HEALTH HAZARD EVALUATION REPORT

HETA 92-0074-2452
HOUGHTALING ELEMENTARY SCHOOL
KETCHIKAN, ALASKA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the work place. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer and authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 92-0074-2452
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HOUGHTALING ELEMENTARY SCHOOL
KETCHIKAN, ALASKA

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I. SUMMARY

On April 7 to 9, 1992, the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the Houghtaling Elementary School in Ketchikan, Alaska. This HHE was conducted in response to a request received on December 3, 1991, from the principal of the school. The request concerned a pattern of illness (over three years) among teachers and students that included pneumonia, respiratory problems, and allergic reactions. This report presents the results of the environmental and medical assessment. The environmental portion of the investigation included a ventilation system inspection, air sampling for bioaerosols, and direct measurement of temperature, humidity, and carbon dioxide (CO_2).

Medical evaluations of workers at the Houghtaling Elementary School were based on the findings from: (1) a brief questionnaire (Appendix) administered to teachers during the industrial hygiene evaluation on November 3 to 7, 1992; (2) telephone interviews with several affected workers; and (3) a review of medical records available from the two workers who signed medical record releases. The primary concern related to possible hypersensitivity diseases such as sinus problems, asthma, and pneumonitis. A high proportion of the teachers who completed the survey questionnaire reported respiratory tract symptoms. There was a trend for more workers in carpeted areas to report the lower respiratory symptoms of bronchitis and pneumonia. Tobacco use did not appear to explain these complaints.

Air flow measurements indicated a significant disparity between the design and measured volumetric air flow values. Additionally, the volumetric air flow to each classroom was progressively reduced as the linear distance from the air handling unit increased. For example, in one classroom at the end of a building wing, the average air flow was 89 cubic feet per minute (cfm), well below the design values of 300 cfm. Carbon dioxide (CO_2) concentrations in most areas of the school increased over the course of the day. Two of the afternoon readings exceeded the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) recommended limit of 1,000 parts per million (ppm). Indoor air temperatures and relative humidity (RH) levels during occupied times either bordered or fell below the lower limits recommended in the ASHRAE guidelines. Non-conformity with these guidelines was primarily the result of indoor RH levels in the mid 20s throughout the school.

Results (total colony counts) of air sampling for fungi, bacteria, and thermoactinomycetes revealed no significant differences in samples collected indoors versus outdoors. The taxonomic rank for bacterial and fungal sample plates was similar among the samples collected outdoors, in the non-complaint areas, and in the complaint areas. However, analysis of bulk carpet samples collected from select classrooms revealed varying concentrations of gram-negative bacteria and yeasts which are characteristic of microbial proliferation due to elevated moisture conditions.

A higher reported prevalence of lower respiratory symptoms among employees in carpeted areas may be related to the microbial contamination of the carpet. Additionally, deficiencies in the ventilation system may have contributed to the occupants' thermal discomfort, especially at the far ends of the building. Recommendations were made to properly balance the ventilation system and remediate microbially contaminated areas (i.e., removal of suspect carpets).

KEYWORDS: SIC 8211 (Elementary and secondary schools), indoor environmental quality, IEQ, thermal comfort, carbon dioxide, microbial contamination, fungi, bacteria, thermoactinomycetes, ventilation.

II. INTRODUCTION

On April 7 to 9, 1992, the National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) at the Houghtaling Elementary School in Ketchikan, Alaska. This HHE was conducted in response to a request received December 3, 1991, from the principal of the school. The request concerned a pattern of illness (over three years) among teachers and students that included pneumonia, respiratory problems, and allergic reactions. This report presents the results of the environmental and medical assessment. The environmental assessment included a ventilation system inspection, air sampling for bioaerosols, and direct measurement of temperature, humidity, and carbon dioxide (CO_2). The medical assessment included private interviews, administration of a questionnaire survey, and a review of select medical records.

III. BACKGROUND

Houghtaling Elementary School (constructed in the early 1960s) is a single-story, metal wall building in a residential area of Ketchikan, Alaska. The approximate occupancy of the building is 280 with the adult staff (including teachers) accounting for approximately 17% of the total population. The building is divided into two "wings" (main floor) and a basement area (lower floor). The majority of the classrooms, kitchen, gymnasium, administrative offices, and resource center are located on the main floor. The library, music room, and three shared area classrooms are located on the lower floor. A walled-off section of the lower floor is used for the storage of school district materials (i.e., lawn mowers, building supplies, etc.). A sketch of the evaluated areas of the building are shown in Figures 1 and 2 (not to scale).

Occupant reports related a history of respiratory health problems among teachers and students in the 5-year period prior to the NIOSH investigation. Respiratory problems (primarily from five teachers) included severe colds, bronchitis, and bouts of pneumonia. Health complaints appeared to be more prevalent in carpeted areas of the school; specifically, Rooms 5 and 25. According to the occupants, respiratory conditions appeared to alleviate when away from the school. Occupant complaints were reported to have initiated subsequent to water damage to building structures caused by leaks in the roof. A new roof was installed in 1987. Continued reports of carpet damage after the roof replacement included "growth so thick that it (carpet) had to be peeled up and replaced."

Requests for safety and health hazard evaluations were submitted to the Alaska Department of Labor (state OSHA) by the school principal in February of 1991, and by a teacher in March of 1991. A state OSHA inspection was conducted in March of 1991, and included an on-site investigation and collection of air samples for formaldehyde, CO_2, nitrogen dioxide, toluene, xylene, styrene, and methyl ethyl ketone, and real-time measurements for temperature and humidity. The OSHA samples did not reveal detectable levels of these substances except for formaldehyde (0.02 ppm) and CO_2 (500 ppm). According to the report, temperature and relative humidity (RH) measurements ranged as high as 81˚F and 35%, respectively. The report concluded that "although no

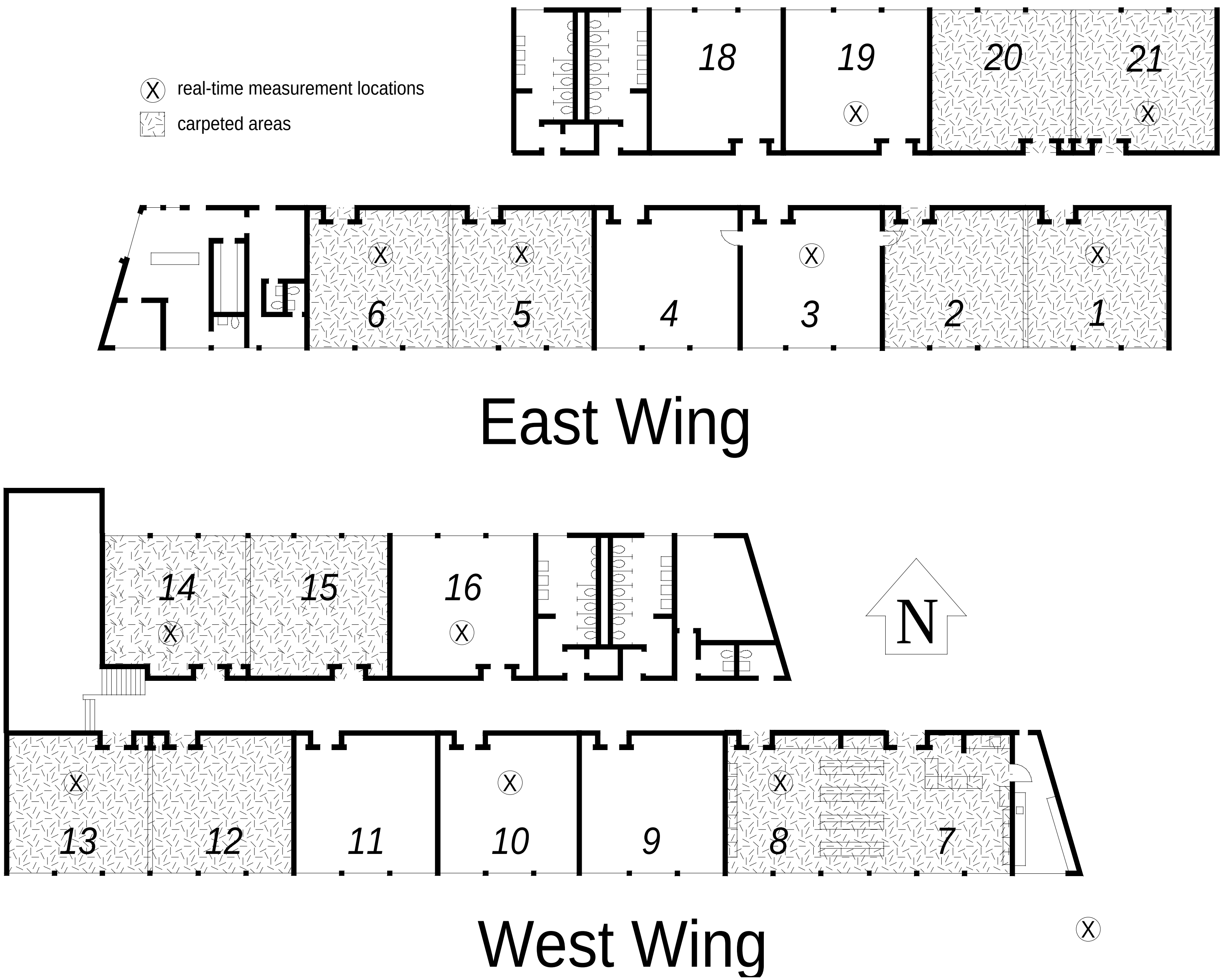


Figure 1. Main Floor Plan Drawing, Houghtaling Elementary School, Ketchikan, Alaska

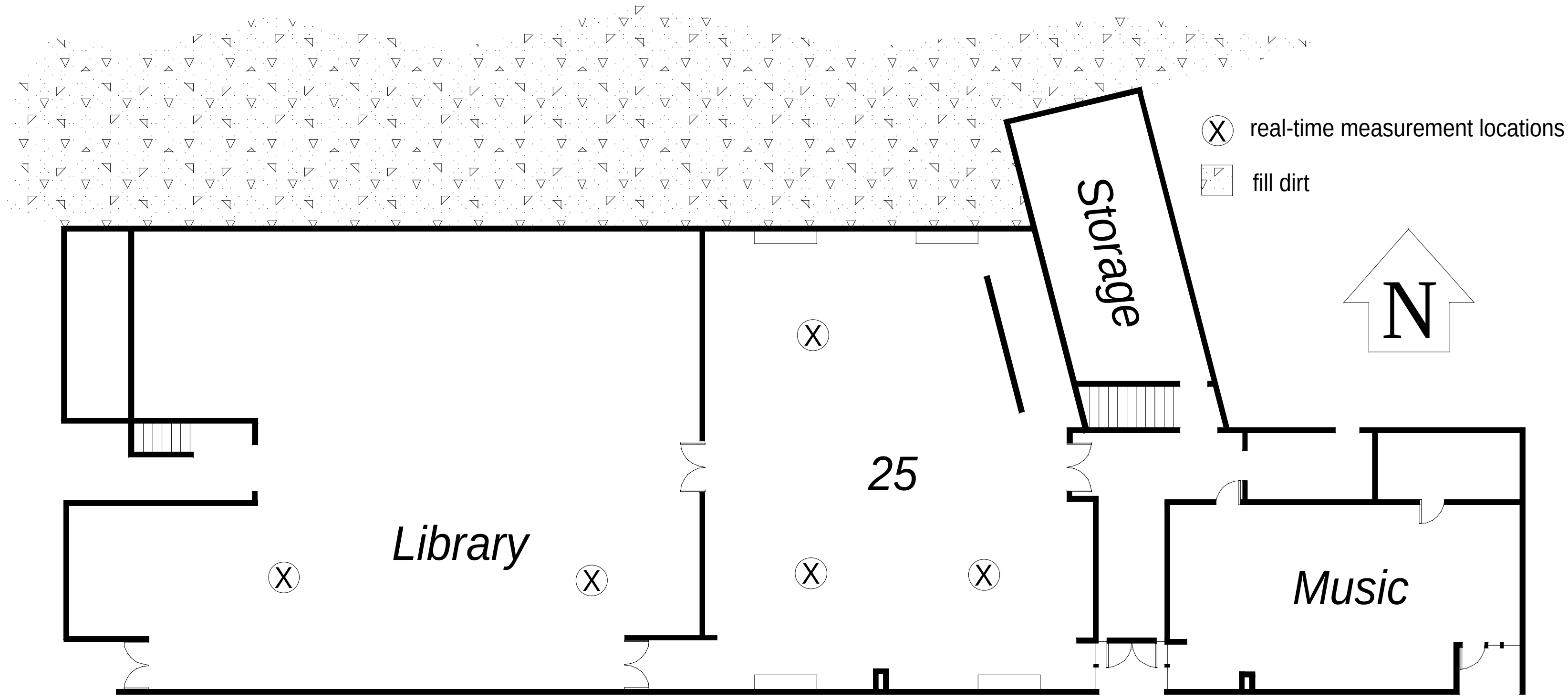


Figure 2. Ground Floor Plan Drawing, Houghtaling Elementary School, Ketchikan, Alaska

contaminants were identified as causing the respiratory problems experienced by the teachers, increased or improved ventilation might alleviate (your) possible air quality problems."

IV. EVALUATION METHODS

Medical Evaluation

The medical evaluation consisted of personal interviews with five current employees, administration of a questionnaire survey, and a review of select medical records. The questionnaire was administered to all available employees (48 personnel including support staff) on April 7, 1992. Personal interviews were offered to all interested employees at the time of the survey and were conducted by the project officer. Follow-up interviews were conducted by the medical officer by telephone.

Environmental Evaluation

Indicators of occupant comfort (i.e., CO_2 concentration, temperature, and RH) were collected at each sample location for three rounds beginning at approximately 7:00 a.m., followed by subsequent sampling rounds at 10:00 a.m. and 3:00 p.m. Carbon dioxide was measured using a Gastech RI 411 CO_2 monitor (Gastech, Inc., Newark, California). This portable, battery-operated instrument uses a non-dispersive infrared absorption detector to measure CO_2 in the range of 0 to 4,975 ppm, with a sensitivity of ±25 ppm. Instrument zeroing and calibration were performed prior to and after use with zero air and a known concentration (800 ppm) of CO_2 span gas (Alphagaz, Division of Liquid Air Corporation, Cambridge, Maryland). Temperature and RH were measured using a Vaisala HM 34 temperature and humidity meter (Vaisala Oy, Helsinki, Finland). This meter is capable of providing direct readings for dry-bulb temperature and RH, ranging from -4 to 140°F and 0 to 100%, respectively. Instrument calibration is performed monthly using primary standards. Chemical smoke was used to visualize air flow in the evaluated areas and to determine potential pollutant pathways to these areas. The volume rate of air flow (cubic feet per minute [cfm]) was measured at the supply air diffusers and exhausts using a Shortridge Airdata™ Multimeter/Flowhood ADM Model 860/8405 with an Electronic Micromanometer.

To determine the concentrations of airborne fungi, bacteria, and thermoactinomycetes (TA), the Andersen 2-stage viable cascade impactor was used at a calibrated flow rate of 28.3 liters per minute (lpm). The 50% effective cutoff diameter for the Andersen two-stage sampler is 8 micrometers (µm)--hence, larger, non-respirable particles are collected on the top stage and smaller, respirable particles are collected on the bottom stage. Standard Plate Count and malt extract agars were used for enumeration of bacteria (including TAs) and fungi, respectively. The sample plates for fungi and bacteria were incubated at 30°C. The sample plates for TAs were incubated at 55°C. The taxa of the microorganisms collected was identified by the following three different methods: Microlog's Biolog® system was used for bacteria, morphological identification for fungi, and incubation and visual inspection for TAs. On April 9, 1992, samples for bioaerosols were collected at three locations inside the school (Room 5, Room 10, and Room 25) and one location outside the school. Samples were collected in 10-minute intervals. At each location, four sample runs were collected for bacteria and fungi; two samples were collected for TAs. Temperature and RH were recorded for each sample run. Additionally, bulk samples, to be analyzed for microbiological content, were collected from the heating, ventilation, and air-conditioning (HVAC) unit and carpet of Rooms 5 and 25.

V. EVALUATION CRITERIA

NIOSH investigators have completed over 1,500 investigations of the occupational indoor environment in a wide variety of non-industrial settings. The majority of these investigations have been conducted since 1979.

The symptoms and health complaints reported to NIOSH by building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritations of the skin, nasal congestion, dry or irritated throats, and other respiratory irritations. Typically, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[1,2,3,4,5] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[6,7] Among these factors are imprecisely-defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[8,9,10,11,12,13] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than any measured indoor contaminant or condition.[14,15,16] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[16,17,18,19]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately-ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems that NIOSH investigators have found in the non-industrial indoor environment have included: poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, emissions from office machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and RH conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[20,21,22] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[23,24] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[25]

Measurement of indoor environmental contaminants has rarely proved to be helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and variable mixtures of organic materials usually found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature and RH, has proven useful in the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems.

NIOSH and the Environmental Protection Agency (EPA) jointly published a manual on building air quality, written to help prevent environmental problems in buildings and solve problems when they occur.[26] This manual suggests that indoor environmental quality (IEQ) is a constantly changing interaction of a complex set of factors. Four of the most important elements involved in the development of IEQ problems are: (1) a source of odors or contaminants; (2) a problem with the design or operation of the HVAC system; (3) a pathway between the contaminant source and the location of the complaint; and (4) the building occupants. A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The basis for measurements made during this evaluation are listed below.

Carbon Dioxide

Carbon dioxide (CO_2) is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ANSI/ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for office spaces and conference rooms, 15 cfm/person for reception areas, and 60 cfm/person for smoking lounges, and provides estimated maximum occupancy figures for each area.[23]

Indoor CO_2 concentrations are normally higher than the generally-constant ambient CO_2 concentration (range 300 to 350 ppm). When indoor CO_2 concentrations exceed 1,000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1992, specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[24]

Microbiological Contaminants

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an adequate supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil or dust particles or water droplets. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In an indoor environment where there is no unusual source of microorganisms, the level of microorganisms will vary as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency) with consistently similar ranking among the microbial species.[27,28]

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease is based on the type and extent of the exposures and, in part, on a genetic predisposition.[29] Allergic diseases typically associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[27] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[30,31,32,33,34,35,36,37]

Symptoms vary with the type of allergic disease: (1) allergic rhinitis is characterized by paroxysms of sneezing; itching of the nose, eyes, palate, or pharynx; nasal stuffiness with partial or total airflow obstruction; rhinorrhea with postnasal drainage; (2) allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath due to bronchial narrowing; (3) ABPA is characterized by the production of IgE and IgG antibodies with symptoms of cough, lassitude, low grade fever, wheezing, and occasional expectoration of mucous.[27,38]

Heavy exposures to airborne microorganisms can result in an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing 4- to 8-hours after exposure. Onset of the chronic form of extrinsic allergic alveolitis is thought to be induced by a continuous low-level exposure, and onset occurs without chills, fever, or malaise but is characterized by progressive shortness of breath with weight loss.[39]

Acceptable levels of airborne microorganisms have not been established, primarily due to the varying immunogenic susceptibilities of individuals. Relationships between health effects and environmental microorganisms must be determined through the combined contributions of medical, epidemiologic, and environmental evaluation.[25] The current strategy for on-site evaluation involves a comprehensive inspection of the problem building to identify sources of microbial contamination and routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples for microorganisms may be collected to document the airborne presence of a suspected microbial contaminant. Airborne dissemination (characterized by elevated levels in the complaint area, compared to outdoor and non-complaint areas, and anomalous ranking among the microbial species) correlated to occupant symptomology may suggest that the contaminant may be responsible for the health effects.

VI. MEDICAL RESULTS

Medical evaluations of workers at the Houghtaling Elementary School were based on the findings from: (1) a brief questionnaire (Appendix) administered to workers (teachers) during the industrial hygiene evaluation on April 7 1992; (2) telephone interviews with several affected workers; and (3) a review of medical records available from the two workers who signed releases. The primary concern related to possible hypersensitivity diseases such as sinus problems, asthma, and pneumonitis.

Of 48 potential employees working at the school, 16 (33%) returned questionnaires. One was incompletely filled out, but the employee did mention two prior episodes of pneumonia. Of those who completed the questionnaire, there were 13 females and 2 males, with a mean age of 42 years and mean tenure in the building of 5 years. One teacher was a current cigarette smoker, and three had quit smoking 8 to 27 years before.

Of the 15 employees completing the questionnaire, 14 indicated the presence of some respiratory tract symptoms. Of the 15, 7 indicated clearly that symptoms began since working at the Ketchikan school. Seven reported one or more episodes of bronchitis, and three had at least one bout of pneumonia since working in the school. Wheezing was noted by four teachers and asthma was reported by two (onset since working at the school).

The relationship between symptoms and certain exposures was examined (Table I). Teachers who reported upper respiratory symptoms (hay fever and sinus problems) were grouped with those who experienced lower respiratory symptoms (episodes of bronchitis or pneumonia). Since new onset wheezing was seen only in two teachers, this was not further evaluated. Molds have

Table I. Respiratory Symptoms in Teachers at Houghtaling Elementary School

RESPIRATORY SYMPTOMS:	PRESENT	ABSENT
Carpeted work area	10	2
Uncarpeted work area	2	1
LOWER RESPIRATORY SYMPTOMS:	**PRESENT**	**ABSENT**
Carpeted Work Area	8	4
Uncarpeted Work Area	1	2
RESPIRATORY SYMPTOMS:	**PRESENT**	**ABSENT**
Never smoker	5	0
Current or former smoker	7	3
LOWER RESPIRATORY SYMPTOMS:	**PRESENT**	**ABSENT**
Never smoker	4	1
Current or former smoker	5	5

been implicated as etiologic agents in hypersensitivity pneumonitis in buildings, and may be found in carpets.[6] Teachers' symptoms were tabulated to determine if the occurrence of symptoms was related to work in a carpeted room. Upper and/or lower respiratory symptoms were reported by 83% and 67% of teachers in carpeted and uncarpeted work areas, respectively. In contrast, lower respiratory symptoms (bronchitis and/or pneumonia) were more commonly reported by workers from carpeted (67%) versus uncarpeted (33%) areas. Prior tobacco smoking did not appear to explain these symptoms (Table I).

Reviews of medical records from two teachers and telephone interviews confirmed treatment for bronchitis and pneumonia. In both cases, no clear infectious cause for these illnesses had been documented.

VII. ENVIRONMENTAL RESULTS

In general, the classroom environments appeared in good condition; all classrooms were well lit and visible surfaces were clean. Carpets were present in only some of the classrooms (Figures 1 and 2) and all appeared dirty and worn with age. In Room 25, the carpet showed evidence of water damage (i.e., stained regions) which was in agreement with occupant reports of water leaks from the ceiling and flooding from the sink located in the back of the classroom. The carpet in Room 5 exhibited ridges "branching" throughout the room. Inspection of the material beneath a randomly selected carpet ridge revealed a fine black dust (possibly from the carpet backing material). Evidence of water damage on ceiling tiles and wall paint was observed in Rooms 102, 103, and 110.

Primary heat for the main floor classrooms was from radiant heaters (low pressure steam) located along the exterior walls. In addition, the main floor heating needs were supplemented by two HVAC systems (a system for each wing), each designed as a single-pass system with separate supply and exhaust units. The supply and exhaust units were located in an enclosed room on the roof above the ground floor ceiling.
Each classroom on the main floor has two supply air diffusers, each designed to provide 300 cubic feet per minute (cfm) of air. Physical inspections of the air handling units (AHUs) did not reveal any visible evidence that would indicate a microbial reservoir. Specifically, the filters appeared free of debris accumulation; the ventilation ducts were in good shape; and the heating coils, and area directly beneath, were absent of standing water and/or "slime" accumulation.

The heating and cooling needs of Room 25 (lower floor) were met by three package wall units located on the exterior walls, one on the north side and two on the south side. The units along the south wall were capable of providing outside air (unknown percentage), whereas, the unit against the north wall was recirculating 100% room air due to the inaccessibility to outdoor air (the south wall was below ground level). Physical inspections of the AHUs did not reveal any visible evidence that would indicate a microbial reservoir.

Environmental CO_2 measurements are presented in Figure 3. Measurements were made at 17 locations throughout the evaluated areas (Figures 1 and 2) and 1 outdoor location. In the building, CO_2 concentrations ranged from 275 to 325 ppm during the first measurement period (~8:00 a.m.), from 425 to 1,525 ppm during the second measurement period (~10:00 a.m.), and from 350 to 975 ppm during the third measurement period (~2:00 p.m.). The outdoor concentrations ranged from 300 to 375 ppm over the three measurement periods. The highest individual concentration observed was 1,525 ppm collected in Room 13 during the second measurement period. The first measurement period was selected at a time when the building was unoccupied, as evidenced by the low CO_2 concentrations. During the second measurement period, the measured CO_2 concentrations in Rooms 13 and 14 exceeded the ASHRAE comfort criterion level of 1,000 ppm of CO_2 for indoor environments.

Temperature and RH measurements are presented in Figure 4 as means of three measurements at each sampling location over the day. In the building, temperatures ranged from 67 to 74.2˚F during the first measurement period (~8:00 a.m.), from 62.2 to 75.3˚F during the second measurement period (~10:00 a.m.), and from 72.3 to 77.6˚F during the third measurement period

(~2:00 p.m.). The outdoor temperatures ranged from 38.2 to 60˚F over the three measurement periods. The RH levels for all measurement periods were fairly stable in the upper teens and lower 20s. The indoor temperatures and RHs are outside the lower limits recommended in the ASHRAE thermal comfort chart (Figure 5). The ASHRAE thermal comfort chart specifies the acceptable (10% dissatisfaction criteria) ranges of operative temperature and humidity for persons clothed in typical summer and winter clothing, performing mainly sedentary activity.[24] Non-conformity to the ASHRAE thermal comfort criterion was primarily the result of indoor RH levels in the mid 20s. However, relative humidities in this range are not uncommon within buildings in cold climates that do not have humidification systems.

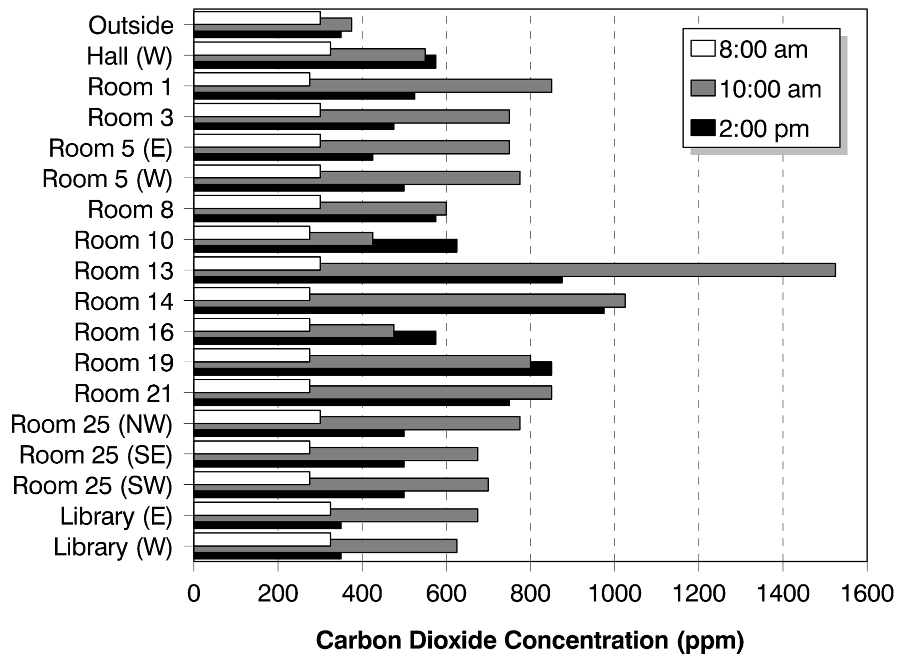


Figure 3. Carbon Dioxide Measurement Results

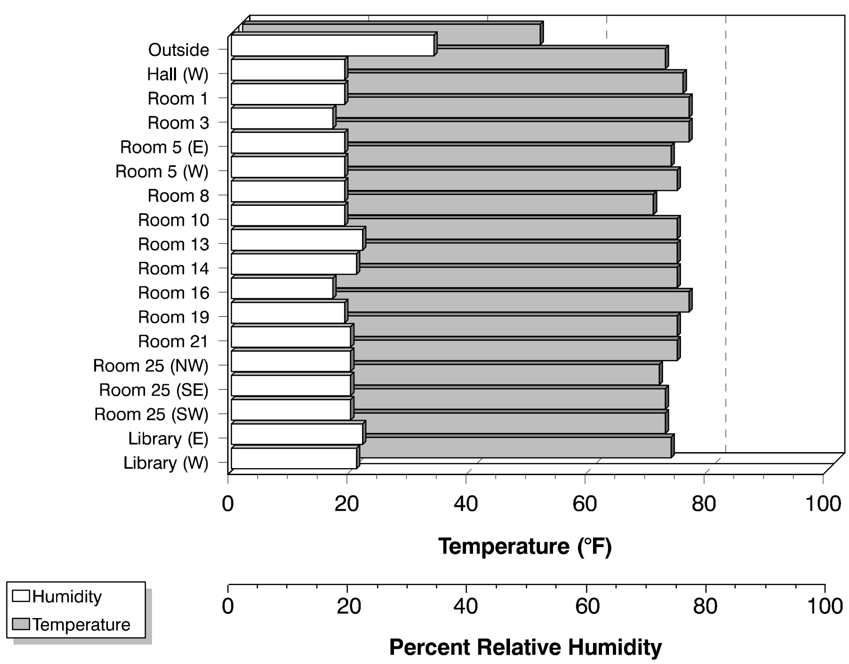


Figure 4. Mean Temperature and Relative Humidity Measurement Results

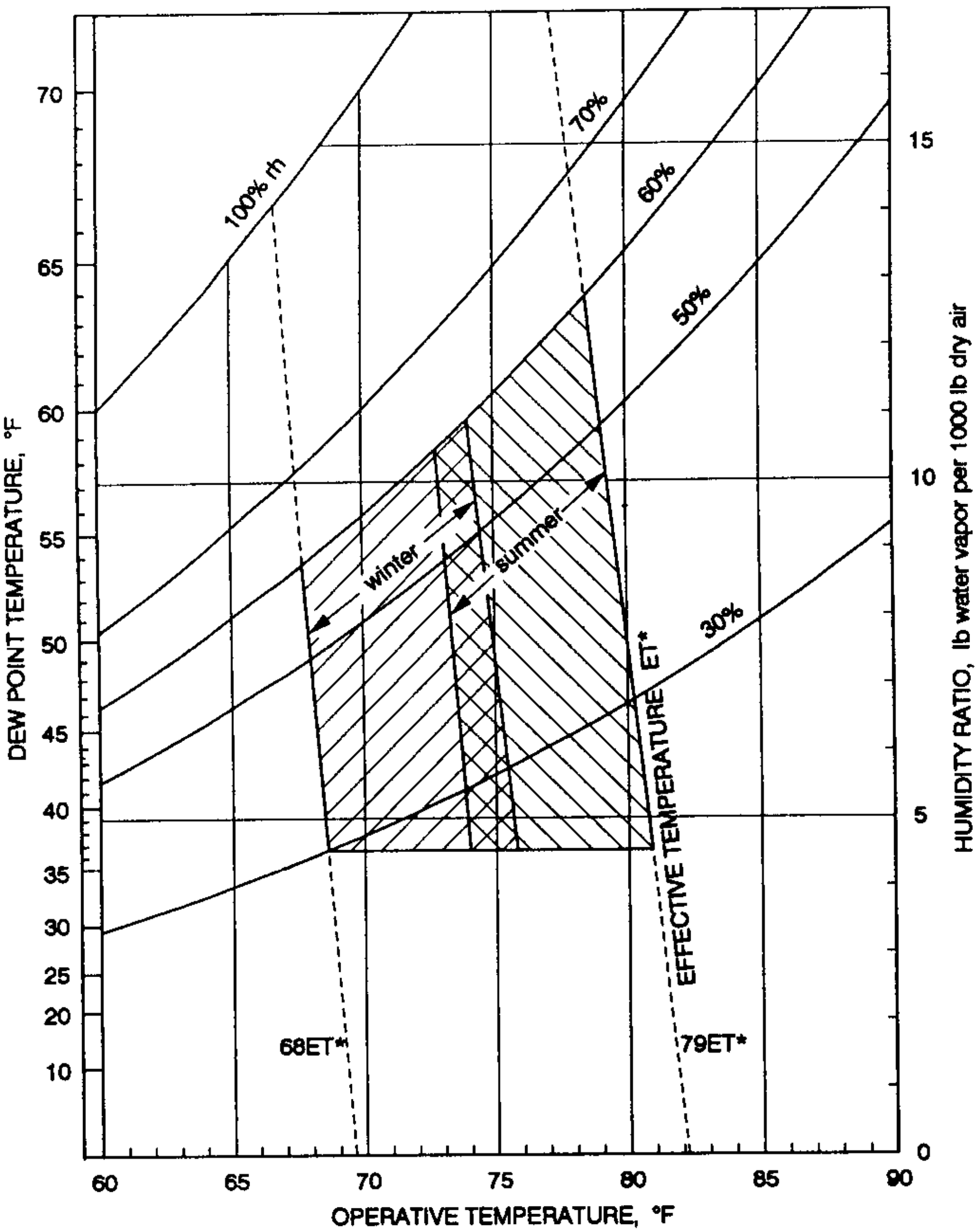


Figure 5. ASHRAE Thermal Comfort Chart

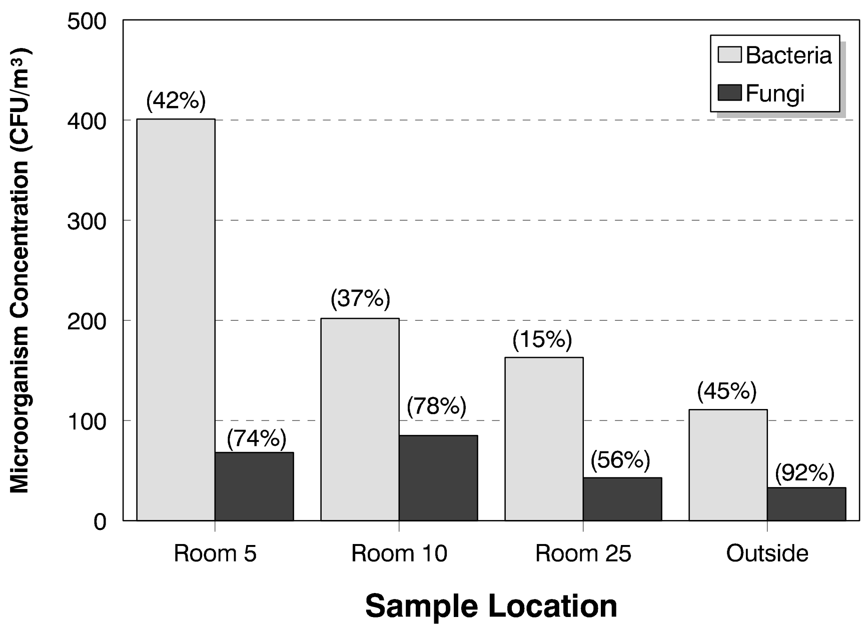
The results of air flow measurements on the main floor are presented in Table II. The air flow values are presented as an average of two measurements in cubic feet per minute (cfm). The original design specifications (i.e., 300 cfm at each diffuser, two supply diffusers per classroom, and 100% outdoor air) are capable of conforming to the ASHRAE (62-1989) criterion of 15 cfm/person of outdoor air for classrooms given the estimated occupancy of 25 students per classroom. However, only in Rooms 5, 6, 8, and 19 were the design specifications for supply air flow (300 cfm per diffuser) satisfied as measured. Air flow rates meeting the design specification are noted as shaded boxes in Table II. Additionally, measured air flow values decreased as the linear distance from the ventilation system fan increased (i.e., from the center of the building to the ends of the wings). The unbalanced nature of the system and inadequate amounts of outdoor air can affect the comfort of individuals in the occupied space.

A graphical summary of the results of bioaerosol sampling of bacteria and fungi is presented in

Table II. Results of Air Flow Measurements

Room Number	Volumetric Air Flow (cfm) Supply Diffuser #1	Supply Diffuser #2
1	114	NA
2	298	117
3	235	178
4	250	279
5	430	242
6	152	434
7	160	186
8	346	230
9	184	172
10	133	168
11	163	244
12	127	174
13	79	104
14	76	96
15	93	165
16	181	85
18	291	191
19	302	266
20	186	136
21	67	186
Special Ed. Room	150	
Administration	115	
Nurse's Office	213	

Figure 6. The mean bacterial count at various locations inside and outside of the building ranged from 111 to 401 colony forming units per cubic meter of air (CFU/m^3). When analysis of variance (ANOVA) was used to compare sample means, there was no significant difference among the mean bacterial values ($\alpha = 0.05$). Speciation of bacterial sample plates showed a random distribution consisting primarily of gram positive microorganisms (*Bacillus*, *Corynebacterium*, *Staphylococcus*, and *Micrococcus*) which are normally found in association with human occupancy (i.e., desquamated skin) and as normal constituents of the soil. Also identified were a variety of yeast colonies and one isolated sample with gram negative bacterial colonies (identified as *Pseudomonas*). Fifteen to forty-five percent of the bacterial particles were in the respirable range. Thermophilic bacteria were not identified in any of the air samples.



Note: Paranthetical values indicate respirable fraction.

Figure 6. Bioaerosol Measurement Results

The mean fungal count at various locations inside and outside of the building ranged from 33 to 85 CFU/m^3. When analysis of variance (ANOVA) was used to compare sample means, there was no significant difference among the mean fungal values ($\alpha = 0.05$). The percentage of fungal particles in the respirable range was higher than that observed in the bacterial samples, with mean values ranging from 56 to 92%. The taxonomic rank was similar among the samples collected outdoors, in the non-complaint areas, and in the complaint areas. Speciation of fungal sample plates showed a random distribution of *Penicillium*, *Cladosporium*, *Alternaria*, *Aspergillus*, *Ulocladium*, *Epicoccum*, and yeasts. Observation of the taxa ranking does **not** indicate amplification of fungal species that have typically been associated with health effects (i.e., *Aspergillus*, *Penicillium*, *Sporobolomyces*, *Alternaria*, etc.).[25] In order to elicit an immunologic response in a susceptible individual, a microorganism must be present in the environment (reservoir), capable of propagation to concentrations necessary to induce a response (amplification), and dispersed as an aerosol to the susceptible individual (dissemination).[40]

The results from the analysis of bulk samples for microbial content are presented in Table III. Carpet samples were selected based on reports of water incursion. The samples collected from the HVAC system (scrapings from the fan blades) did not contain detectable levels of fungi. Sample V2 contained colonies of gram-negative *Pseudomonas paucimobilis* while the other sample (V1) did not contain detectable levels of bacteria. All of the carpet samples from Rooms 5 and 25 contained various yeast colonies ranging from 63 to 8,460,000 CFU/gram of material sampled. Bacterial concentrations in the carpet samples ranged from 300 to 22,800,000 CFU/gram of material. The species identified included *Enterobacter agglomerans*, *Flavobacterium* sp., *Pseudomonas* sp., *Pseudomonas paucimobilis,* and *Staphylococcus capitis* (identified on only one carpet sample). *Staphylococcus* sp., like a number of gram-positive

Table III. Microbiological Results of Bulk Samples

Sample Location	Fungi		Bacteria	
	(CFU/gm)	Taxa Rank	(CFU/gm)	Taxa Rank
V1 (flake sample from HVAC unit)	ND		ND	
V2 (flake sample from HVAC unit)	ND		680	Ps pau
C1 (carpet sample from Room 25)	3,800	Yea	1,900	Flav
C2 (carpet sample from Room 25)	31,600	Yea	24,000	Flav
C3 (carpet sample from Room 25)	1,270,000	Yea	235,000	Ps
C4 (carpet sample from Room 25)	345,000	Yea	1,800,000	Flav>E agg
C (carpet sample from Room 25)	8,460,000	Yea	22,800,000	Flav=Ps situ
C (carpet sample from Room 25)	1,900,000	Yea	16,000,000	St cap>> Flav
C (carpet sample from Room 5)	850	Yea	2,000	Flav
C9 (carpet dust sample from Room 5)	ND		ND	
C10 (carpet sample from Room 5)	63	Yea	300	unid (6)

NOTE: Yea = Yeast
ND = none detected
E agg = *Enterobacter agglomerans*
Flav = *Flavobacterium* sp.
Ps = *Pseudomonas* sp.
Ps pau = *Pseudomonas paucimobilis*
St cap = *Staphylococcus capitis*
unid = unidentified

bacteria, are normally found in association with human occupancy (i.e., from desquamated skin) and as normal constituents of the soil. However, the elevated concentrations of gram-negative bacteria (*Enterobacter agglomerans*, *Flavobacterium* sp., *Pseudomonas* sp.) and yeast are more characteristic of microbial proliferation due to high moisture conditions (i.e., water incursion into the carpet). Specific health concerns related to the identified bacterial species involve the toxic reaction of certain individuals to the outer membrane endotoxin component of gram-negative bacteria and the existence of *Enterobacter agglomerans* as an opportunistic pathogen.

Elevated exposures to endotoxins have been shown to cause fever and malaise, changes in white blood cell counts, respiratory distress, shock, and even death.[25] *Enterobacter agglomerans* has been characterized as an opportunistic pathogen causing burn, wound, and urinary tract infections and occasionally septicemia and meningitis.[41] Some *Pseudomonas* sp. are also opportunistic pathogens that can infect individuals with impaired host defenses. These infections are usually severe, difficult to treat, and hospital acquired.[42]

VIII. CONCLUSIONS AND RECOMMENDATIONS

NIOSH conducted a survey at the Houghtaling Elementary School in Ketchikan, Alaska, in response to a request by the school principal concerned about a pattern of illness among teachers and students that included pneumonia, respiratory problems, and allergic reactions. A high proportion (93%) of the teachers who completed the survey questionnaire (16 respondents of 48 available employees) reported respiratory tract symptoms . There was a trend for more workers in carpeted areas to report the lower respiratory symptoms of bronchitis and pneumonia. Tobacco use did not appear to explain these complaints.

Reports of building-related health complaints have become increasingly common in recent years; unfortunately, the causes of these symptoms have not been clearly identified. As discussed in the criteria section of this report, many factors are suspected (e.g., volatile organic compounds, formaldehyde, microbial proliferation within buildings, inadequate amounts of outside air, etc.). While it has been difficult to identify concentrations of specific contaminants that are associated with the occurrence of symptoms, it is felt by many researchers in the field that the occurrence of symptoms among building occupants can be lessened by providing a properly maintained interior environment. Adequate control of the temperature is a particularly important aspect of employee comfort.

Environmental conditions and deficiencies found by the NIOSH investigators may help explain the symptoms reported by the Houghtaling Elementary employees. Based on the results and observations of this evaluation, the following recommendations are offered to correct those deficiencies and optimize employee comfort:

! The HVAC system should be properly balanced by a qualified engineering consulting company to ensure conformance with the ASHRAE guidelines. Air flow measurements indicated extreme disparity between the design and measured volumetric air flow rates. Additionally, the volumetric air flow to each classroom was progressively reduced as the linear distance from the air handling unit increased.

In the extreme cases, the measured air flow was well below the design values. The original design specifications (i.e., 300 cfm at each diffuser, two supply diffusers per classroom, and 100% outdoor air) would meet the ASHRAE (62-1989) criterion of 15 cfm/person of outdoor air for classrooms, given the estimated occupancy of 25 students per classroom.

! Any visible or suspected microbial contamination (i.e. contaminated carpeting) requires remediation efforts. Remediation should include removal of the contaminated material and/or clean-up with a high efficiency particulate air filter (HEPA) vacuum and decontamination with an effective chemical agent (i.e., 5 to 10% solution of bleach). Removal should be limited to those materials not conducive to clean-up (i.e., porous building components). Remediation personnel should be appropriately equipped with personal protective equipment (i.e., HEPA-filtered respirators, clothing, gloves, etc.). For respirator use, the Occupational Safety and Health Administration requires a respiratory protection program that includes the following components: written standard operating procedures, respirator selection on the basis of hazard, user instruction and training, cleaning and disinfection, storage, inspection, surveillance of work area conditions, evaluation of respirator protection program, medical review, and use of certified respirators.[43]

! The continued use of the open area next to the Music Room as a storage facility is not recommended without proper ventilation. The current design places relief vents for this area directly under main floor windows. This placement allows for re-entrainment of odors into classrooms with open windows. Occupants in the ground floor classroom (Room 25) reported odors emanating from the storage area. The storage area should be mechanically ventilated and capable of maintaining the space under negative pressure to ensure that odors do not enter through the ground floor.

! In a letter to the principal dated February 11, 1994, the NIOSH investigators recommended that replacement carpets would be ill-advised. This decision was based on the results of this NIOSH investigation concerning the state of the current carpet and the local climatic conditions. The findings and recommendations of this final report are consistent with the recommendations of that letter.

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