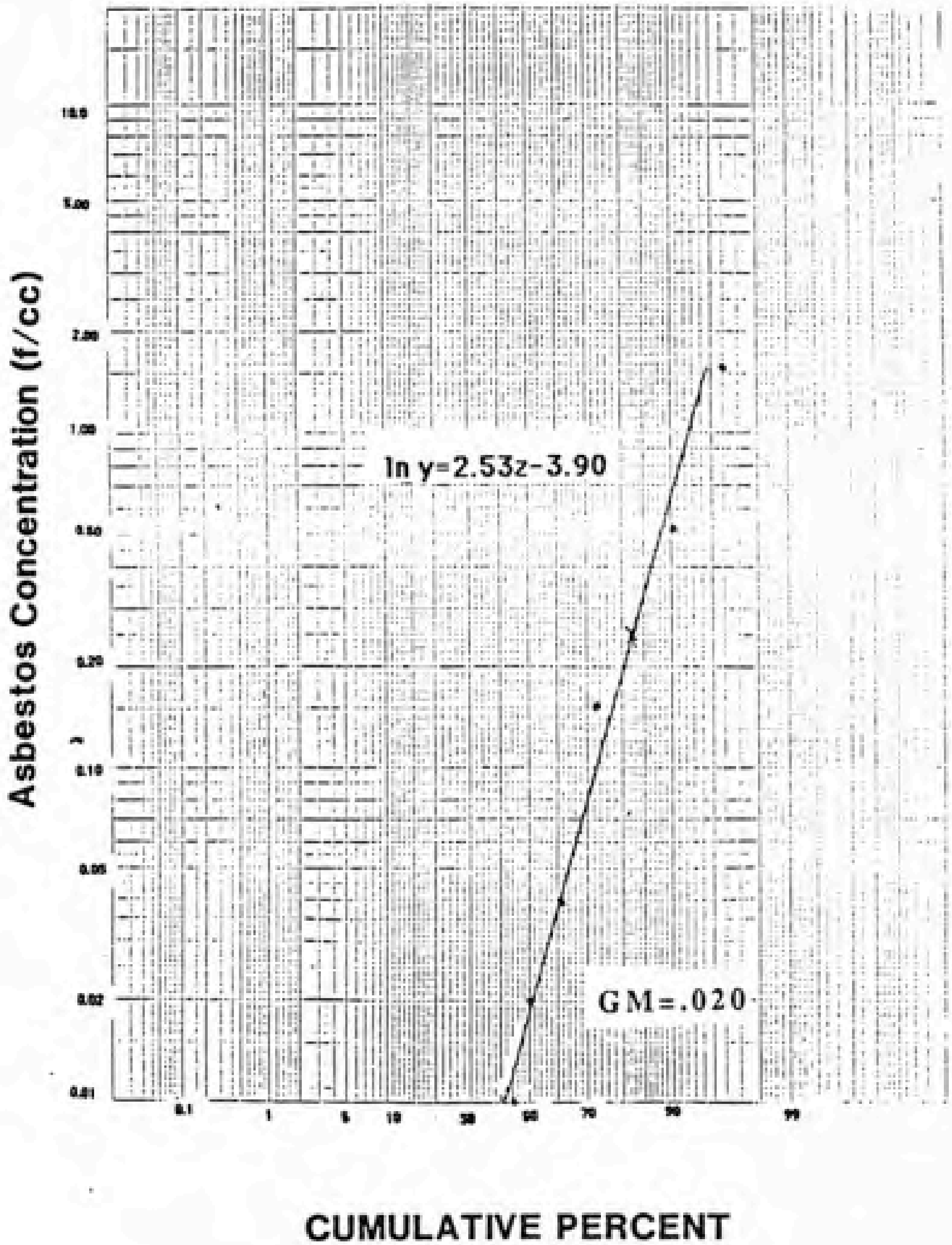
# GRAPH 9

## LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc) USING "PERSONAL" SAMPLING METHODS



## GRAPH 10

LOGNORMAL PROBABILITY GRAPHS OF ASBESTOS CONCENTRATIONS (f/cc) USING "AREA" SAMPLING METHODS



## TABLE 6

COMPARISON OF
AREA VS. PERSONAL SAMPLING METHODS
DURING ASBESTOS REMOVAL

| ACTIVITY CLASS: | AREA | PERSONAL |
|---|---|---|
| **No. of SAMPLES:** | | |
| total samples | 56 | 72 |
| blank/invalid:* | 3 | 0 |
| overloaded:** | 0 | 6 |
| samples used in statistical analysis | 52 | 72 |
| **TECHNIQUES:** | | |
| flowrates: (L/min) | 2-11.2 | .98-2 |
| sample time: (min.) | 30-420 | 16-1210 |
| air volume: (Liters) | 60-4620 | 42-1888 |
| **STATISTICAL PARAMETERS:** | | |
| range: | 0.001-3.01 | .001-10.00 |
| GM: | .02 | .159 |
| GSD: | 12.75 | 11.41 |
| AM: | .51 | 3.08 |

* invalid samples include the samples reported as "blank," "invalid," or discarded due to high lower limits of fiber dectection (i.e .05 f/cc or .09 f/cc)

** Overloaded samples assigned a concentration of 10 f/cc;

The AMs of both the personal (3.08 f/cc) and area (.51 f/cc) concentrations exceed the proposed 0.2 f/cc PEL. The comparison (by Student-t analysis) of the GM "personal" verses "area" concentrations indicates that the average personal exposure is significantly higher than the average area sample. The data indicates that it is not valid to use an area sample to estimate a personal exposure.

3. Limitations of the Data. It is important to note that neither breathing zone samples nor area samples accurately represent the concentration of asbestos inhaled. Both the air sampling methods and the fiber counting techniques have serious limitations. Although the PELs were designed with a margin of safety that accounts for shortcomings of air monitoring, criticism of the techniques has increased. These criticisms are outlined below and detailed in Appendix C.

a. Fiber Counting Limitations. The membrane filter/phase contrast microscope methods employed in this study and prescribed by NIOSH to comply with OSHA monitoring regulations are inaccurate for both fiber counting and fiber identification. The method cannot discern asbestos from non-asbestos fibers. In addition to the filter loading limits summarized in Table 2, the NIOSH methods are limited in their capacity for detection and blank fiber count. Microscope type, air flow rates, and sampling time alter the lower limits of fiber detection. The theoretical limit is described by the following limit of detection equation:

$$\text{LIMIT OF DETECTION} = \frac{\text{Area of filter (mm.}^2\text{) x \# of counted fibers}}{\text{a* x air flow rate (L/min) x \# of fields x time}}$$

$$= \text{Airborne fibers/liter of air}$$

* "a" is the area of the counting field of the microscope in $mm^2$.

Regardless of the number of fibers reported below the detection limit, the statistical data set has been adjusted to the lowest level of detection for each laboratory that analyzed the exposure data. This is valid because it only changes what the laboratory reported to what the laboratory can actually identify. This limit varied from .001 f/cc to .01 f/cc. (see Appendix C).

In addition to determining a valid and consistent lower limit of detection for this investigation, studies indicate that the method has an inherent problem of non-zero and variable fiber count for blank filters (Altree-Williams, 1985). In 1985, two Australian researchers illustrated fiber identification limitations by characterizing the fibers collected on air samples (see Appendix C). The conditions of the experiment were chosen to match the collection efficiency, fiber detectability and convenience of the membrane filter/optical (phase contrast) microscope method. The study concluded that there is a significant discrepancy between the number of asbestos fibers and the combined number of asbestos, (non-asbestos) mineral, and organic fibers. The phase contrast method interprets the combined count as the asbestos count, resulting in a significant exaggeration of the asbestos count.

b. Air Sampling Limitations. As illustrated in Table 2, NIOSH's 7400 method recommends air volumes of 400 to 1920 liters with flowrates of at least .5/L min. The method suggests that collection efficiency is not affected by changes in flowrate in the range of .5 to 16 L/min. Several considerations challenge this assumption. Because the sampling is not isokinetic, fibers may become impacted on the cassette before reaching the filter paper. Impaction is also increased by static electricity. NIOSH now requires cassettes to be wrapped in aluminum foil to decrease this problem. Most or all samples taken in this study were not wrapped. Furthermore, there is no assurance that fibers are uniformly distributed across the filter. Airflow may be uneven across the collection area. In the case of the large flowrates used in this study (up to 11.2 L/min.), the filters may even flex from from the rhythmic action of the pump diaphragms. The researcher knows of no studies quantifying the fiber losses from these sampling problems.

# CHAPTER VI

# UNIVERSITY ASBESTOS MANAGEMENT/ABATEMENT PROGRAMS

# UNIVERSITY ASBESTOS MANAGEMENT/ABATEMENT PROGRAMS

This section reviews each of the three universities participating in the study independently. Primary focus is on the Universities of North Carolina and Illinois, with the University of Michigan reviewed for comparison and supplement. The discussion is subjectively divided into two topics: asbestos management policies and practices, and asbestos abatement funding.

## A. POLICIES AND PRACTICES

The policies and practices of each university are divided into four categories: a) assessment and inspection programs; b) asbestos-related incidents and routine investigations-- hereinafter referred to as incidents; c) abatement projects; and d) training and medical evaluation. Although this section may omit some aspects of asbestos abatement programs, it summarizes all federally regulated aspects. This section places emphasis on issues of health and safety practices.

Each University has separate administrative groups responsible for large contracted building and renovation projects, for maintenance and small renovations, and for health and safety. All of these groups operate within the universities' divisions of Business and Finance. Although the titles of these groups differ at each university, they operate in a similar capacity. Table 7 organizes the groups according to similar functions. Distinctive acronyms are assigned for ease of comparison throughout the chapter.

TABLE 7

DIVISIONS OF BUSINESS AND FINANCE THAT COORDINATE ASBESTOS ABATEMENT ACTIVITIES

| | FUNCTION | | |
|---|---|---|---|
| UNIVERSITY | Health & Safety | Maintenance | Planning |
| North Carolina | Occupational Safety & Health Office (OSHO) | Physical Plant | Facilities Planning |
| Illinois | Division of Environmental Health & Safety (EHS) | Operations and Maintenance (O&M) | Office of Capital Programs |
| Michigan | Dept .of Occupational Safety & Environmental Health (OSEH) | Plant Operations | Plant Extension |

1. <u>University of North Carolina.</u> Information about the program at the University of North Carolina came from review of records and interviews. The primary contributers were administrative and training personnel from the OSHO, the Physical plant, and the Office of Planning. OSHO incident records, sampling and exposure records, and the University planning budget were made available to the researcher.

a. <u>Assessment and Inspection Program.</u> Prior to August of 1985, an attempt was made to assess the asbestos in specified buildings on campus. During the investigations only friable, sprayed-on asbestos was identified. Physical plant workers routinely encountered other asbestos materials such as deteriorating pipe lagging and boiler insulation. In response to increasing asbestos-related problems, the University Occupational Safety and Health Office (OSHO) designated one full time position (as of August 1985) for all campus asbestos assessment, inspection, and training programs. This individual received a week of formal training in asbestos abatement practices at the Georgia Institute of Technology.

The current asbestos abatement program includes a plan to inspect all campus buildings within 2 to 3 years, with a goal of inspecting 200,000 square feet of building this year. The inspection includes a review of architectural plans, a visual walk-through-survey inspection and sampling. The University inspection program will not follow the EPA's recommendation that at least three samples be taken from homogeneous materials in each area (generally considered one room). Rather, groups of homogeneous materials which may extend through several areas or rooms will be identified and sampled as one entity, reducing the number of samples significantly. Air samples are planned only "as necessary." Hazard assessment will be based on the amount, location, and condition of asbestos materials, as well as the estimated airborne concentrations.

b. Asbestos Related Incidents. The number of asbestos related calls to the University OSHO is steadily increasing from about 1 or 2 each week last year to 6 to 10 calls per week this year. The bulk and air sampling for this year (through April 1986) is approximately equal to all of the samples taken during 1985. Although the increased awareness of the asbestos issue by staff, faculty, and students has resulted in periodic inspection requests, almost all sampling/inspection requests come from university physical or power plant personnel. Although staff from the law, geology, and biology departments have requested information, inspections, or monitoring, the program remains an unknown service except to those directly involved in university maintenance or funding activities. Records supplied to the researcher show only one student-generated incident. It became a major university incident due to the involvement of the State OSHA and played a major role in prompting a formalization of asbestos policies.

The OSHO investigates all reported incidents. The asbestos coordinator takes bulk samples when material content is unknown and air samples when the material is friable and there is concern for airborne exposure. Incident records contain the date, location, investigator's name, sample content about airborne exposure, and sampling characteristics.

Results of the investigation are reported to the generator of the incident. Incident memos and response letters are seldom written, since most incidents involve small projects which are routinely resolved by the OSHO and the physical plant.

c. Abatement Projects. There are no routine large abatement projects. Each project involves the initial incident inspection and assessment of a degree of hazard. If a renovation or remodeling project contains friable asbestos, funding is sought and removal is scheduled. Major removal projects have occurred in only two or three buildings thus far. If friable asbestos is found to pose a significant health threat-- a controversial determination at best--the policy is to remove the asbestos as soon as possible. The three largest abatement projects included removal from Wilson Library, the UNC Campus Store, and a small portion of the steam lines. At least one potentially hazardous location, Mitchell Hall attic was identified in approximately 1977. Because it is a major renovation project, funds willnot be available until the upcoming budget is approved (see "B. FUNDING"). Although the location is routinely monitored for air quality, the site is considered potentially hazardous because it contains large amounts deteriorated spray-on amosite. A swab-sample of the visible layer of dust tested approximately 30% amosite-like fibers. Air mixing from large ceiling exhaust fans create the potential to spread asbestos. The attic contains shelves, tables, and boxes of student accessed books and samples. Therefore housekeeping procedures are necessary to eliminate the visible dust build-up. No plan of action has been agreed upon to date, although money has been requested in the planning budget for next year (see "B. FUNDING").

d. Training and Medical Evaluation. The physical plant has a formal training program conducted by the OSHO safety officer and the personnel training director of the physical plant. Two or three people from each craft that encounter asbestos undergo formal abatement training. These crafts include carpentry; heating, ventilation, and air conditioning (HVAC); plumbing; telephone; and sheet metal crafts. Training includes information on asbestos hazards and a discussion of glove-bag and wet removal techniques, personal protection, and reporting and inspection policies between OHSO and the physical plant.

The asbestos abatement program includes respirator training and employee physicals. Individuals who wear respirators, or who should wear respirators, in the performance of their jobs undergo respirator training and physical monitoring. By policy, individuals may smoke but may not wear beards to be certified for respirators. For asbestos abatement projects, 3M disposable respirators are no longer considered adequate protection, and MSA/Comfo II reusable respirators have been substituted. The OSHO uses the banana oil test to fit employees with one of three sizes of MSA half-face respirators and explains proper use and cleaning procedures. In accordance to OSHA regulation, a private physician examines everyone who is certified for wearing a respirator. X-rays are only given when deemed necessary. Approximately 100 people from the paint, HVAC, and insulation and pipefitting shops participate in the respirator program.

2. University of Illinois. Information in this section came from first hand involvement with the program development, review of records, on-site inspections/sampling, and interviews. Major contributers include the Division of Environmental Health and Safety (EHS), Operations and Maintenance (O&M), university employees, contracted laborers (unionized), and removal contractors.

a. Assessment and Inspection Program. Until the summer of 1985, members of the Division of Environmental Health and Safety conducted inspections for asbestos as requested by various campus entities. The leader of the Hazardous Waste Management group generally conducts the inspection. O&M designated one individual as a liaison with the EHS, which trained the liaison in asbestos abatement. During the summer of 1985, EHS hired a temporary "environmental specialist" to coordinate asbestos abatement activities and work with the EHS, O&M, and private contractors during their first major removal project. This 1985 project led to the establishment of a formal inspection and assessment routine.

Asbestos assessments are now conducted as part of the ongoing O&M building inspections. Each building is inspected every three to five years. Memos are written for each building and a copy is sent to EHS. Although the inspection group has gained experience in identifying asbestos, EHS still has primary responsibility for the sampling, identification, and hazard assessment of uncertain friable materials. The EHS also aids O&M in record keeping and abatement decision making.

b. Asbestos Related Incidents. Approximately 8 buildings are inspected by EHS per month. A former state mental health facility, recently occupied by the University, has an ongoing monitoring program for friable asbestos in the ventilation air plenums. Most investigations are routinely initiated by O&M. Investigations occasionally are initiated by requests from the university students and staff. These incidents range from minor concerns about unidentifiable dust deposits to badly damaged pipe insulation. A noteworthy incident involved a student's concern about the repair of an asbestos insulated pipe in the kitchen of a University-owned house. Because of the sensitivity and potential seriousness of the incident, members of O&M, housing, and EHS responded. The incident illustrated a need for improved training of O&M/housing personnel in the identification of common asbestos materials, proper onsite asbestos containment/cleanup procedures, and onsite availability of vacuum cleaners, water spray bottles and personal protection. Air sampling and inspections occurred in two houses, and the University's prompt and concerned response allayed neighborhood concerns.

Bulk sampling occurs during many, but not all inspections. Bulk samples are taken of any materials of unknown composition. Assumptions are always conservative: if a sample is not tested, it is either assumed to be asbestos, or it is positively identified as a recognizable alternative (e.g. fiberglass insulation). Buildings containing sprayed-on asbestos are monitored for airborne exposures on a routine basis. Rarely, they are taken because of friable pipe insulation. Records include the names of the sampler and laboratory analyst, date, location of sample, and sample contents or concentration. Memos of all incidents are placed in the EHS building files and sent to the initiator of the investigation and O&M.

c. Abatement Projects. The University is involved in both major and minor renovation projects. Small routine projects are conducted by O&M; large asbestos removal projects combined with remodeling or involving more than 60 linear feet of asbestos are always contracted. There is a trend toward contracting more of the small asbestos removal projects because of the time, training, and equipment required by OSHA abatement guidelines. During the last year, O&M has adopted more stringent safety precautions for routine procedures (see "Training"). Several major renovation/abatement projects have occurred or are planned for the next two years under the extensive "Build Illinois" Program.

The first of these projects involved removal of asbestos from a three story dairy manufacturing/research building. The project set training and procedural precedents for future projects. It prepared for contingencies requiring access to the building by personnel not involved in the removal, including emergency personnel (e.g. the police and fire departments, elevator or refrigeration repair persons) and the technicians needed to periodically maintain research equipment. The project also served as a training opportunity for ESH and O&M, and established protocol for interactions between the University and contractors.

d. Training and Medical Evaluation. A small group of O&M electricians and carpenters underwent respirator fit tests and procedural on-the-job training to remove the ceiling tiles suspended below asbestos insulation. Because OSHA considers this activity "part of" and not "prior to" asbestos-related renovation, the university Division of ESH required the workers to comply with OSHA guidelines. A select group of emergency and maintenance personnel were also trained and/or fitted for using personal protection. Since this initial project two general training sessions were conducted for approximately 100 O&M and Housing personnel. The training sessions covered the hazards of asbestos, asbestos recognition, respirator usage, and abatement procedures.

O&M orders, maintains, and issues respirators under the advice of EHS, but practices no formal respirator training and fit-test program. Respirators generally are stored at the shop headquarters (e.g. the motor pool for vehicle personnel and the physical plant for carpenter, HVAC, and painter shops). Health and Safety personnel issue and maintain their own respirators. Medical examinations are not required for respirator users.

3. University of Michigan. All information regarding university policy and practices came from Department of Occupational Safety and Environmental Health (OSEH). Additional information came from inspections and discussions with a student environmental concerns group. This discussion focuses on information from OSEH.

a. Assessment and Inspection Program. Asbestos abatement inspections are initiated in three ways: inadvertent discovery of a potential hazard caused by deteriorated asbestos, inspections associated with renovation/demolition planning, and general building surveys. The discovery of friable asbestos generally occurs during routine maintenance or inspections conducted by either plant operations or plant extension. Occasionally it is reported by other staff, faculty, or students. The OSEH assists the Plant Extension in routine building inspections upon request. Although the first assessment mechanism is similar to those at the Universities of North Carolina and Illinois, the inspections by the Plant Extension (in charge of project planning and engineering ) are comparable only to the University of Illinois' routine O&M inspections.

OSEH locates and inspects asbestos as a part of the University's remodeling, building, and demolition program. Asbestos assessments have been informal, with expenses absorbed in the project cost estimations. Currently, however, the University has contracted a large consulting firm to conduct a comprehensive asbestos survey of seventeen medical buildings scheduled for renovation. The inspections will detail the amount and condition of asbestos, and estimate the cost of abatement procedures. This survey is intended to both provide an example for the University in estimating future projects and to expedite the process of renovating the old medical buildings.

b. Asbestos Related Incidents. Incidents involving asbestos continue to increase. Most are reported to the OSEH office by either the plant operations or the plant extension. Although air samples are taken infrequently, bulk samples are taken approximately every other day . Air samples are not generally a criterion for asbestos removal. The decision to take asbestos abatement measures is influenced by the location and condition of the material; the rate of deterioration; the cost, planned renovation, and use of the building; and publicity.

Records are kept without narratives for routine bulk samples and the occasional air samples. Memos are generally not written for small problems that are rectified by plant operations. Inter-office memos or bulk and air sampling records are maintained in building files. Documentation is kept when investigations are initiated by staff, students, or faculty. The extent of documentation or narration depends on the amount and location of the asbestos, administrative or technical abatement problems, and the amount of publicity. Like the Universities of Illinois and North Carolina, involvement in the documentation ranges from the Director of Business to the laborers involved in the abatement activities. Inspections are made by the craft supervisors or manager of the division (e.g. housing) and the OSEH industrial hygienist. Occasionally, if those normally responsible for asbestos inspections are unavailable, a sampling or inspection may be made by the industrial hygienist that is in charge of safety issues for the department.

c. Abatement Projects. Approximately 90% of the abatement projects are resolved by contract. The unionized craft employees remove asbestos only on small jobs due to a shortage of trained experienced personnel. These small jobs are monitored by OSEH to insure compliance with EPA and OSHA regulations. Until recently, the University employed only one full-time and one half-time pipe coverer. The University now has five full time pipe covers and two foremen. It is in the process of training additional craftpersons to abate more of the routine repairs and emergencies. In locations occupied by students and staff, the University removes asbestos on Saturdays or evenings. Larger projects are handled through contracts that are administered by the Plant Extension Department. Two major concerns with the extensive necessity of contracted projects on campus are high costs and the national crisis involving the competency of the contractors to insure both quality and safe work.

d. Training and Medical Evaluation. Last year, personnel from approximately 10 crafts attended one of 3 or 4 large training sessions. The Department of OSEH designed the sessions to comply with the OSEH asbestos regulations. Both the onsite project foremen and the foremen in charge of each craft and project assignments attended the sessions. The same foreman supervises most of the asbestos abatement projects on campus. It is the foreman's responsibility to insure safe practices and to inform the Department of OSEH when and where the abatement projects will occur. It took both effort and persuasion to get the communication between foremen and OSEH running smoothly. Pipe coverers received training on the job and continue to be inspected by the Department of H&S during asbestos abatement projects.

In compliance with the OSHA regulations, an asbestos and respirator examination program was developed by a consultant physician who is affiliated with the University hospital. Examinations are routinely conducted by a University physician at the Ann Arbor Medical Clinic and include appropriate blood tests; examinations of hearing, vision, pulmonary function; and chest X-rays. Frequency of these examinations was based on employee age but is now yearly. Respirator selection, fit-testing, and training occurs at the OSEH office when the respirator is dispensed to the employee by OSEH personnel.

The University of Michigan's medical evaluation program has an interesting history. Three to five years ago the physical plant and the university administration agreed to a program requiring all physical plant craftpersons under 40 years old to undergo physical exams every five years. Persons over 40 years old were required to undergo physical exams every three years. Although OSEH felt that the program was insufficient for many employees, the Department reluctantly agreed. During the ensuing years, employees involved in higher risk occupations, specifically asbestos abatement workers, were placed in a program of yearly monitoring. Plumbers, electricians, pipe fitters, carpenters, sheet metalworkers, and pipe covers are the key asbestos abatement craftpersons involved in yearly physical examinations.

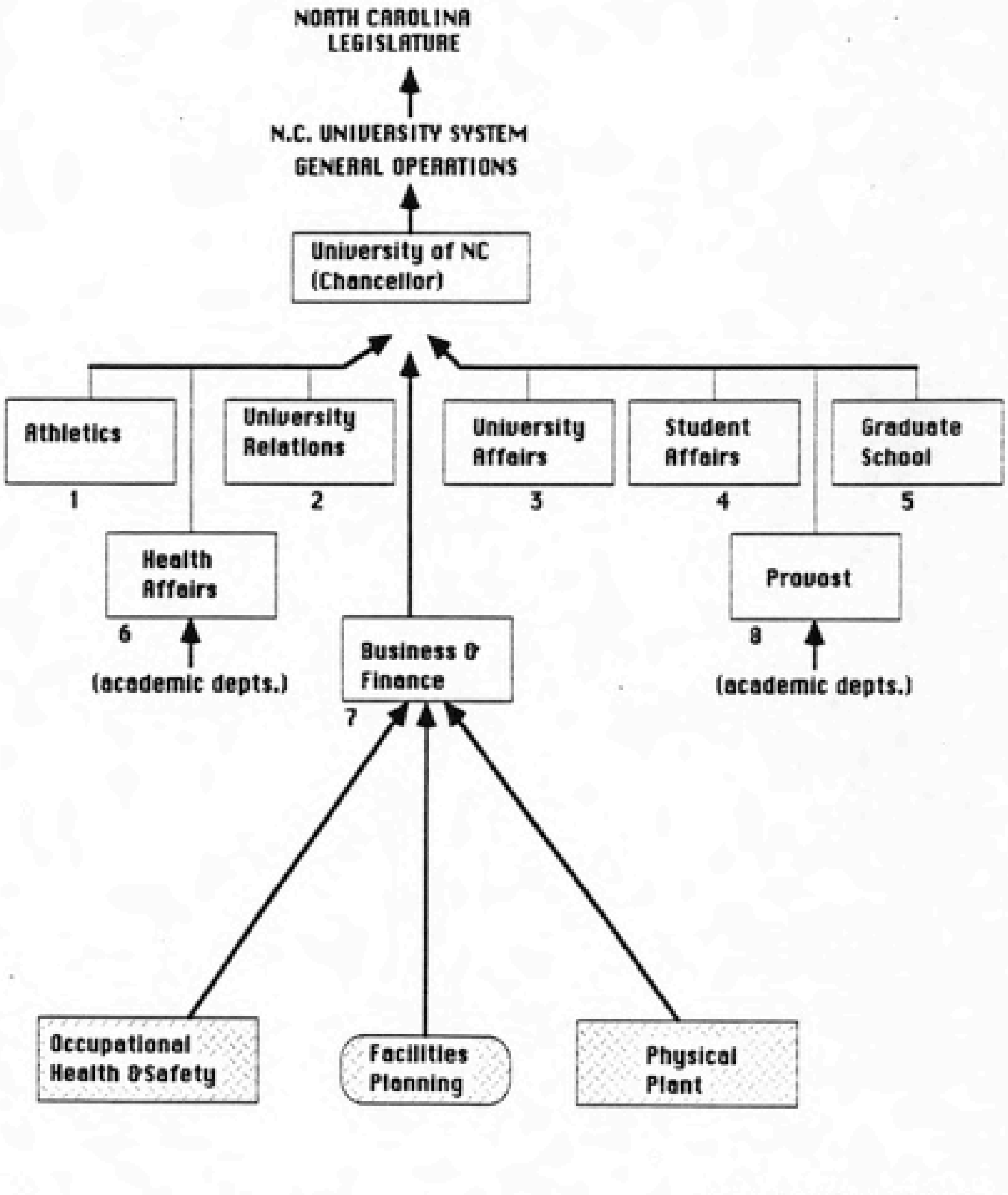
B. <u>REVIEW OF FUNDING AUTHORITY</u>

Funding for university asbestos abatement projects is appropriated through a complex procedure involving direct legislation, special building projects funds allocated by the state's capital development boards, and appropriations extracted from either the universities' routine operations budgets or the capital projects budgets. Usually the operations budgets (referred to as budget "B") or building/planning project budgets (referred to as budget "C") fund large abatement and remodeling projects. Despite changes in names and budget items, the usual funding mechanisms for the three institutions in this study are remarkably similar.

Money sources may include special state building programs, gifts, endowment funds, and self-liquidated investment or mortgage financing. The researcher found that the University of Illinois relied on special state building funds. The "Build Illinois Program" through the State Capital Development Board has appropriated millions of dollars over the next 3 years to major renovation and new buildings on campus.

1. Operational Budgets. Each university has departmental operating budgets which are submitted annually or biannually through hierarchical channels to the univerisity chancellor's office. From the chancellor's office, a university operations budget is sent to the office of the state university system and combined with the budgets of other institutions within the system. One budget is then submitted to the state legislature for approval. The general administration of N.C. university systems requests the 1987-1989 budget from the University of North Carolina by Dec. 1, 1985. Figure 3, modeled from the University of North Carolina, shows a typical flow of these budget requests. The costs of routine, in-house abatement projects are often absorbed in these budgets.

FIGURE 3




ORGANIZATIONAL FLOWCHART OF THE
OPERATIONS BUDGET REQUESTS
UNIVERSITY OF NORTH CAROLINA

The size of an abatement project is defined by the amount of asbestos removed and cost of removal. Small projects are almost always well below the EPA reportable 260 linear feet (80 linear meters) or 160 square feet (15 square meters) of asbestos containing material and are below a contract-bid limitation. Contract limits vary for each University. For instance, the University of North Carolina's physical plant performs approximately 1.5 million dollars of construction/ year. It limits individual renovation projects to less than $75,000 (North Carolina Dept. of Administration, 1982). Projects of greater than $75,000 must be submitted to the university planning office for funding. The university allows projects of less than $30,000 to be done by a licensed contractor on an informal bid basis, while all projects (financed by budget A, B, or C) greater than $30,000 must be formally advertised for bid. Since asbestos is removed and repaired during the routine operations and maintenance of plumbing and HVAC systems, the physical plants absorb most costs of small abatement projects. If the project is under the jurisdiction of administrative or academic department, e.g. repair of departmental equipment or remodeling, expenses are charged to the department. The health and safety offices absorb the cost of inspections, training, and sampling, while the policy for protective equipment varies with each university. If an abatement project is contracted, it may also be budgeted by the facility planning/engineering office.

At the University of Michigan, approximately 90% of the asbestos abatement projects are performed by contract and are, therefore, budgeted through the Plant Extension Department. Small repairs are conducted and budgeted by the Plant Operations Department. Personal protection equipment such as respirators, coversuits, caution signs, and asbestos disposal bags are procurred by the OSEH. A monthly tabulation of these expenditures along with the costs for hours of labor must be approved by the Director of Business Operations. Typical expenses for the months of July 85 through Jan. 86 are shown in Figure 4. Large initial expenditures for items such as the micro-air filtering vacuums and the air filtration units occurred prior to July of 1985 and are, therefore, not included in the figures. The items purchased and dispensed by OSEH are stored on Central campus at the OSEH office; it is approximately two miles from the plant operations facility. Plant operation craftpersons generally pass within two blocks of the OSEH on their way to Central campus. Craftpersons must make a special trip to the OSEH when the abatement project is located on North Campus, the site of the art and engineering schools, research facilities, and student housing.

# FIGURE 4

ASBESTOS RELATED COSTS
OCCUPATIONAL SAFETY & ENVIRONMENTAL HEALTH
1984-85

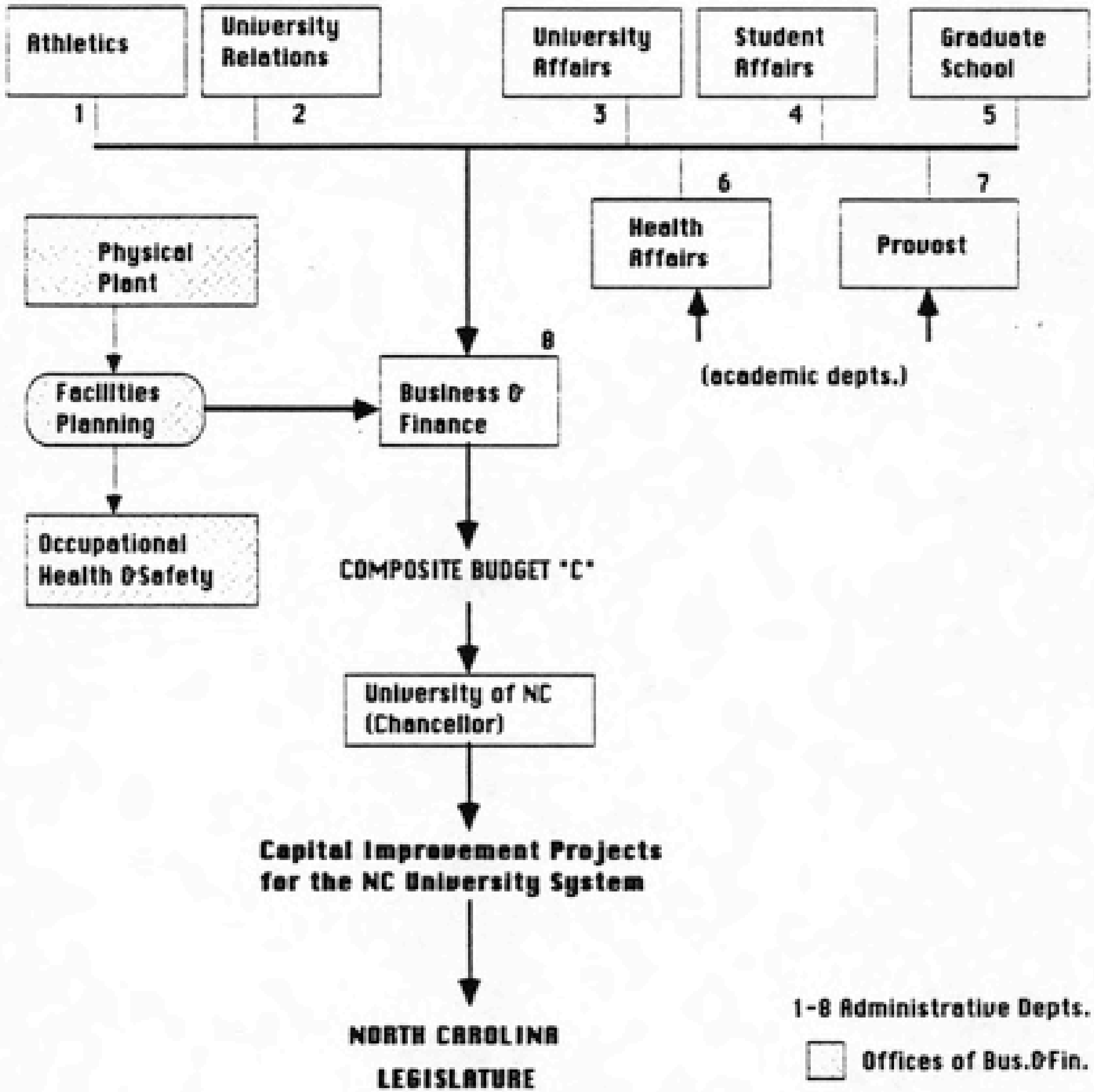
| Description | July | August | September | October | November | December | January | February | March | April | May | June | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asbestos Disposal | $3750.00 | | | | $1500.00 | $750.00 | $750.00 | $630.00 | | $300.00 | $1380.00 | | $9060.00 |
| CANTON Laboratory Analysis | | | | | | | | | | | $499.50 | | $499.50 |
| ERG Laboratory Analysis | | | | $120.00 | $315.00 | $70.00 | $1450.00 | $945.00 | $1960.00 | $585.00 | $765.00 | | $6210.00 |
| Decontamination - Chemistry | | | $2000.00 | | | | | | | | | | $2000.00 |
| Disposable Coveralls | | $56.16 | $112.32 | | | | $86.64 | | $113.45 | | $390.00 | | $758.57 |
| Disposal Bags | | | | | $23.86 | | $47.72 | | | | | | $71.58 |
| Equipment | | | | | | | | $4488.15 | | $258.00 | | | $4746.23 |
| Glove Bags | | | | | | | $106.14 | | $17.00 | | $439.66 | | $562.80 |
| Gloves - Surgical | | | | | | | $7.62 | | $45.83 | | | | $53.45 |
| Miscellaneous Supplies | | | | | | | $134.00 | $69.98 | $36.24 | $9.24 | $13.33 | | $262.79 |
| Respirators | $51.60 | $135.25 | $34.36 | $35.90 | $33.92 | | | | $50.60 | $18.46 | $4.42 | | $365.51 |
| Signs/Labels | | $259.50 | | | | | | | | | | | $259.50 |
| Training (Slide Presentation) | | | | | | | | | | | $586.00 | | $586.00 |
| Vacuum - NILFISK | | | | | | | $214.26 | $1096.75 | | $109.26 | $601.47 | | $2021.74 |
| Wetting Agent | | | | | | | | | | | | | $0.00 |
| | | | | | | | | | | | | | $0.00 |
| | | | | | | | | | | | | | $0.00 |
| TOTALS | $3801.60 | $450.91 | $2146.68 | $155.90 | $1872.78 | $820.00 | $2796.38 | $7229.88 | $2224.12 | $1280.04 | $4679.38 | $0.00 | $27457.67 |

ASBESTOS RELATED COSTS
OCCUPATIONAL SAFETY & ENVIRONMENTAL HEALTH
1985-86

| Description | July | August | September | October | November | December | January | February | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asbestos Disposal | $660 | $210 | | $585 | $2250 | | $735 | $45 | $495 | | | | $4980 |
| Asbestos Management Lab | | | | | | | $93 | $74 | | | | | $167 |
| Asbestos Removal | | $3142 | | | | $1137 | | | | | | | $4279 |
| CANTON Laboratory Analysis | $333 | $1117 | $187 | | $477 | $19 | | | | | | | $2133 |
| ERG Laboratory Analysis | | | $70 | $373 | | | | | | | | | $443 |
| Sierra Analytical | | | | | | | $268 | $385 | $193 | | | | $846 |
| Decontamination - Chemistry | | | | | | | | | | | | | $0 |
| Disposable Coveralls | | $69 | | | $90 | | | | | | | | $159 |
| Disposal Bags | | | | | $13 | | | | | | | | $13 |
| Equipment | | | | | | | | | | | | | $0 |
| Glove Bags | | | | | $65 | | | | | | | | $65 |
| Gloves - Surgical | $14 | | | | | | | | | | | | $14 |
| Miscellaneous Supplies | | $22 | | $46 | $22 | | | | | | | | $90 |
| Respirators/Filters | $412 | | $306 | | | $176 | | $192 | $114 | | | | $1200 |
| Signs/Labels | | | | | | | | | | | | | $0 |
| Training/Slide Program | | | $650 | ($650) | $525 | $10 | | | | | | | $535 |
| Vacuum - NILFISK | | | | | | | | | | | | | $0 |
| Wetting Agent | | | | | | | | | | | | | $0 |
| TOTAL | $1419 | $4560 | $1213 | $354 | $3450 | $1342 | $1096 | $696 | $802 | $0 | $0 | $0 | $14922 |

2. <u>Capital Planning and Improvements Budgets.</u> Major renovation, demolition, and building projects are submitted in requests to the universities' planning and extension offices. Requests are compiled under the business and finance departments and sent via the chancellors to the university systems' capital development/improvement boards. Once received, the funds are managed and distributed by the planning offices. Unspent funds must be returned at the end of the fiscal year. A typical flow of these budget requests, modeled from the University of North Carolina, is portrayed in Figure 5. Budget type "C" items are divided into several categories including "C1" for utilities and walk/roadways, "C2" for Occupational Safety and Health and Disability Barrier Removal, and "C3" for Renovation and Major Remodeling. The next UNC budget has requested $87,000 for asbestos removal (Mitchell Hall) under item "C3" approximately $700,000 for asbestos removal at 440 W. Franklin Street (Business Offices) and over $2,000,000 to Occupational Safety and Health projects which may include asbestos abatement (item"C2").

FIGURE 5




FLOWCHART OF CAPITAL IMPROVEMENT REQUESTS
UNIVERSITY OF NORTH CAROLINA

# CHAPTER VII

# SUMMARY AND CONCLUSION

# VII. SUMMARY AND CONCLUSION

Review of the university asbestos abatement programs and policies show that large multifunctional institutions have the infrastucture to operate adequate asbestos abatement programs. The business and finance offices supervise departments for health and safety, operations and maintenance, and building and planning. Although they lack expertise in the specifics of asbestos abatement activities, they have or can contract skills necessary to inspect buildings, monitor the air for potentially hazardous asbestos exposures, and conduct or contract for the removal or repair of deteriorated asbestos materials.

The reduction of the legal permissible exposure levels (PELs) from 2 f/cc to 0.2 f/cc (TWA) will affect asbestos abatement programs at the universities involved in this study. The following tables and discussion summarize the compliance status of the universities based on 1) a comparison of the PELs to the arithmetic mean (AM) of the airborne asbestos concentrations found and 2) the standard asbestos management policies and practices at the universities.

## A. DATA SUMMARY

Tables 8 summarizes the studies of airborne asbestos concentrations at the study locations with the OSHA 0.2 f/cc TWA PEL standard. As shown, the AM concentration (3.10 f/cc) during asbestos removal exceeds the proposed PEL. The mean concentration is above the PEL when either wet or dry removal techniques are used. These findings imply that employees should use protective measures during abatement activities. It does not necessarily mean that the actual exposures of employees during an 8 hour TWA working period actually exceed the PEL.

**Table 8**

ARITHMETIC MEAN AIRBORNE ASBESTOS CONCENTRATIONS EXCEEDING THE PROPOSED OSHA/EPA PERMISSIBLE EXPOSURE LIMITS

| Exposure Scenerio | AM (f/cc) | PEL(TWA) (0.2 f/cc) | Action Level (0.1 f/cc) | Ceiling (10 f/cc) |
|---|---|---|---|---|
| Air Quality | 0.00 | no | no | no |
| Pre-removal | 0.00 | no | no | no |
| Removal | 3.10 | yes | yes | no |
| (out Containment.) | .11 | no | yes | no |
| Final | .01 | no | no | no |
| During Abatement (inside Cont.) | | | | |
| Wet | 3.04 | yes | yes | yes |
| Dry | .79 | yes | yes | yes |
| Ceiling | .04 | no | no | no |
| Personal | 2.43 | yes | yes | yes |
| Area | 2.55 | yes | yes | yes |

(Compliance Summary: based on the arithmetic mean concentration approximating the 8 hour time-weighted average )

Other noteworthy findings include a significant difference between using area and personal sampling methods. The Student -t test $_{(95\%\ 2\ sided)}$ indicated a significantly higher asbestos concentration using personal sampling methods as compared to area sampling methods. Secondly, the AM concentration found outside of the contained removal area (.11 f/cc) exceeds the proposed OSHA action level. Although this finding does not prove that the actual asbestos exposures exceed the PEL, it supports the establishment of policies such as frequent inspection of the containment structure, control over activities that may contaminate any air-lock chambers, and policies to restrict public access to areas near asbestos abatement activities. Finally, the AM concentration during the removal of contaminated ceiling tiles does not exceed the PEL. Therefore, it may not be necessary for universities to implement asbestos-related safety measures during tile removal.

B. CONCLUSION

The thesis hypothesis states that many large instititutions fail to a) comply with federal law and b) provide a safe and healthy living environment. Using both exposure levels and model programs from three major universities, it has been shown that institutions can expect that airborne asbestos levels will exceed current PELs during asbestos removal. This will require implementation of the OSHA/EPA practices (e.g. reporting, employee protection, and abatement practices) outlined by this paper. If the PEL is reduced to 0.2 f/cc and an action level of 0.1 f/cc, OSHA/EPA compliance measures may become necessary during pre-removal and removal (both inside and outside of containment) as well.

Table 9 summarizes the basic components of asbestos abatement programs at the three universities. Although it is important to note that the status of these items changes continually as the universities strive to comply with OSHA requirements, some important elements of these programs remain out of compliance. The shortcomings include inadequate respirator and medical evalution programs. Respirator training, fitting, and maintenance were virtually non-existent at one study location. The researcher found that OSHA's "no beards" policy for respirator users is virtually unenforced. Employees often do not use respirators which are appropriate for the job. One study location entirely lacked asbestos-related medical surviellance. While workers often fail to follow OSHA/EPA policies during routine activities there is a higher level of compliance with OSHA/EPA regulations during large, supervised abatement projects. This is due in part because of contractual agreement and the increased propensity of EPA to inspect. It may also be due to the longer duration and the higher expected exposures during the projects.

Table 9

CHARACTERISTICS OF ASBESTOS ABATEMENT PROGRAM AT THE UNIVERSITIES OF NORTH CAROLINA, ILLINOIS, AND MICHIGAN

| CHARACTERISTICS | UNC | U OF I | U OF M |
|---|---|---|---|
| **Assessment & Inspections:** | all campus | all campus | ~20 buildings |
| Time frame | 3 years | 5 years | pre-renovation |
| Inspectors | OSHO* | O & M** | contractors |
| **Incidents Involving Asbestos:** | routinely | 12 buildings/mo; | 6-10/week |
| Monitoring: | | | |
| Bulk Sampling | routine | routine | routine |
| Air Sampling | most | often | often |
| Written Incident Records: | | | |
| Incoming requests | no | yes | no |
| Cum. Data Tabulation: | | | |
| bulk samples | yes | yes | yes |
| air samples | yes | yes | sometimes |
| Letters of Response : | | | |
| H & S Building files | seldom | yes | yes |
| Physical Plant/Housing or Planning | seldom | yes | seldom |
| Incident initiator | seldom | yes | yes |
| **Abatement Projects:** | | | |
| Major Funding Source: | | | |
| small projects | O & M | O & M | O & M |
| large projects | Facilities Planning | Capital Programs | Plant Extension |
| Removal: | | | |
| O & M; Housing | 60-80% | less than 20% | 20-40% |
| Contractors | only large renovation projects | all but small O & M projects | all but small O & M projects |
| **Employee Safety:** | | | |
| Abatement Training | 2-3 per/craft | 2 sessions (~150 people) | only O & M (abatement team) |
| Respirator Program | noncompliance | noncompliance unknown | yes/compliance |
| Physicals exams | yes,compliance w/ OSHA respiratory requirements only | no | yes |

Funding is another forseeable problem for institutional asbestos abatement programs. The decision to fund an asbestos abatement project is based on the recommendation from the offices of health and safety, on the remodeling and renovation schedules of the offices of building and planning or on public relations considerations. The author found no formal written decision-making process for determining the necessity of abatement activities. Large abatement projects generally utilize university building funds, which take a minimum of two years to acquire. Officials in the planning office or above typically are not informed in asbestos requirements. If the proposed PELs are implemented and enforced, there will be an even greater financial demand for asbestos abatement programs.

## C. RECOMMENDATIONS

If institutions decide to remove asbestos during routine maintenance, they should comply with the respirator and medical evalution programs outlined in this paper. The programs at the university of Michigan and North Carolina have shown the feasibility of medical evaluations. The respirator and personal protection programs at all three universities fall short of legal requirements. The solution is enforcement and education. Since craft-crews encounter asbestos on a daily basis, it is not reasonable for one asbestos abatement coordinator to inspect every project. Rather, the coordinator should have access to the crew schedules and should randomly conduct surprise inspections. All operations and maintenance personnel should be trained to recognize asbestos and deal with it effectively, regardless of supervision. The best motivation for compliance is supervision and health/safety education.

University planning and engineering offices should also be aware of asbestos abatement requirements. Improved communication between health and safety and the planning and budgeting office is recommended. Knowledge of the legal and technical requirements will allow the budgeting office to appreciate the necessity of large capital outlays for asbestos removal. This problem will become more pressing as exposure limits decrease and existing asbestos materials deteriorate. The project planners and engineers need to appreciate the legal difficulties, time and cost involved in compliance.

## LIST OF REFERENCES


1. Altree-Williams and J. S. Preston, "Asbestos and Other Fibre Levels in Buildings," *Annals Occupational Hygiene*, Vol. 29, No. 3, pp. 357-363, 1985.

2. American Conference of Governmental Industrial Hygienists, *Threshold Limit Values for Chemical Substances and Physical Agents in the Work Environment and Biological Exposure Indices with Intended Changes for 1984-1985*, American Conference of Governmental Industrial Hygienists, P.O. Box 1937, Cincinnati, 1984, p. 34.

3. American National Standards Institute, Inc., *American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971*, New York, NY, 1971.

4. American National Standards Insitute, Inc., *American National Standard For Respiratory Protection--Respirator use--Physical Qalifications for Personnel, ANSI Z88.6-1984*, New York, 1971.

5. Artvinli, M., and Baris, Y.I., "Malignant Mesotheliomas in a Small Village in the Anatolian Region of Turkey: An Epidemiology Study, "*Journal of the National Cancer Institute*, Vol. 63, p. 17, 1979.

6. "Asbestos Fibers in Air: Method No. P&CAM 239," *NIOSH Manual of Analytical Methods*, 2nd. ed., Part 1, U.S. Dept. of HEW, p. 239-1, 1977.

7. "Asbestos Fibers in Air: Method No.7400," *NIOSH Manual of Analytical Methods*, 3rd. ed., Vol. 1., U.S. Dept. of HEW, p.7400-1, 1984

8. Asbestos International Association, "Asbestos International Association Recommended Technical Method No. 2 (RTM2): Determination of Airborne Asbestos Fibres and Other Inorganic Fibres by Scanning Electron Microscopy," London, 1984.

9. Auribault, *Bullitan de l'Inspection du Travail et de l'Hygiene Industrielle*, Department of Labor Caen, France, 1906.

10. Baris, Y.I., Sahin, A. A., Ozesmi, M., Kerse, I., Ozen, E., Kolacan, B., Altinors, Goktepeli, A., "An Outbreak of Pleural Mesothelioma and Chronic Fibrosing Pleurisy in the Village of Karain/Urgup in Anatolia," *Thorax*, Vol. 1 33, p. 181-192, 1978.

11. Berry, G., Gilson, J. C. Holmes, S. Lewinsohn, H. C. , Roach, S. A., "Asbestosis: Study of Dose- Response Relationships in An Asbestos Textile Factory," *British Journal of Industrial Medicine*, Vol. 36, pp. 98-112, 1979.

12. Berry, G. and N. E. Day, "The Statistical Analysis of the Results of Sampling

an Environment for A Contaminant When Most Samples Contain An Undetectable Level," *American Journal of Epidemiology*, Vol. 97, No. 3, pp. 160-166, 1973.

13. Clarence Borel v. Fibreboard , 493 F.2d, 1076 (5th Cir 1973), cert. denied 419 U.S. 869 (1974).

14. Breslin, A.J., Ong, L., Glauberman, L., George, A. C., and LeClare, P., "The Accuracy of Dust Exposure Estimates Obtained from Conventional Air Sampling," *American Industrial Hygiene Association Journal*, 1967, Vol. 28, pp. 56-21.

15. Brodeur, Paul, "Failure to Warn-- The Asbestos Industry on Trial, Part I," *The New Yorker* , p. 49 (36), June 10, 1985.

16. Brodeur, Paul, "Discovery-- The Asbestos Industry on Trial, Part II,"*The New Yorker* , p. 45 (52), June 17, 1985.

17. Brodeur, Paul, "Judgment-- The Asbestos Industry on Trial, Part III,"*The New Yorker* , p. 37 (32), June 24, 1985.

18. Brodeur, Paul, "Bankruptcy-- The Asbestos Industry on Trial, Part IV,"*The New Yorker* , p. 36 (41), July1, 1985.

19. Code of Federal Regulations, 29 CFR §1910.1001 (d) (2) (iv) "Asbestos" through §1910.134 (b) (10),"Respiratory Protection," 34 CFR § 230.1, 40 CFR § 61.150.

20. Cooke, W. E., "Pulmonary Asbestosis,"*British Medical Journal*, Vol. 2, pp.1024-1025, 1927.

21. Dement, John McCray, "*Estimation of Dose and Evaluation of Dose Response In A Retrospective Cohort Mortality Study of Chrysotile Asbestos Textile Workers*," dissertation presented to the Department of Environmental Sciences and Engineering, at the University of North Carolina, Chapel Hill, NC in 1980 for the fulfillment of the requirements for the degree of Doctor of Philosophy.

22. Doll, R., "Mortality from Lung Cancer In Asbestos Workers," *British Journal of Medicine*, Vol. 12, p. 81, 1955.

23. Environmental Protection Agency, "*Asbestos Containing Materials in School Buildings: A Guidance Document, Part 1 and Part 2, EPA-450/2-78-014*, EPA Office of Toxic Substances, Washington DC, 1979.

24. Environmental Protection Agency, *Guidance for Controlling Friable Asbestos-Containing Materials in Buildings:, EPA 560/5-83-002* , EPA Office of Toxic Substances, Washington DC, 1983.

25. Federal Register, "Asbestos Abatement Projects, Subpart G," Vol. 50, No.134, pp. 28537-28540, July 12, 1985, (to be codified at 40 CFR Part 763.120-124).

26. Federal Register, "Friable Asbestos-Containing Materials in Schools; Identification and Notification," Vol. 47, No. 103, pp. 23360-23389, May 27, 1982, (to be codified at 40 CFR Part 763).

27. Federal Register, "Hazard Communication; Final Rule," Vol. 48, No. 228,

pp. 53280-5334, Nov. 25, 1983 (to be codified at 29 CFR Part 1910).

28. Federal Register, "National Emissions Standards for Hazardous Air Pollutants; Amendments to Asbestos Standard; Final Rule," Vol. 49, No. 67, pp. 13658-13665, Apr. 5, 1984, (to be codified at 40 CFR Part 61).

29. Federal Register, "Occupational Exposure to Asbestos; Emergency Temporary Standard," Vol. 48, No. 215, pp. 51086-51140, Nov. 4, 1983 (proposed regulation: not adopted).

30. Federal Register, "Respirators" Vol. 37, p. 6244, Mar. 25, 1972, (to be codified at 29 CFR Part 1910).

31. Gardner L. V., "Chrysotile Asbestos as an Indicator of Subtile Differences in Animal Tissues,"*American Review of Tuberculosis*, Vol. 45, p. 762, 1942.

32. "Government Concentrates: EPA Extends Asbestos Protection Rules," *Chemical and Engineering News*, Vol. 63, No. 26, July 1, 1985, p.18.

33. Hammond E. Cuyler, Selikoff, Irving J., and Seidman, Herbert, "Asbestos Exposure, Cigarette Smoking and Death Rates," *Annals of the New York Academy of Sciences* , Vol. 330, pp.473-490, 1979.

34. Hunter, D., *The Diseases of Occupation*, 4th ed. London, English Universities Press, 1969, p. 1009.

35. Kerr, G. W., "Use of Statistical Methodology in Environmental Monitoring," *American Industrial Hygiene Association Journal*, 1962, Vol. 23, pp. 75-82.

36. Ki Poong Lee, "Lung Response to Particulates with Emphasis on Asbestos and Other Fibrous Dusts," *CRC Critical Reviews in Toxicology*, Vol. 14, Issue 1, 1985, pp. 33-86.

37. Leidel, Nelson A., Stephen Bayer, Ralph D. Zumwalde, and Kenneth A. Busch, "USPHS/NIOSH Membrane Filter Method For Evaluating Airborne Asbestos Fibers," U.S. HEW/NIOSH, p.8-14, 1979.

38. Leidel, Nelson A., Kenneth A. Busch, and Jeremiah R. Lynch, *Occupational Exposure Sampling Strategy Manual*, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, 1977.

39. Leineweber, J. P., "Fiber Toxicology," *Journal of Occupational Medicine*, Vol. 23, No. 6, June 1981.

40. McDonald, Alison D. and McDonald, Corbett J., "Mesothelioma after Crocidolite Exposure during Gas Mask Manufacture," *Environmental Research*, Vol. 17, p. 340-346, 1978.

41. McDonald, J.C., Liddell, F.D.K., Gibbs, G.W., et al," Dust Exposure and Mortality in Chrysotile Mining: 1910-1975," *British Journal of Industrial Medicine*, Vol. 37, p. 11, 1980.

42. Merewether, E. R. A., "Asbestosis and Carcinoma of the Lung," in *Annual Report of the Chief Inspector of Factories for the Year 1947*, London, H. M. Stationery

Office, 1949.

43. Merewether, E. R. A., ed., *Industrial Medicine and Hygiene*, Vol. 3, Butterworth and Co. LTD, London, 1956, pp.104-114.

44. Merewether, E. R. A., and Price, C.W., *Report on the Effects of Asbestos Dust on the Lungs and Dust Suppression in the Asbestos Industry*, London, H. M. Stationery Office, 1930.

45. Murray, M., *Departmental Committee for Compensation for Industrial Diseases, Great Britain Parliment Command Papers 3495 and 3496*, London, Her Majesty's Stationery Office, 1907.

46. Newhouse, Muriel, L., and Berry, G., "Predictions of Mortality from Mesothelial Tumors in Asbestos Factory Workers," *British Journal of Industrial Medicine*, Vol. 33, p. 147, 1976.

47. North Carolina Department of Administration, The Division of State Construction, *General Statutes Relating to the Constuction Manual, 1st ed., Raleigh, July, 1982*, pp. 87-1 et seq.

48. Roach, S. A., E. J. Baier, H .E. Ayer, and R. L. Harris, "Testing Compliance with Threshold Limit Values for Respirable Dusts," *American Industrial Hygiene Association Journal*, Vol. 27, pp. 1-12, 1966.

49. Remington and Schork, "Estimation" and "Hypothesis Testing,"*Statistics with Applications to the Biological Sciences* , 2nd. ed., Prentice-Hall, 1985, pp. 123-201.

50. Ryckman, Mark D. and DeVere W. Ryckman and Jeffrey Peters, "Asbestos Control Programs for Institutional Facilities," *Journal of Environmental Engineering*, Vol. 109, No. 2., pp. 275-287, Apr. 1983.

51. Saracci, R., "Asbestos and Lung Cancer: An Analysis of the Epidemiological Evidence on the Asbestos--Smoking Interaction," *International Journal of Cancer*, Vol. 20, p. 323-331, 1977.

52. Seaton, Anthony, "Asbestos-Related Disease," *Occupational Lung Diseases*, 2nd ed., W. B.Saunders Co., 1984, pp. 323-376.

53. Selikoff, I. J., Churg, J., and Hammond, E. C., "Asbestos Exposure and Neoplasia," *Journal of the American Medical Association* , Vol. 188, p.142-146, 1964.

54. Selikoff, I. J., Hammond, E. C., Churg, J.," Asbestos Exposure, Smoking and Neoplasia,"*Journal of the American Medical Association* , Vol. 204, p. 106-112, 1968.

55. Sigurdson, Eunice E., Levy, Barry S., Mandel, Jack, McHugh Richard, Michienzi, Leonard J., Jagger, Helen, Pearson, John, "Cancer Morbidity Investigations: Lessons from the Duluth Study of Possible Effects of Asbestos in Drinking Water," *Environmental Research*, Vol. 25, p.50, 1981.

56. Trosko, James E., and Chia-Cheng Chang, "Environmental Carcinogenesis: An Integrative Model," *The Quarterly Review of Biology*, Vol. 53, p. 115-141, 1978.

57. University of North Carolina, Occupational Safety and Health Resource Center, *NIOSH Course 582, Sampling and Evaluation Airborne Asbestos Dust* , Oct. 7, 1985.

58. U.S. Veterans Administration, "Medical Center Memorandum #138-3, Asbestos Control Program," Danville, Illinois, June 1985, pp.1-29.

59. U.S. Navy, "Asbestos Exposure Control Program," in the *Navy Environmental and Preventive Medicine Unit No. 5 Shipboard Occupational Health Manual*, Directive: OPNAVINST 5100.23A, Jan. 1981 (adopted from the Navy Environmental and Preventive Medicine Unit No. 2, Norfork, Virginia).

60. Wagner, J. C., Sleggs, C. A. and Marchand Paul, "Diffuse Pleural Mesothelioma and Asbestos Exposure in the North Wertern Cape Province," *British Journal of Industrial Medicine*, Vol. 17, p. 260, 1960.

61. Whitwell, F., Scott, Jean, and Grimshaw, Myra, "Relationship Between Occupations and Asbestos-fibre Content of the Lungs In Patients with Pleural Mesothelioma, Lung Cancer, and Other Diseases," *Thorax*, 32, p. 377-386, 1977.

62. Wood, W. B., and Gloyne, S. R., Pulmonary Asbestosis: a Review of 100 Cases, *Lancet*, Vol. 2, p.1383, 1934.

63. Yazicioglu, S., Ilçayto, R., Balci, K., Sayli, B.S., and Yorulmaz, B., "Pleural Calcification, Plueral Mesotheliomas, and Brochial Cancers Caused by Tremolite Dust," *Thorax*, 35, p. 564-569, 1980.

# APPENDIX A:

# ASBESTOS RELATED DISEASES AND FIBER TOXICOLOGY

ASBESTOS RELATED DISEASES AND FIBER TOXICOLOGY

Epidemiology studies strongly associate asbestos with cancer and fibrotic lung disease. Toxicology studies repeatedly induce tumors in animals exposed to asbestos by various routes of entry. The following discussion is intended to describe asbestos minerals, explain why asbestos has disease causing potential, and overview the asbestos-related diseases.

## 1. ASBESTOS MINERALS

Asbestos is a group of natural, serpentine or amphibole silicates. The most commonly used asbestos serpentine mineral is chrysotile ($Mg_3Si_2O_5(OH)_4$) (Seaton, 1984). It is white, lustrous, and sheers into curly, very fine fibrous bundles due to the molecular silicate sheets encased by magnesium and hydroxide ions. The fibrous amphibole minerals are generally crocidolite ($Na_2(MgFe^{3+}Fe^{2+})Si_8O_{22}(OH)$/ slightly blue), amosite ($(MgFe^{2+})_7Si_8O_{22}(OH)_2$/ brown, magenta, or yellow), anthophyllite ($(MgFe^{2+})_7Si_8O_{22}(OH)_2$), actinolite ($Ca_2(MgFe^{2+})_5Si_8O_{22}(OH)_2$), and tremolite ($Ca_2(MgFe^{2+})_5Si_8O_{22}$). The amphiboles differ from the sepentines in that the crystals are in straight, double chains rather than curled plates. Amosite is characterized by long fibers which have poor spinning properties, but are useful in fabricated building materials (Merewether, 1956). Chrysidolite is useful in products resistent to chemical reactions and tremolite, which is brittle and not suited for manufactured cloth, is used chiefly for insulation on pipe lagging and steam conduits. A mentionable but less common asbestos form is percidolite. It is distinctively blue and is used primarily to insulate boilers.

All asbestos fibers are composed strong fibers that are physically durable and chemically stable. The looseness and friability (the tendency of bonded fibers to lose integrity and become airborne when disturbed by hand pressure) of asbestos fiber bundles depend on both the mineral state and the degree of processing. Fiber bundles vary in size from a few microns of individual strands to clearly, visible groups of bonded materials. Three important characteristics of asbestos fibers are durability, respirable size, and barbed-wire shape. These factors contribute to asbestos toxicity (Leineweber, 1981). Although chrysotile often occurs in thick fiber bundles which are too large to enter lung aveoli, the highly toxic chrositolite fibers are finely differentiated and readily lodge into the lung aveoli.

## 2. ASBESTOS-RELATED DISEASES

Asbestos is linked to asbestosis, mesotheliomas, and bronchial and lung cancers. There is unclear association of asbestos to cancers of the digestive tract such as the stomach, colon, and rectum ( Gardner, 1942; Selikoff, Hammand, Churg, 1964 and 1968; McDonald and McDonald, 1978; Yazicioglu, et al, 1980; Whitwell, Scott, and Grimshaw, 1977). Although the correlation is less certain, asbestos related diseases may also be caused by drinking or eating asbestos contaminated water and food (Baris, et al, 1981; Sigurdson, et al, 1980). Because the association between occupational asbestos exposures and cancers of the digestive tract is uncertain, this section emphasizes incurable diseases that are strongly associated with exposure to airborne asbestos. The justification for the emergency 0.5 f/cc TWA standard (48 Fed. Reg. 51086-51140, 1983) contains an excellent overview of recent epidemiological and toxicological studies . A detailed description of asbestos-related fibrotic lung diseases (with pictures) appears in Ki Poong Lee (1985) and Seaton (1984).

a. Asbestosis. This incurable, fibrotic lung disease usually results from prolonged or excessive occupational exposure to any of the common types of asbestos (Seaton, 1984). Microscopic fibers become embedded in the lungs, causing the formation of non-functional scar tissue. The result is a continual decrease in lung elasticity and functional capacity. Although symptoms may remain dormant or latent for 10 to 30 years, the disease is degenerative and gradually causes or contributes to death. Individuals with asbestosis often die asbestosis-related complications such as brochogenic, gastrointestinal, and pleural neoplasms. Cigarette smoking is believed to be associated with asbestosis morbidity (Berry, G., Gilson, J. C., Holmes, S., Lewinsohn, H. C., Roach, S.A., 1979).

b. Mesotheliomia. This is a rare and always fatal cancer that affects the lining of the chest and abdominal cavity. Mortality usually occurs within one year of diagnosis. Asbestos is the only known cause in this part of the world. The disease is not associated with smoking. Although the latency period is estimated at 20-30 years, it has occurred both without long latency periods and with either short-term or low-levels of exposure (McDonald and McDonald, 1978). Of the three most common asbestos forms chrysidolite appears to have the greatest potential to cause mesotheliomia, followed by amosite and then chrysotile (Seaton, 1984). Spouses of asbestos workers are known to contract mesothelioma. It is thought that airborne exposures are generated from laundering asbestos contaminated work clothes; hence, disposable coveralls are now recommended to reduce the occurrence of the disease.

Asbestos is the only known causative agent for mesotheliomia in the U.S.. It is plausible that agents having fibrotic properties similar to asbestos (see "Factors of Fiber Toxicology") could also cause the disease. These agents could include fubrous erionite from volcanic deposits (Artvinli and Baris, 1979) and microscopic plant materials (i.e. non-spherical pollens; related during discussions with Warren Cook, February 1986).

c. Lung and Bronchial Cancers. Lung cancer accounts for approximately 20% of all deaths in heavily exposed asbestos workers (Hammond, Selikoff and Seidman, 1979). Asbestos workers who smoke are estimated to be approximately 53 times more likely to die of lung cancers than are members of the general population who do not smoke. Asbestos workers who were heavy smokers show a statistical increase in the risk of dying from lung cancer by 87 times. Lung cancer differs from Mesotheliomia in that it directly affects the lung tissue and has a latency period of 10-30 years.

3. FACTORS OF FIBER TOXICOLOGY.

Knowledge about the disease potential of asbestos comes from epidemiological and animal toxicological studies, fiber deposition modeling, and in-vitro cell culture experiments (Leineweber, 1981). According to current theory, the important determinants for the biological activity leading to disease are fiber size and dimensions, dose, and durability or insolubility of the fibers in the system.

a. Size and Dimension. Fibers of lengths greater than 8 micrometers (ums) and diameters less than 1.5 ums have the greatest tumor causing potential, with the maximum biological activity occurring from fibers of about .25 ums. All experiments published up to 1981, support the hypothesis that long thin fibers (as described above) have the greatest malignancy potential. In contrast to equidimensional particles that have a deposition limit of approximately 10 ums, fibers up to approximately 200 ums can penetrate the distal portions of the lung and become lodged in the brochial branching points or the alveoli sacs. The limiting factor of respirability seems to be fiber diameter, with 3 ums as the approximate upper limit. Although removal by the muco-ciliary clearance mechanism does not seem limited by particle size or shape, evidence suggests that macrophages are unable to remove fibers that are longer than 10 ums.

b. Dose. Perhaps the toxicity factor most relevant to determining an appropriate abatement exposure level, is the dose. The dose refers to the amount of respirable asbestos which the worker is exposed to times the duration of the exposure. It is influenced by the concentration of inhaled fibers, which is estimated in this study by sampling techniques prescribed by OSHA in asbestos abatement programs. The effective dose ultimately depends on the penetration of the fibers into the respiratory system and the efficiency of the clearance mechanisms previously described.

Morbidity usually increases with the dose. Threshold limits for toxins were developed by professional committees to identify the level at which the dose of a substance is no longer safe. Even though these threshold limits often become occupational legal exposure limits (PELs), popular cancer theory holds that there is no safe threshold limit for carcinogens because genetic mutations by one unit of a carcinogen (i.e. a fiber) can initiate or promote the development of cancer (Trosko and Chia-Cheng Chang). It follows that a "no risk level" is only obtained by no exposure. It is virtually impossible to obtain this no risk level. Asbestos is environmentally ubiquitous because of the extensive usage-- and consequential deterioration-- of asbestos materials since the early 1900s.

c. Durability. The third factor of fibers toxicity is their apparent durability. Whereas, body fluids etch, pit, and weaken glass fibers, asbestos fibers do not readily deteriorate. The body seems unable to either dissolve asbestos into non-toxic products nor weaken them to the point of breaking into pieces small enough to be removed by macrophages.

4. CONCLUDING REMARKS.

Removal of asbestos insulation is expensive and usually necessitates replacement. Since size and shape apparently influences toxicity, there is a potential that fibrous asbestos substitutes may also be toxic. Little is known about low levels of exposures, especially complicated by smoking, radiation, or chemical laboratory exposures. Despite, EPA/OSHA clean air checks following abatement projects, there is insufficient evidence that indicates a lower level of exposure exists when asbestos is removed prematurely. It is certain, however, that environmental and occupational exposures increase during asbestos removal.

# APPENDIX B

# DATABASE

ASBESTOS DATA: UNIVERSITY OF NORTH CAROLINA

| DATE | ID NO. | TYPE | SPECIFICS | ANALYST: CO. NAME | LOCATION | LOCALE or room | ACTIVITY (e-g asbestos removal) | PUMP no. | FLOW (L/min) | TIME (min) | AIR-VOLUME (L) | ASBESTOS level | COMMENTS | SAMPLER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/9/85 | 10 | area | | Quality Analytical Services,Inc | UNC/NCBC | reception/6 ft | air quality | | 11.20 | 180 | 2016 | 0.000 | | Willhalt |
| 4/9/85 | 11 | area | | Quality Analytical Services,Inc | UNC/NCBC | rm end of hall/6 ft | air quality | | 11.20 | 180 | 2016 | 0.000 | | Willhalt |
| 4/9/85 | 12 | area | | Quality Analytical Services,Inc | UNC/NCBC | penthouse | air quality | | 11.20 | 180 | 2016 | 0.000 | | Willhalt |
| 5/1/85 | 1602 | area | | Quality Analytical Services,Inc | UNC/NCBC | rm 404 | air quality | bgl/0884 | 11.20 | 240 | 2688 | 0.010 | | GA |
| 5/1/85 | 1603 | area | | Quality Analytical Services,Inc | UNC/NCBC | hallway/4 ft | air quality | bgl/0884 | 11.20 | 180 | 2016 | 0.001 | | GA |
| 5/1/85 | 1616 | area | | Quality Analytical Services,Inc | UNC/NCBC | rm 402 | air quality | bgl/0884 | 11.20 | 390 | 4368 | 0.000 | | GA |
| 5/15/85 | 1713 | area | | Quality Analytical Services,Inc | UNC/NCBC | Bus. office | air quality | bgl/0884 | 11.20 | 360 | 4032 | 0.001 | | W/GA |
| 5/22/85 | 1775 | area | | Quality Analytical Services,Inc | UNC/Brauer hall | asbestos/work area | no data | bgl/0884 | 11.20 | 120 | 1344 | 0.025 | | W/GA |
| 5/7/85 | 2287 | area | | Quality Analytical Services,Inc | UNC/Carrington | rm 5 | wall demolition | bgl/0884 | 11.20 | 180 | 2016 | 0.001 | | G. Armistead |
| 6/21/85 | 2314 | area | | Quality Analytical Services,Inc | UNC/NCBC | penthouse | air quality | bgl/0884 | 11.20 | 240 | 2688 | 0.000 | | G. Armistead |
| 6/13/85 | 2362 | area | | Quality Analytical Services,Inc | UNC/Carrington | rm 5 | air quality | bgl/0884 | 11.20 | 180 | 2016 | 0.002 | | G. Armistead |
| 6/24/85 | 2436 | area | | Quality Analytical Services,Inc | UNC/NCBC | fl 6/corridor fund? | air quality | bgl/0884 | 11.20 | 240 | 2688 | 0.000 | | G. Armistead |
| 6/17/85 | 2437 | area | | Quality Analytical Services,Inc | UNC/Carrington | rm 5 | air quality | bgl/0884 | 11.20 | 240 | 2688 | 0.001 | | G. Armistead |
| 7/19/85 | 2912 | area | | Quality Analytical Services,Inc | UNC/NCBC | suite 203 rm 218 | air quality | bgl1 | 11.20 | 450 | 5040 | 0.000 | | G. Armistead |
| 7/19/85 | 2913 | area | | Quality Analytical Services,Inc | UNC/NCBC | penthouse | air quality | bgl2 | 11.00 | 480 | 5280 | 0.000 | | G. Armistead |
| 7/22/85 | 2914 | area | | Quality Analytical Services,Inc | UNC/Daniels | contractors work area | | bgl2 | 11.00 | 180 | 1980 | 0.002 | | G. Armistead |
| 7/25/85 | 3001 | area | | Quality Analytical Services,Inc | UNC/Joyner Resid. Hall? | s.w. exit | rem.pipe lag.s | bgl1 | 11.20 | 180 | 2016 | 0.015 | | G. Armistead |
| 7/26/85 | 3044 | area | | Quality Analytical Services,Inc | UNC/Daniels | work area | rem, light | bgl2 | 11.00 | 180 | 1980 | 0.003 | | G. Armistead |
| 7/29/85 | 3104 | area | | Quality Analytical Services,Inc | UNC/Daniels | near microtrap | | bgl2 | 11.00 | 360 | 3960 | 0.001 | | G. Armistead |
| 7/29/85 | 3105 | area | | Quality Analytical Services,Inc | UNC/power plant | at coal pulverizers | | bgl1 | 11.20 | 180 | 2016 | 0.001 | | G. Armistead |
| 7/30/85 | 3106 | area | | Quality Analytical Services,Inc | UNC/Daniels | near Microtrap | | bgl2 | 11.00 | 360 | 3960 | 0.002 | | G. Armistead |
| 7/30/85 | 3108 | area | | Quality Analytical Services,Inc | UNC/H.W.airport | admin. bldg/437u/lobby | | bgl1 | 11.20 | 180 | 2016 | 0.000 | | G. Armistead |
| 7/30/85 | 3156 | area | | Quality Analytical Services,Inc | UNC/power plant | area of coal pulverizers | no data | bgl2 | 11.00 | 180 | 1980 | 0.001 | | G. Armistead |
| 8/1/85 | 3157 | area | | Quality Analytical Services,Inc | UNC/power plant | conv/pipe&valve station | | bgl1 | 11.20 | 180 | 2016 | 0.005 | | Willhalt |
| 7/30/85 | 3158 | ersonal | Cassidy | Quality Analytical Services,Inc | UNC/Daniels | | removal | HSB | 1.56 | 1210 | 1888 | 0.003 | | Willhalt |
| 7/31/85 | 3159 | area | | Quality Analytical Services,Inc | UNC/Daniels | | rem/duct&hangers | bgl2 | 11.00 | 420 | 4620 | 0.001 | | Willhalt |
| 8/1/85 | 3160 | area | | Quality Analytical Services,Inc | UNC/Daniels | | rem/duct/decor finish | bgl2 | 11.00 | 420 | 4620 | 0.001 | | Willhalt |
| 8/2/85 | 3161 | area | | Quality Analytical Services,Inc | UNC/Daniels | | rem/decor finish | bgl2 | 11.00 | 362 | 3982 | 0.001 | | Willhalt |
| 8/2/85 | 3162 | area | | Quality Analytical Services,Inc | UNC/Daniels | | | bgl1 | 11.20 | 204 | 2285 | 0.001 | | Willhalt |
| 8/5/85 | 3239 | area | | Quality Analytical Services,Inc | UNC/power plant | return breeching to boilers | none | bgl1 | 11.20 | 180 | 2016 | 0.000 | | v/ps |
| 8/6/85 | 3240 | area | | Quality Analytical Services,Inc | UNC/Daniels | corridor/near microtrap | none | bgl2 | 11.00 | 300 | 3300 | 0.002 | | v/ps |
| 8/5/85 | 3243 | ersonal | Cassidy | Quality Analytical Services,Inc | UNC/Daniels | | scraping and cleaning | HSB | 1.56 | 1050 | 1638 | 0.009 | | v/ps |
| 8/7/85 | 3244 | area | | Quality Analytical Services,Inc | UNC/Daniels | | rem/dec.fin.&clean | bgl2 | 11.00 | 300 | 3300 | 0.005 | | v/ps |
| 8/8/85 | 3318 | area | | Quality Analytical Services,Inc | UNC/Daniels | corridor/near microtrap | gross rem/cleanup | bgl2 | 11.00 | 375 | 4125 | 0.011 | | v |
| 8/8/85 | 3319 | area | | Quality Analytical Services,Inc | UNC/power plant | by #2 boiler | removal | bgl2 | 11.20 | 180 | 2016 | 0.001 | | v |
| 8/9/85 | 3320 | area | | Quality Analytical Services,Inc | UNC/power plant | across form file cabinet | making a hole | bgl2 | 11.00 | 240 | 2640 | 0.003 | | v |
| 8/10/85 | 3365 | area | | Quality Analytical Services,Inc | UNC/Brauer Hall | room 107 | scrape pan ceiling | bgl2 | 11.20 | 180 | 2016 | 0.001 | | v/ps |
| 8/13/85 | 3366 | area | | Quality Analytical Services,Inc | UNC/Daniels | conduit | removal/cleanup | bgl1 | 11.00 | 390 | 4290 | 0.003 | | v/ps |
| 8/13/85 | 3367 | ersonal | Cassidy | Quality Analytical Services,Inc | UNC/Daniels | flow equipment | illegible | HSB | 1.00 | 210 | 210 | 0.518 | | v/ps |
| 8/14/85 | 3394 | area | | Quality Analytical Services,Inc | UNC/Daniels | contractors area | clearance | bgl2 | 11.00 | 360 | 3960 | 0.009 | | v |
| 8/21/85 | 3525 | area | | Quality Analytical Services,Inc | UNC/440W Franklin | room 34 | air quality | bgl1 | 11.20 | 240 | 2688 | 0.005 | very trashy | BHW |
| 9/17/85 | 85121 | area | | Quality Analytical Services,Inc | UNC/NCBC | foyer by suite 400 | air quality | bgl1 | 11.20 | 360 | 4032 | 0.000 | high traffic area | Williams |
| 9/17/85 | 85122 | area | | Quality Analytical Services,Inc | UNC/dental school | outside room 107 | air quality | bgl2 | 11.00 | 540 | 5940 | 0.001 | vinyl asbestos tile | BHW |
| 9/20/85 | 85123 | area | | Quality Analytical Services,Inc | UNC/NCBC | suite 600 | air quality | bgl1 | 11.20 | 360 | 4032 | 0.001 | high traffic area | Williams |
| 9/26/85 | 85128 | ersonal | | Quality Analytical Services,Inc | UNC/Phillips & Wilson Lib | | removal/insulation | HSA-HSA | 1.70 | 150 | 255 | 0.017 | | Williams |
| 10/16/85 | 85134 | area | | Quality Analytical Services,Inc | UNC/NCBC | suite 502 | air quality | bgl1 | 11.20 | 360 | 4032 | 0.000 | | Rickelley |
| 9/24/85 | 85135 | | | Quality Analytical Services,Inc | UNC/NCBC | renovation site | | HSB-HSA | 1.70 | 420 | 714 | 0.016 | | Williams |
| 9/24/85 | 85127 | area | | Quality Analytical Services,Inc | UNC/Daniels | work site | | HSB-HSA | 11.20 | 360 | 4032 | 0.001 | | Williams |
| 11/4/85 | 85138 | ersonal | | Quality Analytical Services,Inc | UNC/Daniels | basement | spray and scrape | HSO-rr-2 | 4.40 | 270 | 1188 | 0.001 | | Williams |
| 11/4/85 | 85139 | area | | Quality Analytical Services,Inc | UNC/Daniels | basement | spray and scrape | bgl1 | 11.20 | 270 | 3024 | 0.000 | | Williams |
| 11/18/85 | 85143 | area | | Quality Analytical Services,Inc | UNC/NCBC | room 501 | air quality | bgl1 | 11.20 | 360 | 4032 | 0.000 | | Williams |
| 11/20/85 | 85144 | area | | Quality Analytical Services,Inc | UNC/Student Union | room 16 | | bgl1 | 11.20 | 135 | 1512 | 0.000 | | |
| 11/20/85 | 85145 | ersonal | | Quality Analytical Services,Inc | UNC/Student Union | room 16 | | HSO-rr-2 | 1.70 | 135 | 230 | 0.000 | | |

## ASBESTOS DATA: UNIVERSITY OF ILLINOIS

| DATE | ID NO. | TYPE | SPECIFICS | ANALYST: CO. NAME | LOCATION | LOCALE or room | ACTIVITY (a-p-de-do removal) | PUMP no. | FLOW (L/min) | TIME (min) | AIR-VOLUME (L) | ASBESTOS level | COMMENTS | SAMPLER | COUNTER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/16/85 | 72305 | area | | Randolph & Associates | Univ/Dairy Man. | rm. 208 test lab | pre-removal | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/16/85 | 72306 | area | | Randolph & Associates | Univ/Dairy Man. | attic/mechanical rm | pre-removal | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/16/85 | 72307 | area | | Randolph & Associates | Univ/Dairy Man. | rm. 106 1st fl | pre-removal | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/16/85 | 72308 | area | | Randolph & Associates | Univ/Dairy Man. | basement/ammonia rm | pre-removal | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/16/85 | 72309 | area | | Randolph & Associates | Univ/Dairy Man. | outside/east entrance | pre-removal | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/16/85 | invalid | area | | Randolph & Associates | Univ/Dairy Man. | no data | no data | n.d. | 4 | 30 | 120 | n.d. | no sample received | J.M./J | Persen |
| 7/24/85 | 70101 | area | | Randolph & Associates | Univ/Dairy Man. | lab/2nd fl | rem | n.d. | 4 | 30 | 120 | 0.160 | | J.M./J | Persen |
| 7/24/85 | 73002 | area | | Randolph & Associates | Univ/Dairy Man. | magnetic rm/1st fl | rem,drg | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/24/85 | 73003 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | rem | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/25/85 | 73004 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | rem | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/25/85 | 73005 | area | | Randolph & Associates | Univ/Dairy Man. | equipment rm | rem | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/25/85 | 73006 | area | | Randolph & Associates | Univ/Dairy Man. | penthouse/cooling rm | rem | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/25/85 | 73007 | area | | Randolph & Associates | Univ/Dairy Man. | rm.208 | rem | n.d. | 4 | 30 | 120 | 0.160 | | J.M./J | Persen |
| 7/29/85 | 80105 | area | | Randolph & Associates | Univ/Dairy Man. | inside work area | no data | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/29/85 | 80106 | area | | Randolph & Associates | Univ/Dairy Man. | inside work area | during removal | n.d. | 4 | 30 | 120 | 0.340 | | J.M./J | Persen |
| 7/29/85 | 80107 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | rem | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 7/29/85 | 80108 | area | | Randolph & Associates | Univ/Dairy Man. | work area/1st fl | rem | n.d. | 4 | 30 | 120 | 0.260 | | J.M./J | Persen |
| 7/30/85 | 80109 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | rem | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 7/30/85 | 80110 | area | | Randolph & Associates | Univ/Dairy Man. | attic cooling | final | n.d. | 4 | 300 | 1200 | -0.009 | | J.M./J | Persen |
| 7/30/85 | 80111 | area | | Randolph & Associates | Univ/Dairy Man. | floor 2 | final | n.d. | 4 | 300 | 1200 | -0.009 | | J.M./J | Persen |
| 7/31/85 | 80112 | area | | Randolph & Associates | Univ/Dairy Man. | floor 1 | rem | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 7/31/85 | 80113 | area | | Randolph & Associates | Univ/Dairy Man. | equipment rm/1st fl/in | none | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 7/31/85 | 80114 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | no data | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 7/31/85 | 80115 | area | | Randolph & Associates | Univ/Dairy Man. | floor 1 | no data | n.d. | 4 | 240 | 960 | 0.010 | | J.M./J | Persen |
| 8/1/85 | 80703 | area | | Randolph & Associates | Univ/Dairy Man. | basement/work area/in | none | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/1/85 | 80704 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | no data | n.d. | 4 | 30 | 120 | 0.350 | | J.M./J | Persen |
| 8/1/85 | 80705 | area | | Randolph & Associates | Univ/Dairy Man. | equipment rm/elevator/in | none | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/1/85 | 80706 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | no data | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/2/85 | 80707 | area | | Randolph & Associates | Univ/Dairy Man. | no data | no data | n.d. | 4 | 60 | 240 | no data | filter wet | J.M./J | Persen |
| 8/2/85 | 80708 | area | | Randolph & Associates | Univ/Dairy Man. | inside work area | rem | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/5/85 | 80709 | area | | Randolph & Associates | Univ/Dairy Man. | outside air | none | n.d. | 4 | 30 | 120 | -0.090 | | J.M./J | Persen |
| 8/5/85 | 80710 | area | | Randolph & Associates | Univ/Dairy Man. | basement | rem | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/5/85 | 80711 | area | | Randolph & Associates | Univ/Dairy Man. | basement | rem | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/5/85 | 80712 | area | | Randolph & Associates | Univ/Dairy Man. | equipment rm/elevator/in | none | n.d. | 4 | 60 | 240 | -0.050 | | J.M./J | Persen |
| 8/6/85 | 80713 | area | | Randolph & Associates | Univ/Dairy Man. | basement | final | n.d. | 4 | 300 | 1200 | -0.010 | | J.M./J | Persen |
| 8/12/85 | 81244 | area | | Randolph & Associates | Univ/Dairy Man. | main floor | final | n.d. | 10 | 300 | 3000 | -0.010 | | J.M./J | Persen |
| 8/12/85 | 81245 | area | | Randolph & Associates | Univ/Dairy Man. | basement | final | n.d. | 10 | 300 | 3000 | -0.010 | | J.M./J | Persen |
| 8/12/85 | 81241 | area | | Randolph & Associates | Univ/Dairy Man. | floor 3 | final | n.d. | 10 | 300 | 3000 | -0.010 | | J.M./J | Persen |
| 8/12/85 | 81243 | area | | Randolph & Associates | Univ/Dairy Man. | penthouse | final | n.d. | 10 | 300 | 3000 | -0.010 | | J.M./J | Persen |
| 8/12/85 | 81242 | area | | Randolph & Associates | Univ/Dairy Man. | outside | final | n.d. | 10 | 300 | 3000 | -0.010 | | J.M./J | Persen |
| 7/22/85 | 1 | per | laborer | Wallace Corp | Univ/Dairy Man. | magnet room | drg rem | d4 | n.d. | n.d. | 232 | 0.74 | | Woggel | Wallace |
| 7/22/85 | 2 | area | | Wallace Corp | Univ/Dairy Man. | magnet room | drg rem | ma1 | 2 | 110 | 220 | 0.67 | | Woggel | Wallace |
| 7/22/85 | 3 | per | laborer | Wallace Corp | Univ/Dairy Man. | magnet room | drg rem | d | 2 | 116 | 232 | 99.999 | sample overloaded | Woggel | Wallace |
| 7/23/85 | 4 | area | | Wallace Corp | Univ/Dairy Man. | magnet room | drg rem | d | 3 | 110 | 330 | 0.330 | | Woggel | Wallace |
| 7/17/85 | 5 | area | | Wallace Corp | Univ/Dairy Man. | magnet room | pre-rem | ma2 | 1 | 57 | 57 | -0.010 | | Woggel | Wallace |
| 7/17/85 | 6 | area | ext | Wallace Corp | Univ/Dairy Man. | east outside | pre-rem | d | 4 | 36 | 144 | -0.010 | | Woggel | Wallace |
| 7/17/85 | 7 | area | wall | Wallace Corp | Univ/Dairy Man. | magnet room/wall | pre-rem | ma1 | 0.84 | 257 | 216 | -0.010 | (slot covered/n.read | Woggel | Wallace |
| 7/17/85 | 8 | area | | Wallace Corp | Univ/Dairy Man. | room 208 | pre-rem | d4 | 4 | 30 | 120 | -0.010 | | Woggel | Wallace |
| 7/17/85 | 9 | area | | Wallace Corp | Univ/Dairy Man. | attic penthouse | pre-rem | d | 4 | 30 | 120 | -0.010 | | Woggel | Wallace |
| 7/17/85 | 10 | area | | Wallace Corp | Univ/Dairy Man. | ammonia room | pre-rem | d | 3.1 | 32 | 99 | -0.010 | | Woggel | Wallace |
| 7/18/85 | 11 | area | | Wallace Corp | Univ/Dairy Man. | kitchen | pre-rem | d5 | 4 | 38 | 152 | -0.010 | | Woggel | Wallace |
| 7/19/85 | 12 | area | | Wallace Corp | Univ/Dairy Man. | magnet room/computer lap | ceiling tile rem | d1 | 3 | 44 | 132 | -0.010 | | Woggel | Wallace |
| 7/19/85 | 13 | per | T Proctor | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | d2 | 2 | 26 | 52 | 0.060 | | Woggel | Wallace |
| 7/19/85 | 14 | per | carpenter | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | d | 2 | 62 | 124 | 0.040 | | Woggel | Wallace |
| 7/19/85 | 15 | per | laborer | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | d1 | 3 | 16 | 48 | 0.060 | | Woggel | Wallace |
| 7/19/85 | 16 | per | Scott | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | d3 | 2 | 54 | 108 | 0.040 | | Woggel | Wallace |
| 7/19/85 | 17 | per | Aldip | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | d4 | 2 | 21 | 42 | 0.020 | | Woggel | Wallace |
| 7/19/85 | 18 | area | | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | ma1 | 1.24 | 79 | 98 | 0.070 | | Woggel | Wallace |
| 7/19/85 | 19 | per | Botch/electrician | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | d5 | 2 | 54 | 108 | 0.030 | | Woggel | Wallace |
| 7/19/85 | 20 | per | Scott | Wallace Corp | Univ/Dairy Man. | magnet room | ceiling tile rem | ma2 | 1.68 | 50 | 84 | 0.030 | | Woggel | Wallace |

| DATE | ID NO. | TYPE | SPECIFICS | ANALYST: CO. NAME | LOCATION | LOCALE or room | ACTIVITY (a-p details removal) | PUMP no. | FLOW (L/min) | TIME (min) | AIR-VOLUME (L) | ASBESTOS level | COMMENTS | SAMPLER | COUNTER |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/20/89 | 21 | per | Proctor | Nafisco Corp | UofI/Dairy Man. | magnet room | ceiling tile rem | 42 | 2 | 90 | 180 | 0.050 | | Weggel | Nafisco |
| 7/25/89 | 22 | area | | Nafisco Corp | UofI/D.K.Hall | basement/rm 23 | air quality | | 2 | 290 | 580 | 0.010 | | Weggel | Nafisco |
| 7/25/89 | 23 | area | | Nafisco Corp | UofI/D.K.Hall | basement/mechanical rm | air quality | | 2 | 300 | 600 | 0.010 | | Weggel | Nafisco |
| 7/25/89 | 24 | area | out | Nafisco Corp | UofI/D.K.Hall | outside air | air quality | | 2 | 300 | 600 | 0.010 | | Weggel | Nafisco |
| 7/26/89 | 25 | area | | Nafisco Corp | UofI/D.K.Hall | basement/s wing (p 4) | air quality | | 2 | 300 | 600 | 0.010 | | Weggel | Nafisco |
| | 26 | | | Nafisco Corp | blank | blank | air quality | | 2 | 455 | 910 | blank | | Weggel | Nafisco |
| 7/30/89 | 27 | area | in house | Nafisco Corp | UofI/housing | box 1801 Carle Drive | air quality | | 2 | 778 | 1556 | -0.010 | time unreliable | Weggel | Nafisco |
| 7/30/89 | 28 | area | in house | Nafisco Corp | UofI/housing | box 1803 Carle Drive | air quality | | 3.5 | 240 | 840 | -0.010 | | Weggel | Nafisco |
| 7/26/89 | 29 | area | | Nafisco Corp | UofI/Kinney gym | linen room | air quality | | 3.5 | 240 | 840 | -0.010 | | Weggel | Nafisco |
| 7/26/89 | 30 | area | | Nafisco Corp | UofI/Kinney gym | outside air/s.side Kinney | air quality | | 2 | 30 | 60 | -0.010 | | Weggel | Nafisco |
| 7/31/89 | 31 | per | Halverson | Nafisco Corp | UofI/Dairy Man. | removal area | rem | | | | 120 | 0.020 | | Weggel/R | Nafisco |
| 7/31/89 | 32 | per | Halverson | Nafisco Corp | UofI/Dairy Man. | removal area | rem | | | | 120 | -0.010 | | Weggel/R | Nafisco |
| 7/31/89 | 33 | per | Donnelly | Nafisco Corp | UofI/Dairy Man. | removal area | rem | | | | 120 | -0.010 | | Weggel/R | Nafisco |
| 7/31/89 | 34 | per | Donnelly | Nafisco Corp | UofI/Dairy Man. | removal area | rem | | | | 120 | -0.010 | | Weggel/R | Nafisco |

## ASBESTOS DATA: UNIVERSITY OF MICHIGAN

| DATE | ID NO. | TYPE | SPECIFICS | ANALYST: CO. NAME | LOCATION | LOCALE or room | ACTIVITY (a-p denote removal) | PUMP no. | FLOW (L/min) | TIME (min) | AIR-VOLUME (L) | ASBESTOS level | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8/16/85 | 8194 | area | ia | CAL | UofM; Lorch Hall | room 327 | pre-removal | hi-vol | | | | 0.030 | |
| 8/16/85 | 8195 | area | ia | CAL | UofM; Lorch Hall | (v.) | pre-removal | hi-vol | | | | -0.010 | |
| 8/19/85 | 8231 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #1 | abatement | CAL-43F | | | | 0.490 | |
| 8/19/85 | 8204 | area | out cont | CAL | UofM; Lorch Hall | background area | none | CAL-42F | | | | 0.040 | |
| 8/19/85 | 8205 | area | out cont | CAL | UofM; Lorch Hall | contiguous area #1 | none | CAL-43F | | | | -0.010 | |
| 8/19/85 | 8206 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #1 | abatement | CAL-41F | | | Overloads = | 99.999 | |
| 8/19/85 | 8207 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-44F | | | | 99.999 | |
| 8/19/85 | 8232 | area | out cont | CAL | UofM; Lorch Hall | background area | none | CAL-41F | | | | 0.026 | |
| 8/19/85 | 8233 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-44F | | | | 0.720 | |
| 8/19/85 | 8234 | area | out cont | CAL | UofM; Lorch Hall | contiguous area #1 | none | CAL-42F | | | | 0.016 | |
| 8/20/85 | 8249 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #1 | abatement | CAL-10A | | | | 2.700 | |
| 8/20/85 | 8250 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #1 | abatement | CAL-10A | | | | 4.000 | replat filt/overload |
| 8/20/85 | 8251 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-8a | | | | 2.400 | |
| 8/20/85 | 8252 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-8a | | | | 4.100 | replat filt/overload |
| 8/20/85 | 8253 | area | out cont | CAL | UofM; Lorch Hall | contiguous area | none | CAL-1A | | | | 0.110 | |
| 8/20/85 | 8254 | area | out cont | CAL | UofM; Lorch Hall | background area | none | CAL-4A | | | | 0.090 | |
| 8/20/85 | 8255 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #1 | abatement | CAL-10A | | | | 2.200 | |
| 8/20/85 | 8256 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-8A | | | | 99.999 | |
| 8/20/85 | 8257 | area | out cont | CAL | UofM; Lorch Hall | contiguous area | none | CAL-8A | | | | 0.050 | |
| 8/20/85 | 8258 | area | out cont | CAL | UofM; Lorch Hall | background area | none | CAL-1A | | | | 0.070 | |
| 8/21/85 | 8270 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #1 | abatement | CAL-8A | | | | 99.999 | |
| 8/21/85 | 8271 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-10A | | | | 99.999 | |
| 8/21/85 | 8272 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #2 | abatement | CAL-10A | | | | 0.540 | replat filt/overload |
| 8/21/85 | 8273 | per | approx. breath zone | CAL | UofM; Lorch Hall | work area #3 | abatement | CAL-11A | | | | 0.760 | |
| 8/21/85 | 8274 | area | out cont | CAL | UofM; Lorch Hall | contiguous area #1 | none | CAL-1A | | | | 0.210 | replat filt/overload |
| 8/21/85 | 8275 | area | out cont | CAL | UofM; Lorch Hall | contiguous area #1 | none | CAL-1A | | | | 0.090 | |
| 8/21/85 | 8276 | area | out cont | CAL | UofM; Lorch Hall | background area | none | CAL-4A | | | | 0.090 | |
| 8/21/85 | 8277 | area | out cont | CAL | UofM; Lorch Hall | background area | none | CAL-8A | | | | 0.070 | replat filt/overload |
| 8/22/85 | 8281 | area | final | CAL | UofM; Lorch Hall | no data | final | hi vol | | | | 0.040 | |
| 8/22/85 | 8282 | area | final | CAL | UofM; Lorch Hall | no data | final | hi vol | | | | 0.010 | fibers/filter: |
| | 21989 | area | pre-rem | Clayton Envir. Consul | UofM; tunnel | no data | pre-removal | no data | | | 180 | 0.072 | 15000 |
| | 21971 | area | pre-rem | Clayton Envir. Consul | UofM; tunnel | no data | pre-removal | no data | | | 240 | 0.046 | 11000 |
| | 21986 | area | pre-rem | Clayton Envir. Consul | UofM; tunnel | no data | pre-removal | no data | | | 240 | 0.096 | 23000 |
| | 21999 | area | final | Clayton Envir. Consul | UofM; tunnel | no data | final | no data | | | 240 | 0.210 | 51000 |
| | 21996 | area | pre-rem | Clayton Envir. Consul | UofM; tunnel | no data | pre-removal | no data | | | 240 | 0.054 | 13000 |
| | 21970 | area | final | Clayton Envir. Consul | UofM; tunnel | no data | final | no data | | | 240 | 0.030 | 8000 |
| | 21977 | area | final | Clayton Envir. Consul | UofM; tunnel | no data | final | no data | | | 240 | 0.020 | 4000 |
| | 21972 | area | final | Clayton Envir. Consul | UofM; tunnel | no data | final | no data | | | 240 | 0.02 | 4000 |
| | 21981 | area | final | Clayton Envir. Consul | UofM; tunnel | no data | final | no data | | | 240 | 0.01 | 3000 |
| | 21982 | area | final | Clayton Envir. Consul | UofM; tunnel | no data | final | no data | | | 240 | 0.01 | 3000 |

## ASBESTOS DATA: N.C. GRADESCHOOLS

| date | sample | type | specifics | analyst | location | inside or room | activity x-y denote removal activity | pump no. | flow (L/min) | time (min) | air-volume (L) | Asbestos level | Comments | Sampler | Counter |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/2/84 | 932 | area | is | Health & Hygiene, Inc. | Guilford Middle | s. cafeteria | pre-removal | 48 | 10.81 | 204 | 2205 | 0.000 | | Dyess | Eure |
| 7/2/84 | 1017 | area | is | Health & Hygiene, Inc. | Guilford Middle | home ec | pre-removal | 57 | 11.57 | 203 | 2349 | 0.002 | | Dyess | Eure |
| 7/2/84 | 906 | area | is | Health & Hygiene, Inc. | Guilford Middle | w. cafeteria | pre-removal | 59 | 11.96 | 202 | 2416 | 0.001 | | Dyess | Eure |
| 8/8/84 | 1656 | personal | Stinson | Health & Hygiene, Inc. | Guilford Middle | cafeteria | p | 1853 | 1.04 | 120 | 125 | 0.042 | | Conover | Cohen |
| 8/8/84 | 1657 | personal | Scales | Health & Hygiene, Inc. | Guilford Middle | cafeteria | s | 1850 | 1.09 | 120 | 151 | 0.044 | | Conover | Cohen |
| 8/8/84 | 1658 | area | in scaf | Health & Hygiene, Inc. | Guilford Middle | scaffold/caf | s | 1855 | 1.04 | 120 | 125 | 0.032 | | Conover | Cohen |
| 8/8/84 | 1663 | personal | Beach | Health & Hygiene, Inc. | Guilford Middle | cafeteria | s,b | 1853 | 1.04 | 120 | 125 | 0.050 | | Conover | Cohen |
| 8/8/84 | 1662 | personal | Hicks | Health & Hygiene, Inc. | Guilford Middle | cafeteria | s,b | 1850 | 1.09 | 120 | 151 | 0.115 | | Conover | Cohen |
| 8/8/84 | 1664 | area | out scaf | Health & Hygiene, Inc. | Guilford Middle | kitchen | s | 1855 | 1.04 | 120 | 125 | 0.008 | | Conover | Cohen |
| 8/9/84 | 1666 | personal | Beach | Health & Hygiene, Inc. | Guilford Middle | cafeteria | b,c | 1853 | 1.04 | 120 | 125 | 0.519 | | Conover | Cohen |
| 8/9/84 | 1667 | personal | Hicks | Health & Hygiene, Inc. | Guilford Middle | cafeteria | b | 1850 | 1.09 | 120 | 131 | 0.115 | | Conover | Cohen |
| 8/9/84 | 1665 | area | is | Health & Hygiene, Inc. | Guilford Middle | scaffold/caf | s | 1855 | 1.04 | invalid | invalid | invalid | | Conover | Cohen |
| 8/13/84 | 1668 | area | out | Health & Hygiene, Inc. | Guilford Middle | kitchen | s | 3780 | 1.03 | 162 | 167 | 0.001 | | Conover | Eure |
| 8/13/84 | 1669 | area | is | Health & Hygiene, Inc. | Guilford Middle | scaffold/caf | s | 1855 | 0.80 | 120 | 96 | 0.432 | | Conover | Eure |
| 8/13/84 | 1670 | personal | Smith | Health & Hygiene, Inc. | Guilford Middle | cafeteria | b | 1853 | 1.04 | 120 | 125 | 4.643 | | Conover | Eure |
| 8/17/84 | 1682 | area | final | Health & Hygiene, Inc. | Guilford Middle | home ec | none | 41 | 10.76 | 181 | 1948 | 0.000 | | Conover | Cohen |
| 8/17/84 | 1680 | area | final | Health & Hygiene, Inc. | Guilford Middle | cafeteria | none | 57 | 11.57 | 230 | 2661 | 0.001 | | Conover | Cohen |
| 8/17/84 | 1679 | area | final | Health & Hygiene, Inc. | Guilford Middle | kitchen | none | 48 | 10.81 | 222 | 2400 | 0.000 | | Conover | Cohen |
| 8/17/84 | 1688 | area | final | Health & Hygiene, Inc. | Guilford Middle | room near home ec | none | 55 | 11.00 | 219 | 2409 | 0.000 | | Conover | Cohen |
| 6/18/84 | 1211 | per | Pemberton | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | shop building | rem | 1853 | 0.95 | 120 | 114 | 0.810 | Corrugated ceiling | Conover | Dyson |
| 6/18/84 | 1216 | per | Young | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | shop building | bag | 1854 | 1.08 | 120 | 130 | 0.740 | | Conover | Dyson |
| 6/18/84 | 1221 | area | out | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | out scaf/shop building | none | 41 | 6.65 | 250 | 1663 | 0.002 | <10 fibers | Conover | Dyson |
| 6/19/84 | 1252 | per | McDonald | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | bag | 1849 | 0.98 | 104.5 | 102 | 0.690 | | Conover | Dyson |
| 6/19/84 | 1237 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | none | 1855 | 1.00 | 106.5 | 106 | 0.490 | | Conover | Dyson |
| 6/19/84 | 1236 | per | Locklear | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | rem | 1850 | 1.05 | 102.9 | 106 | 0.440 | | Conover | Dyson |
| 6/19/84 | 1253 | area | out | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | outside shop building | none | 41 | 6.65 | 271 | 1802 | 0.001 | <10 fibers | Conover | Dyson |
| 6/19/84 | 1222 | per | Hicks | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | rem | 1853 | 1.02 | 120 | 122 | 0.580 | | Conover | Dyson |
| 6/19/84 | 1206 | per | Locklear | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | rem | 1850 | 1.03 | 45.1 | 46 | 0.720 | | Conover | Dyson |
| 6/19/84 | 1226 | per | Scales | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | shop building | rem,bag | 1849 | 0.98 | 123 | 121 | 0.450 | * | Conover | Dyson |
| 6/29/84 | 1002 | per | Bosse | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | rem,c | 1850 | 1.09 | 120 | 131 | 0.059 | (pres.spray washer | Conover | Eure |
| 6/29/84 | 1166 | per | Lovette | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | main building | rem,c | 1855 | 1.05 | 120 | 126 | 0.045 | used/work stopped | Conover | Eure |
| 6/29/84 | 941 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | scaf/auditorium | none | 1853 | 1.04 | 115 | 120 | 0.092 | after 1 hr.) | Conover | Eure |
| 7/2/84 | 1219 | per | Locklear | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | auditorium | rem,gf | 1853 | 1.04 | 120 | 125 | 0.777 | | Conover | Eure |
| 7/2/84 | 1214 | per | Hicks | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | auditorium | rem,gf | 1850 | 1.09 | 120 | 131 | 1.123 | | Conover | Eure |
| 7/2/84 | 1209 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | scaf/auditorium | none | 1855 | 1.05 | 120 | 126 | 1.180 | | Conover | Eure |
| 7/2/84 | 937 | per | Jackson | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | hallway | rem,f | 1849 | 1.05 | 120 | 124 | 1.760 | | Conover | Eure |
| 7/10/84 | 1014 | per | Terry | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | lecture room | s,b | 3776 | 1.03 | 67 | 69 | 1.183 | | Dyess | Eure |
| 7/10/84 | 1079 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | scaf/auditorium | none | 3778 | 0.99 | 61 | 60 | 0.246 | | Dyess | Eure |
| 7/10/84 | 1231 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | scaf/auditorium | none | 3777 | 0.97 | 65 | 63 | 0.468 | | Dyess | Eure |
| 7/13/84 | 1255 | per | Pittle | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | no data | c,f | 3779 | 0.96 | 68 | 65 | 0.087 | | Dyess | Eure |
| 7/25/84 | 1611 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | room 11 | none | 54 | 11.96 | 180 | 2153 | 0.001 | | Conover | Eure |
| 7/25/84 | 1610 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | hallway/by room 9 | none | 57 | 11.53 | 176 | 2029 | 0.001 | | Conover | Eure |
| 7/25/84 | 1612 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | room 1 | none | 48 | 10.18 | 190 | 1934 | 0.001 | | Conover | Eure |
| 7/25/84 | 1609 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | room 6 | none | 57 | 11.57 | 175 | 2025 | 0.000 | | Conover | Eure |
| 7/31/84 | 1633 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | shop building | final | 57 | 11.57 | 178 | 2059 | 0.000 | | Conover | Eure |
| 7/31/84 | 1625 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | auditorium | final | 48 | 10.81 | 186 | 2011 | 0.000 | | Conover | Eure |
| 7/31/84 | 1632 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | office | final | 54 | 11.96 | 175 | 2093 | 0.001 | | Conover | Eure |
| 7/31/84 | 1624 | area | is | Health & Hygiene, Inc. | Ellerbe Jr.H.S. | room 15 | final | 57 | 11.53 | 177 | 2041 | 0.000 | | Conover | Eure |
| 6/20/84 | 1263 | area | is | Health & Hygiene, Inc. | Northwest H.S. | media center | pre-removal | 53 | 6.74 | 351 | 2366 | 0.002 | * | Dyess | no data |
| 6/20/84 | 1259 | area | out | Health & Hygiene, Inc. | Northwest H.S. | courtyard | pre-removal | 41 | 6.82 | 350 | 2387 | 0.001 | * | Dyess | no data |
| 6/20/84 | 1275 | area | is | Health & Hygiene, Inc. | Northwest H.S. | home ec | pre-removal | 69 | 6.82 | 351 | 2394 | 0.001 | * | Dyess | no data |
| 6/20/84 | 1265 | area | out | Health & Hygiene, Inc. | Northwest H.S. | back walkway | pre-removal | 55 | 7.04 | 346 | 2456 | 0.000 | | Dyess | no data |
| 6/20/84 | 1277 | area | is | Health & Hygiene, Inc. | Northwest H.S. | gymnasium | pre-removal | 48 | 7.12 | 345 | 2456 | 0.001 | * | Dyess | no data |
| 7/7/84 | 1180 | area | is | Health & Hygiene, Inc. | Northwest H.S. | scaf/removal area/rm 7 | no data | 3778 | 0.99 | 47 | 47 | 1.540 | | Dyess | Dyson |
| 7/7/84 | c18 | per | Sturdivant | Health & Hygiene, Inc. | Northwest H.S. | no data | no data | 3779 | 0.96 | 46 | 44 | 1.580 | | Dyess | Dyson |
| 7/7/84 | 1006 | per | Brown | Health & Hygiene, Inc. | Northwest H.S. | no data | no data | 3776 | 1.03 | 42 | 43 | 1.600 | | Dyess | Dyson |
| 7/7/84 | 975 | area | is | Health & Hygiene, Inc. | Northwest H.S. | scaf/removal area 7 | no data | 3776 | 1.03 | 96 | 99 | 0.230 | min. time recorded | Dyess | Dyson |
| 7/7/84 | 983 | per | Faison | Health & Hygiene, Inc. | Northwest H.S. | no data | no data | 3779 | 0.96 | 146 | 140 | 0.560 | | Dyess | Dyson |
| 7/7/84 | 1267 | per | Sturdivant | Health & Hygiene, Inc. | Northwest H.S. | no data | no data | 3778 | 0.99 | 92 | 91 | 0.400 | min. time recorded | Dyess | Dyson |
| 7/9/84 | 1070 | per | Bayless | Health & Hygiene, Inc. | Northwest H.S. | cafeteria | rem | 3776 | 1.03 | 68 | 70 | 2.290 | | Dyess | no data |
| 7/9/84 | 1276 | area | is | Health & Hygiene, Inc. | Northwest H.S. | cafeteria/window unit | none | 3778 | 0.99 | 77 | 76 | 2.550 | | Dyess | no data |
| 7/9/84 | 1262 | area | is | Health & Hygiene, Inc. | Northwest H.S. | scaf/cafeteria | none | 3777 | 0.97 | 71 | 69 | 3.010 | | Dyess | no data |
| 7/13/84 | 1109 | area | is | Health & Hygiene, Inc. | Northwest H.S. | office | none | 3776 | 0.99 | 65 | 64 | 0.225 | (cleaning in cafe- | Dyess | Eure |

| date | sample | type | specifics | analyst | location | locale or room | activity x-y denote removal activity | pump no. | flow (L/min) | time (min) | air-volume (L) | Asbestos level | Comments | Sampler | Counter |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7/13/84 | 1076 | per | Mills | Health & Hygiene, Inc. | Northwest H.S. | lobby | x,rem | 3776 | 1.05 | 61 | 40 | 0.337 | tarts, dry to wall) | Dypas | Euro |
| 7/13/84 | 1277 | per | Stallings | Health & Hygiene, Inc. | Northwest H.S. | lobby | x,rem | 3777 | 0.97 | 61 | 63 | 0.253 | s) | Dypas | Euro |
| 7/20/84 | 1601 | per | Mattrom | Health & Hygiene, Inc. | Northwest H.S. | hallway | b,c | 1855 | 1.02 | 80.1 | 78 | 0.020 | | Conover | Euro |
| 7/21/88 | 1602 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | hallway | none | 1860 | 1.05 | 78.6 | 83 | 0.025 | | Conover | Euro |
| 7/24/84 | 1508 | per | Wheelock | Health & Hygiene, Inc. | Northwest H.S. | room 103 | c(2nd) | 3778 | 0.99 | 114 | 113 | 0.040 | | Dypas | Euro |
| 7/24/84 | 1507 | per | Mills | Health & Hygiene, Inc. | Northwest H.S. | library | rem,g | 3777 | 0.97 | 116 | 113 | 0.024 | | Dypas | Euro |
| 7/24/84 | 1509 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | asst/library | none | 3779 | 0.96 | 115 | 110 | 0.029 | | Dypas | Euro |
| 7/28/84 | 1519 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | storage room | post rem/clean air | 57 | 11.57 | 218 | 2522 | 0.001 | | Dypas | Euro |
| 7/28/84 | 1520 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | cafeteria | post rem/clean air | 54 | 11.96 | 218 | 2607 | 0.000 | | Dypas | Euro |
| 7/28/84 | 1521 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | hallway | post rem/clean air | 57 | 11.55 | 216 | 2490 | 0.000 | | Dypas | Euro |
| 7/28/84 | 1522 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | office | post rem/clean air | 41 | 10.75 | 216 | 2324 | 0.000 | | Dypas | Euro |
| 8/3/84 | 1546 | per | McCallum | Health & Hygiene, Inc. | Northwest H.S. | no data | rem,g | 1854 | 1.04 | 120 | 125 | 0.030 | | Robert | Euro |
| 8/3/84 | 1544 | per | McCallum | Health & Hygiene, Inc. | Northwest H.S. | no data | rem,g | 1851 | 1.03 | 120 | 124 | 0.029 | | Robert | Euro |
| 8/3/84 | 1538 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | close room doorway | none | 79 | 11.35 | 96 | 1088 | 0.003 | | Robert | Euro |
| 8/3/84 | 1540 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway and/at restrooms | none | 55 | 11 | 120 | 1320 | 0.000 | | Robert | Euro |
| 8/3/84 | 1539 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway | none | 69 | 11.87 | 120 | 1424 | 0.001 | | Robert | Euro |
| 8/3/84 | 1550 | per | McCallum | Health & Hygiene, Inc. | Northwest H.S. | no data | x | 1854 | 1.04 | 130 | 135 | 0.024 | | Robert | Euro |
| 8/3/84 | 1541 | area | out | Health & Hygiene, Inc. | Northwest H.S. | of door to classroom | none | 79 | 11.35 | 120 | 1360 | 0.001 | | Robert | Euro |
| 8/8/84 | 1659 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | guidance room | final | 67 | 11.53 | 202 | 2329 | 0.001 | | Conover | Colton |
| 8/8/84 | 1660 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | room 102 | final | 57 | 11.57 | 197 | 2279 | 0.001 | | Conover | Colton |
| 8/8/84 | 1661 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | library | final | 48 | 10.81 | 196 | 2119 | 0.005 | | Conover | Colton |
| 8/13/84 | 1671 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway/by room 104 | none | 57 | 11.57 | 172 | 1990 | 0.000 | | Conover | Colton |
| 8/13/84 | 1672 | per | Quick | Health & Hygiene, Inc. | Northwest H.S. | no data | b,c | 1853 | 1.04 | 120 | 125 | 0.010 | | Conover | Colton |
| 8/13/84 | 1673 | per | Moloff | Health & Hygiene, Inc. | Northwest H.S. | no data | b | 1850 | 1.09 | 120 | 131 | 0.020 | | Conover | Colton |
| 8/13/84 | 1674 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | scaffold | none | 1855 | 1.04 | 120 | 125 | 0.026 | | Conover | Colton |
| 8/15/84 | 1564 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | outside room 111 | none | 54 | 11.96 | 214 | 2559 | 0.000 | | Dypas | Euro |
| 8/15/84 | 1607 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | room 106 | none | 47 | 11.86 | 214 | 2538 | 0.001 | | Dypas | Euro |
| 8/15/84 | 2046 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | hallway | none | 69 | 1.87 | 211 | 395 | 0.001 | | Dypas | Euro |
| 8/16/84 | 2024 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | room 109 | none | 57 | 11.55 | 209 | 2410 | 0.000 | | Dypas | Euro |
| 8/20/84 | 1689 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | room 116 | none | 69 | 11.87 | 203 | 2410 | 0.001 | | Conover | Dypas |
| 8/20/84 | 1650 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | teachers lounge | none | 54 | 11.96 | 202 | 2416 | 0.008 | | Conover | Dypas |
| 8/20/84 | 1693 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | room 115 | none | 57 | 11.55 | 201 | 2318 | invalid | unable to count | Conover | Dypas |
| 8/20/84 | 1692 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | hallway/betw. 113-114 | none | 55 | 11.00 | 198 | 2178 | 0.002 | | Conover | Dypas |
| 8/29/84 | 1608 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | hallway/back foyer | none | 54 | 11.96 | 220 | 2631 | 0.000 | mix altered;<10 fibers | Dypas | no data |
| 8/29/84 | 2049 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | under storage room/by 17 | none | 57 | 11.53 | 219 | 2525 | 0.000 | mix altered;<10 fibers | Dypas | no data |
| 8/29/84 | 1619 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | room 111 | none | 53 | 10.92 | 218 | 2381 | 0.000 | mix altered;<10 fibers | Dypas | no data |
| 8/29/84 | 1609 | area | ? | Health & Hygiene, Inc. | Northwest H.S. | room 113 | none | 69 | 11.87 | 217 | 2576 | 0.000 | mix altered;<10 fibers | Dypas | no data |
| 9/4/84 | 2058 | area | out | Health & Hygiene, Inc. | Northwest H.S. | barrier/auditorium foyer | none | 57 | 11.55 | 180 | 2075 | 0.000 | stab. & staff present | Dypas | Colton |
| 9/5/88 | 1608 | area | out | Health & Hygiene, Inc. | Northwest H.S. | barrier/t.lounge foyer | none | 54 | 11.96 | 180 | 2153 | 0.000 | stab. & staff present | Dypas | Colton |
| 9/6/84 | 1736 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway/near offices | none | 47 | 11.86 | 247 | 2929 | 0.000 | | Conover | Colton |
| 9/6/84 | 1737 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway/by attend. office | none | 54 | invalid | invalid | invalid | invalid | | Conover | Colton |
| 9/6/84 | 1738 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | asst/auditorium | rem,f(in auditorium) | 1853 | 1.03 | 120 | 124 | 0.040 | | Conover | Colton |
| 9/6/84 | 1739 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | asst/auditorium | rem,f(in auditorium) | 1860 | 1.08 | 120 | 130 | 0.020 | | Conover | Colton |
| 9/6/84 | 1740 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway/by attend. office | none | 54 | 11.96 | 176 | 2105 | 0.002 | | Conover | Colton |
| 9/9/84 | 1741 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | hall betw. gym and aud | final | 54 | 11.96 | 196 | 2344 | 0.000 | | Conover | Colton |
| 9/9/84 | 1744 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | behind stage | final | 47 | 11.86 | 195 | 2313 | 0.000 | | Conover | Colton |
| 9/9/84 | 1742 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | center auditorium | final | 37 | 11.57 | 195 | 2256 | 0.000 | | Conover | Colton |
| 9/9/84 | 1743 | area | out | Health & Hygiene, Inc. | Northwest H.S. | gymnasium | final | 55 | 11.00 | 184 | 2024 | 0.001 | | Conover | Colton |
| 9/12/88 | 1745 | area | out | Health & Hygiene, Inc. | Northwest H.S. | barrier/attend. office | none | 55 | 11.00 | no data | #VALUE! | 0.001 | altered info | Conover | Colton |
| 9/11/84 | 1746 | area | out | Health & Hygiene, Inc. | Northwest H.S. | barrier/main office | none | 47 | 11.86 | no data | #VALUE! | 0.001 | altered info | Conover | Colton |
| 9/14/84 | 1747 | area | out | Health & Hygiene, Inc. | Northwest H.S. | hallway by gym doors | none | 54 | 11.96 | no data | #VALUE! | 0.000 | altered info | Conover | Colton |
| 9/14/84 | 1753 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | music room | post rem/clean air | 55 | 11.00 | 192 | 2112 | 0.000 | | Dypas | Colton |
| 9/14/84 | 1752 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | room 20 | post rem/clean air | 69 | 11.87 | 190 | 2255 | 0.000 | | Dypas | Colton |
| 9/14/84 | 1748 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | arts & crafts room | post rem/clean air | 79 | 11.33 | 191 | 2164 | 0.001 | | Dypas | Colton |
| 7/2/84 | 921 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | Shop building/room 204 | pre-removal | 47 | 11.86 | 199 | 2360 | 0.001 | | Dypas | Euro |
| 7/2/84 | 715 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | Shop building/office | pre-removal | 67 | 11.53 | 197 | 2271 | 0.000 | | Dypas | Euro |
| 9/17/84 | 1757 | per | Lozier | Health & Hygiene, Inc. | Northwest H.S. | shop building | x,e | 1855 | 1.04 | 120 | 125 | 0.050 | | Conover | Colton |
| 9/17/84 | 1758 | per | Alston | Health & Hygiene, Inc. | Northwest H.S. | shop building | x,e | 1850 | 1.54 | 120 | 185 | 0.035 | | Conover | Colton |
| 9/17/84 | 1759 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | asst/shop building | none | 1850 | 1.03 | 120 | 124 | 0.060 | | Conover | Colton |
| 9/17/84 | 1760 | area | out | Health & Hygiene, Inc. | Northwest H.S. | shop building | none | 54 | 11.96 | 70 | 837 | 0.005 | | Conover | Colton |
| 9/20/84 | 1761 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | vocation building/rm. 1761 | post rem/clean air | 57 | 11.53 | 190 | 2181 | 0.001 | | Dypas | Colton |
| 9/21/88 | 1762 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | vocation building/rm. 1762 | post rem/clean air | 41 | 10.75 | 188 | 2025 | 0.001 | | Dypas | Colton |
| 9/21/84 | 1765 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | asst/boiler rm/voc. build. | none | 1850 | 1.08 | 56 | 60 | 0.148 | water in sampling pump | Conover | Colton |
| 9/22/88 | 1766 | per | Miller | Health & Hygiene, Inc. | Northwest H.S. | boiler rm/vocation build. | rem,g | 1853 | 1.03 | 75 | 77 | 0.104 | | Conover | Colton |
| 9/25/88 | 1767 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | boiler rm/main building | none | 53 | 10.92 | 186 | 2031 | 0.000 | | Conover | Colton |
| 9/25/88 | 1768 | area | ls | Health & Hygiene, Inc. | Northwest H.S. | boiler rm/voc. building | none | 57 | 11.53 | 181 | 2087 | 0.000 | | Conover | Colton |

# APPENDIX C

# DISCUSSION OF FIBER COUNTING METHODS

## DISCUSSION OF FIBER COUNTING METHODS

Electron microscopy and the membrane filter/phase contrast methods are two recognized means of evaluating asbestos in environmental samples. The electron microscope methods ( e.g. Asbestos International Association RTM2, 1984 ) utilize an electron beam to scan the loaded asbestos filter samples for fibers. The electron microscope methods are the most accurate commonly acceptable method of identifying and counting asbestos fibers. The methods are expensive and, therefore, not generally used. The membrane filter/phase contrast microscope methods (e.g. NIOSH Methods P&CAM 239, 1977 and Method 7400, 1984) can be used to comply with OSHA's air monitoring regulations. Unfortunately, the phase contrast methods are inaccurate for both fiber counting and fiber identification.

### 1. FIBER COUNTING AND DETECTION LIMITS

NIOSH filter/phase contrast microscope methods have variable lower limits of fiber detection and uncertain blank fiber counts. Variations in sampling techniques and analysis equipment result different lower limits of fiber detection. The theoretical limit is derived by the following limit-of- detection equation:

**TABLE $A_c$**

$$\text{LIMIT-OF-DETECTION} = \frac{\text{Area of filter (mm}^2\text{) x \# of counted fibers}}{\text{a* x air flow rate (L/min) x \# of fields x time}}$$

$$= \text{Airborne fibers/liter of air}$$

* "a" is the area of the counting field of the microscope ($mm^2$).
Listed here are typical values for a:

| Microscope | field area ($mm^2$) |
|---|---|
| B & L | 0.006084 |
| Nikon | 0.004225 |
| Leitz | 0.007225 |
| Olympus | 0.006724 |
| Zeiss | 0.006806 |

Based on one half of a fiber count, the theoretical limit-of-detection can be 0.0005 fibers/cc in a 2000 liter air sample. The lowest limit-of-detection in this study is 0.001 fibers/cc used by Quality Analytical Inc.. Although data from Health and Industrial Hygiene Laboratory show detection levels as low as .001 f/cc, representatives of the company believe that fiber counts less than 10 f/100 fields are invalid and use a more conservative upper limit of 0.002 f/cc. Nalsco, CAL, and Clayton Environmental reported it lowest ranges as 0.0 to 0.01 f/cc. Randolph and Associates reported various limits of detection varying from .01 to .09 f/cc. In addition to determining a valid and consistent lower limit-of-detection for this investigation, studies indicate that the method has an inherent problem of non-zero and variable fiber counts for blank filters (Altree-Williams, 1985).

## 2. FIBER IDENTIFICATION

In 1985, two Australian researchers characterized the fibers collected on air samples (Altree-Williams, 1985). They filtered the air on a Nucleopore filter via traditional sampling means and examined the results using a Filter/Scanning Electron Microscope method (NPF/SEM). The conditions of the experiment were chosen to match the collection efficiency, fiber detectability and convenience of the membrane filter/optical (phase contrast) microscope method. Table $B_c$ illustrates the discrepancy between the number of asbestos fibers and the combined number of asbestos, (non-asbestos) mineral, and organic fibers. The phase contrast method interprets the combined count as the asbestos count.

# TABLE $B_c$

## MONITORING RESULTS OF AIRBORNE FIBER CONCENTRATIONS IN 22 BUILDINGS

STUDY PROFILE: 193 sample taken in 9 offices and 3 plant buildings;
ASBESTOS TYPES IN BUILDINGS: Chrysotile = 9,
Amosite = 9,
Crocidolite = 2,
Asbestos removed = 3,
none = 2;

### ASBESTOS CONCENTRATIONS

| No. of Samples | fibers/liter | fibers/cc |
|---|---|---|
| 1 | 22 | .022 |
| 3 | 3 | .003 |
| 5 | 2 | .002 |
| 22 | 1 | .001 |
| 162 | 0 | .000 |

### ORGANIC FIBER CONCENTRATIONS

| No. of Samples | fibers/liter | fibers/cc |
|---|---|---|
| 1 | 63 | .063 |
| 1 | 59 | .059 |
| 1 | 25 | .025 |
| 13 | 10-20 | .010-.020 |
| 58 | 5-9 | .005-.009 |
| 119 | 0-4 | .000-.004 |

### MINERAL (NON-ASBESTOS) FIBER CONCENTRATIONS

| No. of Samples | fibers/liter | fibers/cc |
|---|---|---|
| 3 | 10-13 | .010-.013 |
| 10 | 59 | .050-.090 |
| 36 | 25 | .020-.040 |
| 144 | 10-20 | .000-.001 |

# APPENDIX D

# CATEGORIZATION OF AIRBORNE ASBESTOS CONCENTRATIONS

# CATEGORIZATION OF AIRBORNE ASBESTOS CONCENTRATIONS

| AIR QUALITY | PREREMOVAL | REMOVAL | REMOVAL | FINAL | REMOVAL TECHNIQUES | | | SAMPLING TECHNIQUES | |
|---|---|---|---|---|---|---|---|---|---|
| | | outside containment | inside containment | | WET | DRY | CEILING TILE | PERSONAL | AREA |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | 0-.09 | 0-.01 | 0-0.001 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | 0.53 | 0.02 | 0.003 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | 0.67 | 0.03 | 0.009 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | 0.74 | 0.03 | 0-0.01 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | overload=10 | 0.04 | 0-0.01 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | | 0.04 | 0-0.01 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | | 0.05 | 0.01 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | | 0.06 | 0.017 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | | 0.06 | 0.02 | 0.001 |
| 0-.001 | 0.001 | 0.001 | 0.001 | 0-0.001 | 0.001 | | 0.07 | 0.02 | 0.001 |
| 0-.001 | 0.001 | 0.002 | 0.001 | 0-0.001 | 0.001 | | | 0.02 | 0.001 |
| 0-.001 | 0.001 | 0.002 | 0.001 | 0-0.001 | 0.001 | | | 0.02 | 0.001 |
| 0-.001 | 0.002 | 0.003 | 0.001 | 0-0.001 | 0.001 | | | 0.024 | 0.001 |
| 0-.001 | 0.002 | 0.008 | 0.001 | 0-0.001 | 0.001 | | | 0.024 | 0.001 |
| 0-.001 | 0.01 | 0.01 | 0.001 | 0-0.001 | 0.001 | | | 0.029 | 0.002 |
| 0-.001 | 0.01 | 0.016 | 0.002 | 0-0.001 | 0.002 | | | 0.03 | 0.003 |
| 0.002 | 0.01 | 0.026 | 0.005 | 0-0.001 | 0.005 | | | 0.03 | 0.003 |
| 0.005 | 0.01 | 0.04 | 0.003 | 0-0.001 | 0.003 | | | 0.03 | 0.003 |
| 0.01 | 0.01 | 0.05 | 0.003 | 0-0.001 | 0.003 | | | 0.036 | 0.003 |
| 0-.01 | 0.01 | 0.07 | 0.005 | 0.005 | 0.003 | | | 0.04 | 0.006 |
| 0-.01 | 0.01 | 0.07 | 0.003 | 0-.009 | 0.003 | | | 0.04 | 0.008 |
| 0-.01 | 0.01 | 0.09 | 0.005 | 0-.009 | 0.005 | | | 0.04 | 0.01 |
| 0-.01 | 0.05 | 0.09 | 0.008 | 0-0.01 | 0.008 | | | 0.042 | 0.01 |
| 0-.01 | 0.046 | 0.09 | 0.009 | 0-0.01 | 0.009 | | | 0.044 | 0.011 |
| 0-.01 | 0.064 | 0.11 | 0.01 | 0-0.01 | 0.01 | | | 0.046 | 0.015 |
| 0-.01 | 0.072 | 0.21 | 0.01 | 0-0.01 | 0.01 | | | 0.05 | 0.02 |
| 0-.01 | 0.096 | 0.36 | 0.01 | 0-0.01 | 0.01 | | | 0.05 | 0.025 |
| blank: | detection limit too high: | detection limit too high: | 0.01 | 0-0.01 | 0.01 | | | 0.05 | 0.025 |
| | 0-.09 | 0-0.05 | 0.01 | 0.01 | 0.01 | | | 0.059 | 0.026 |
| | 0-.09 | 0-0.05 | 0.01 | 0.01 | 0.011 | | | 0.06 | 0.029 |
| | 0-.09 | 0-0.05 | 0.011 | 0.01 | 0.015 | | | 0.06 | 0.032 |
| | 0-.09 | 0-0.05 | 0.015 | 0.02 | 0.017 | | | 0.087 | 0.04 |
| | 0-.09 | 0-.09 | 0.017 | 0.02 | 0.02 | | | 0.104 | 0.06 |
| | | 0-.09 | 0.02 | 0.03 | 0.02 | | | 0.115 | 0.07 |
| | | 0-.09 | 0.02 | 0.04 | 0.02 | | | 0.115 | 0.092 |
| | | 0-.09 | 0.02 | 0.21 | 0.02 | | | 0.233 | 0.148 |
| | | | 0.02 | | 0.024 | | | 0.31 | 0.16 |
| | | | 0.02 | | 0.024 | | | 0.319 | 0.16 |
| | | | 0.024 | | 0.025 | | | 0.337 | 0.225 |
| | | | 0.024 | | 0.025 | | | 0.38 | 0.23 |
| | | | 0.025 | | 0.026 | | | 0.4 | 0.246 |
| | | | 0.025 | | 0.029 | | | 0.44 | 0.26 |
| | | | 0.026 | | 0.029 | | | 0.45 | 0.34 |
| | | | 0.029 | | 0.03 | | | 0.49 | 0.432 |
| | | | 0.029 | | 0.032 | | | 0.54 | 0.488 |
| | | | 0.03 | | 0.035 | | | 0.56 | 0.49 |
| | | | 0.03 | | 0.04 | | | 0.69 | 0.53 |
| | | | 0.03 | | 0.04 | | | 0.72 | 0.67 |
| | | | 0.032 | | 0.042 | | | 0.72 | 1.18 |
| | | | 0.035 | | 0.044 | | | 0.74 | 1.34 |
| | | | 0.04 | | 0.046 | | | 0.74 | 2.55 |
| | | | 0.04 | | 0.05 | | | 0.76 | 3.01 |
| | | | 0.04 | | 0.05 | | | 0.777 | invalid |
| | | | 0.04 | | 0.059 | | | 0.81 | invalid |
| | | | 0.042 | | 0.06 | | | 1.125 | invalid |
| | | | 0.044 | | 0.087 | | | 1.183 | detection limit too high: |
| | | | 0.046 | | 0.092 | | | 1.58 | 0-0.09 |
| | | | 0.05 | | 0.104 | | | 1.6 | |
| | | | 0.05 | | 0.115 | | | 1.76 | |
| | | | 0.05 | | 0.115 | | | 2.2 | |
| | | | 0.059 | | 0.148 | | | 2.29 | |
| | | | 0.06 | | 0.16 | | | 2.4 | |
| | | | 0.06 | | 0.16 | | | 2.7 | |
| | | | 0.06 | | 0.225 | | | 4 | |
| | | | 0.07 | | 0.23 | | | 4.1 | |
| | | | 0.087 | | 0.233 | | | 4.643 | |
| | | | 0.092 | | 0.246 | | | overload=10 | |
| | | | 0.104 | | 0.26 | | | overload=10 | |
| | | | 0.115 | | 0.31 | | | overload=10 | |
| | | | 0.115 | | 0.319 | | | overload=10 | |
| | | | 0.148 | | 0.337 | | | overload=10 | |
| | | | 0.16 | | 0.34 | | | overload=10 | |
| | | | 0.16 | | 0.38 | | | | |
| | | | 0.225 | | 0.4 | | | | |
| | | | 0.23 | | 0.432 | | | | |
| | | | 0.233 | | 0.44 | | | | |
| | | | 0.246 | | 0.45 | | | | |
| | | | 0.26 | | 0.488 | | | | |
| | | | 0.31 | | 0.49 | | | | |
| | | | 0.319 | | 0.49 | | | | |
| | | | 0.337 | | 0.54 | | | | |
| | | | 0.34 | | 0.56 | | | | |
| | | | 0.38 | | 0.69 | | | | |
| | | | 0.4 | | 0.72 | | | | |
| | | | 0.432 | | 0.72 | | | | |

| AIR QUALITY | PREREMOVAL | REMOVAL outside containment | REMOVAL inside containment | FINAL | REMOVAL TECHNIQUES WET | DRY | CEILING TILE | SAMPLING TECHNIQUES PERSONAL |
|---|---|---|---|---|---|---|---|---|
| | | | 0.44 | | 0.74 | | | |
| | | | 0.45 | | 0.76 | | | |
| | | | 0.486 | | 0.777 | | | |
| | | | 0.49 | | 0.81 | | | |
| | | | 0.49 | | 1.123 | | | |
| | | | 0.53 | | 1.18 | | | |
| | | | 0.54 | | 1.183 | | | |
| | | | 0.56 | | 1.54 | | | |
| | | | 0.67 | | 1.58 | | | |
| | | | 0.69 | | 1.6 | | | |
| | | | 0.72 | | 1.76 | | | |
| | | | 0.72 | | 2.2 | | | |
| | | | 0.74 | | 2.29 | | | |
| | | | 0.74 | | 2.4 | | | |
| | | | 0.76 | | 2.55 | | | |
| | | | 0.777 | | 2.7 | | | |
| | | | 0.81 | | 3.01 | | | |
| | | | 1.123 | | 4 | | | |
| | | | 1.18 | | 4.1 | | | |
| | | | 1.183 | | 4.643 | | | |
| | | | 1.54 | | overload-10 | | | |
| | | | 1.58 | | overload-10 | | | |
| | | | 1.6 | | overload-10 | | | |
| | | | 1.76 | | overload-10 | | | |
| | | | 2.2 | | overload-10 | | | |
| | | | 2.29 | | invalid | | | |
| | | | 2.4 | | invalid | | | |
| | | | 2.55 | | invalid | | | |
| | | | 2.7 | | | | | |
| | | | 3.01 | | | | | |
| | | | 4 | | | | | |
| | | | 4.1 | | | | | |
| | | | 4.643 | | | | | |
| | | | overload-10 | | | | | |
| | | | overload-10 | | | | | |
| | | | overload-10 | | | | | |
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| | | | overload-10 | | | | | |
| | | | overload-10 | | | | | |
| | | | invalid | | | | | |
| | | | invalid | | | | | |
| | | | invalid | | | | | |
| | | | detection limit too high: | | | | | |
| | | | 0-.09 | | | | | |