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The Effect of Ventilation and Relative Humidity upon Airborne Bacteria in Schools

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ABSTRACT

It is hypothesized that the increase in respiratory diseases in winter is caused by the reduced indoor relative humidity increasing the survival time of airborne bacteria and viruses. This paper reports the effect of ventilation and relative humidity upon the number of airborne colony-forming units per m^3 (cfu/m^3) in six schools. The airborne bacteria found were mainly nonpathogenic with a few pathogenic bacteria appearing in December, January, and February. The number of cfu/m^3 were mainly a function of occupancy: in nonoccupied periods, the numbers of cfu/m^3 were in the range of 40 to 70, which increased to 300 to 700 as soon as the students entered the classroom. The average level of the cfu/m^3 was largely a function of the air recirculation rate, because the filter removed 90% of the airborne bacteria. Ordinary filters are very effective in removing bacteria from air and could be used as a protection from sources disseminating pathogenic bacteria in ventilating systems. The number of classroom airborne bacteria was reduced slightly as the relative humidity decreased, which does not support the hypothesis proposed for the increase of respiratory illnesses in winter. They were, however, mainly nonpathogenic, and the pathogens may have a different survival pattern with relative humidity. In general, the level of airborne bacteria in the classroom was mainly a function of occupancy and air recirculation rate through a filter.

INTRODUCTION

Airborne infections are caused by bacteria and virus that survive their transport through the air, find a favorable landing site, and cause an infection. Survival depends upon a number of factors, and this paper investigates two of them, indoor relative humidity and ventilation. Relative humidity affects the survival of airborne microorganisms, and the general rule seems to be that the midrange of relative humidity is the most lethal (Akers and Dimmick 1969). A number of investigators (Sale 1972; Hemes, Kool, and Winkler; Hope-Simpson 1958) attribute the increase in respiratory infections in winter to the lower indoor relative humidity of that season permitting an increased survival of airborne infectious microorganisms. Studies that have been conducted with a population divided into two groups--one in a higher humidity, not exceeding 50% RH, the other with a lower humidity--have found the incidence of colds or absenteeism was reduced in 9 out of 13 experiments with the higher humidity. If the cause of reduction in colds and absenteeism is the reduced survival of airborne infectious agents in the high humidity range, then another cause in reduction should occur with increased ventilation, as the airborne-viable contents of the air will be diluted. This investigation tries to validate the hypothesis that indoor relative humidity and ventilation affect the transmission of colds. The airborne microbial count was measured in six schools along with ventilation or recirculation rates, relative humidity, dust, and absentee rates to determine if there was a relationship between these factors.

STUDIES OF THE EFFECT OF INDOOR RELATIVE HUMIDITY ON RESPIRATORY ILLNESSES

Respiratory illnesses have a yearly cyclical frequency that is at a peak in winter and a

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minimum in the summer. Investigators (Hemmes, Kool, and Winkler; Hope-Simpson 1958) have hypothesized that the increase is partly caused by the decrease in winter indoor relative humidity. There have been eight studies (Sale 1972; Green 1974; Green 1981; Dang, Guberan, and Sweetman 1978; Menduke and Sataloff 1963; Serati and Wuthrich 1969; Ritzel 1966) conducted with a population divided between humidified and unhumidified buildings in the same city so as to eliminate the effect of the weather variables. The location and the conditions of the studies are shown in Table 1, and the results are presented in Figures 1 and 2 where the absenteeism or occurrences of upper respiratory illness rate are plotted versus indoor relative humidity. Children have many more respiratory illnesses than adults: children less than five years old have five times as many colds, hence, their results are plotted separately.

If one considers the slopes of all the tests, including replicates in Figures 1 and 2, rejecting any slope that could have either a positive or negative slope ($\alpha = 0.5$) and the Halifax data are rejected, then there are nine slopes that indicate a decreasing absenteeism or occurrences of colds with increasing indoor relative humidity out of the total of 13 studies. The application of the sign test indicates there is a 19 in 20 possibility ($\alpha = 0.0539$) that increasing relative humidity does decrease absenteeism or the number of common colds.

While the weight of the evidence is on the side of decreasing colds with increasing humidity, which is also supported by medical practitioners who report cases where increased humidity in homes has been beneficial (Gregg 1968; Lubart 1962; Menduke and Sataloff 1963; Personal communication), but it is, as Sir Arthur Edington has remarked, "a good rule not to put too much confidence in the observational results that are put forward until they are confirmed by theory."

In all the studies, the subjects were concentrated in the controlled humidity spaces for less than 12 hours per day so the cause of reduction is likely an effect dependent upon the transmission of the disease in the space. Also, it has been established that the common cold is an infection transmitted by airborne and/or contact mechanisms. Several studies show that the life of virus and bacteria on surfaces are affected by the surrounding air humidity. The most commonly suggested cause for the decrease in illness has been the reduced transmission of infection because of the reduced survival of airborne microorganisms in the midrange of relative humidities (Akers and Dimmick 1969). Factors other than survival should be considered with changes in humidity. Some aerosols of organisms show high survival rates but reduced ability to infect at certain relative humidities. Higher relative humidities produce larger particles, which are shown to have reduced infectivity (Druett 1967). The drying and cracking (Lubart 1962) of nasal passages at low relative humidity may act in conjunction with survival and the ability to infect. Thus, the increase of indoor relative humidity toward 50 % affects a number of factors that tend to reduce the probability of the transmission of respiratory infections.

Animal experiments have demonstrated the reduced infectivity at the midrange of humidities. Schulman and Kilborne (Kilbourne and Schulman 1962) placed influenza virus infected mice in the same cage but separated by a double-mesh wire screen from noninfected mice and obtained an incidence of transmitted infection at various rates of airflow and relative humidity. They concluded that the transmission of influenza virus with mice is enhanced by conditions of low relative humidity and diminished ventilation (Figure 3). Lester (Lester 1948) exposed white mice to atmospheres containing known amounts of atomized influenza virus suspension under conditions of varying humidity. It was found that an amount of atomized virus produced a 100% mortality rate in animals exposed at less than 30% and greater than 80% relative humidity, respectively. When exposed to 50% RH only 40% were infected, resulting in the death of only 22.5% (Figure 4).

Sale (Sale 1972), during his study of changes in absenteeism with increased relative humidity upon nursery school children, also measured the bacteria count of the air in humidified and nonhumidified schools. The reductions in the airborne counts with increased relative humidity are shown in Figure 5. A similar effect was apparent in the data plotted by the author from data of airborne counts provided by Drs. E. Guberan and G. Ducel of Zurich (Personal communication) taken in three different office buildings at varying relative humidities. The majority of the airborne bacteria in this investigation were nonpathogenic. The reduction in viable, mainly nonpathogenic airborne bacteria demonstrated in these studies may be an indicator of a reduction of airborne virus and bacteria causing illness with increasing relative humidity. Ventilation (outdoor air) also reduces the counts of airborne microorganisms, and neither of these studies measured the ventilation rate in the buildings so

the results must be considered tentative.

The objective of this study is to investigate the effect of relative humidity and ventilation rates on the concentration of airborne bacteria in elementary schools.

MEASUREMENTS AND METHODS

With the objective of getting random samples of airborne bacteria and relative humidity, the study began with measurements of airborne bacteria, relative humidity, dust, and surface bacteria in 12 schools. A single classroom in each school of about 20 Grade 3 students of ages 7, 8, or 9 was selected.

It was noted that the airborne bacteria counts were a function of the time of day (Figure 6). Airborne bacteria counts in the schools increased rapidly up to the recess period, decreased, then increased until noon, and decreased rapidly during the noon hour. The airborne counts were obviously a function of the number of students, so daily hourly readings had to be taken, which was not possible for 12 schools. Therefore, the study was reduced to the six schools whose heating and ventilation characteristics are shown in Table 2. A more extensive measurement study was undertaken of school (HC) for more detailed analysis of airborne counts.

Readings of relative humidity, dust, and airborne counts were taken before the class started 08:30, then repeated at 09:30, 10:00, 11:00, 11:30, 12:15, 12:40, and 12:35. A typical plot of the results is shown in (Figure 6).

Relative humidity was measured with an aspirating psychometer with readings taken during the microbial sampling period.

The airborne bacteria counts were made with an Andersen sampler that collects air at 28.3 L/min through six stages with decreasing diameter holes in each succeeding plate. As the jet velocity increases with the decreasing diameters of the holes, smaller particles are recovered at each successive stage. Below each plate, a surface containing the nutrient agar receives the airborne particles separated according to their aerodynamic dimensions. Samples were taken for 5-15 minutes, then the petri plates were removed, incubated, and the colonies counted by the 'positive hole' method (Andersen 1968).

The reproducibility of the Anderson sampler was confirmed by using two additional samplers side by side. The results were within 10% over the entire range of up to 2200 colony-forming units/m^3 (cfu/m^3).

Airborne dust samples were taken simultaneously with the airborne bacteria collection with the sampler. A respirable aerosol mass monitor was used to determine the respirable mass content of the air. Mass content of the air was registered in Mg/m^3 by a piezoelectric balance. A cut-off impactor of 10 microns rejected all sizes above that value. Sampling rate was one litre per minute, with a measuring time concentration of 120 seconds and the repeatibility and accuracy of $\pm$10% plus one digit on 4 decimal digits.

The air-change rate of a classroom is a sum of the infiltration plus the air quantity entering the room through the diffusers. The air-change rate was determined by using N_2O as a tracer gas. A predetermined quantity of N_2O was released into the air and additional mixing was created in empty classrooms with two 24-inch propellor fans. After a mixing period, a sample was taken every five minutes by pumping the room air into a sample bag for later analysis. Five samples were taken in each test. Analysis of the gas was made with an infrared analysis instrument. Results were consistent and checked with measured airflow quantities from the diffusers. The combined room air-change rate resulting from the infiltration and recirculation will be referred to as the recirculation rate, as the air is mostly recirculated in the study of the school, HC.

Since the natural death of airborne bacteria is a logorithmic function (described in the next section), the decay rate of viable bacteria in an empty classroom was determined by taking samples at selected time intervals. These cfu/m^3 were plotted on semilog paper to determine the equivalent air change rate of the decay of the viables.

The records of absenteeism in the schools were obtained from the teachers on a monthly basis. The absenteeism for all causes was used since respiratory infections account for 60%

of all absence from classes (Green 1974).

RESULTS

Airborne cells and bacteria are dispersed by the human body at a rate of 5×10^8 cells per day and about 10^7 particles bear viable organisms (Noble and Somerville 1970). A very high percentage of the particles are nonpathogenic. Table 3 lists the bacteria found in this study and by two other investigators (Personal communication; Simard, Trudel, Pagnette, Payment 1983). The pathogens that appeared in each study were β Streptococcus and Staphylococcus aureus. In this study, in the schools in which 10 to 20 samples were taken per week, the pathogens did not appear until January and February, the months in which respiratory infections occur in greater numbers. Table 4 gives the results.

As would be expected from the dispersion of the 10^7 viables per day per person, the number of airborne viable particles colony-forming units (cfu/m^3) is mainly dependent on the number of occupants in a space. Figure 6 demonstrates the variation in cfu/m^3 throughout the morning that occurred in all schools. Before the class, normal readings were less than 50 cfu/m^3. They increased at a rapid rate the instant the average 20 pupils entered the classroom and continued to increase at a lesser rate until recess at 10:00 a.m., then dropped rapidly. The readings increased when the pupils returned until noon, when the count again decreased until the pupils returned for the afternoon class. It was noted that the degree of movement in the class increased the cfu/m^3. To check that the increase in counts was not due to stirring of dust and deposited bacteria on the floor, fans were used to agitate the floor air. There was no increase in cfu/m^3 when this was done in unoccupied classrooms in the morning.

The decay of viable particles in the duct system was studied (Figure 7). The number of viable counts was determined in the room, before the filter (air washer) but after the fresh air inlet, after the filter, and the supply air to the room with the air washer not operating. Note that the dilution by the ventilation air is not large, but there is a large reduction in the filteration process. When the air washer was operating and the filter was sprayed, there was a greater reduction in airborne bacteria. This is a single test, and further tests need to be done to prove this.

To study this effect of the two variables, relative humidity, and airchange rate, a procedure was derived to take into account the transient nature of the cfu/m^3 generated by the occupants.

The decay of viable particles in the air is often expressed as "logorithmic death" (Akers and Dimmick, 1969). This is identical with the logorithmic decay of a tracer gas in infiltration ventilation studies.

The relationship is

$$\frac{N}{N_o} = e^{-Kt} \quad \text{or} \quad K = \frac{\log_e N_o - \log_e N}{\Delta t} \qquad (1) \text{ If the supply air cfu/m}^3 = 0$$

$$\text{or} \quad K = \frac{\log_e (N_o - N_i) - \log_e (N - N_i)}{\Delta t} \qquad (2) \text{ If supply air cfu/m}^3 = N_i$$

N_o = number of cells initially or gas concentration
N^o = number of cells at interval t or gas concentration
K = constant, i.e., slope on semi-log paper
N_i = number of cells in supply air.

The supply air cfu/m^3 were measured by placing a chamber over the supply grilles and the sampler was placed inside so that only the supply air was sampled. Numerous samples were taken, and the average cfu/m^3 in the supply air was about 30 to 50, which compares favorably with the air samples taken before occupancy began in the morning.

Background cfu/m^3, as the count before occupation was called, were four to five times higher in one classroom that had a carpet with a nap (Table 5). The test was repeated and compared with uncarpeted rooms in the same school, and the background level was much higher in the carpeted room even without occupants. Comparison in the second school that had an outdoor carpet with practically no nap gave cfu/m^3 approximately the same as an uncarpeted room in the

same school.

The mechanism of the death of viable particles, which have been studied in an aerosol chamber, has shown two slopes: the initial decay, K_1, and a later decay constant, K_2. In this study, a mean decay was determined because of the length of time required for airborne bacteria sampling.

The loss of viable airborne bacteria in the air is considered as the sum of the dilution loss due to the recirculated air rate and the decay loss due to the natural occurring death in the air, which has been shown to be a function of a number of factors, one of which is relative humidity, which has a significant effect (Akers and Dimmick 1969).

The study of the separate effect of air changes per hour and relative humidity was carried out by determining the slope, K, of the decay curves. In Figure 8, a study of the effect of air-change rate in a single school at a constant relative humidity is shown. The test began at 11:55, so the cfu/m^3 are at a maximum; then the students leave, so the occupancy is zero. Curves A was are obtained by turning off the ventilation fans so that the decay represents the lowest air-change rate, caused by infiltration only, which was found with tracer-gas decay equal to, 0.30 AC/hr. At the same time, samples of air were taken with the sampler to find the decay rate of cfu/m^3 with no occupancy. This slope is given by Curve A' equal to 1.80 AC/hr. The loss of viability due to biological death is represented by the difference in slopes between A and A'. The decay rate was equivalent to 1.5 = (1.8-0.3) AC/hr. Repeating the test with the ventilation fans on, Curve B is the decay rate represented by the dilution of the ventilation air and Curves B' are the combined effect of ventilation and biological death. The biological decay rate of curve B is 5.62 - 3.0 = 2.62 AC/hr.

The increase in cfu/m^3 resulting from a reduction in recirculation rate is shown in Figure 9.

Figure 10 shows the reduction in the cfu/m^3 that occurred in one school with reduction in indoor humidity. All the data showed the same trend, that is, a reduction in indoor relative humidity resulted in a reduction of viable airborne bacteria.

Several species of the non-pathogenic airborne viables from the schools were grown in culture so they could be atomized into the air of a chamber that could be kept at a selected relative humidity. Samples taken at time intervals established the viability of the bacteria at various humidities. The tests showed that the survival time of bacteria decreased with lowered relative humidity.

Respirable dust levels of 10 micron or less showed a relationship to the cfu/m^3 increased as the duct content increased as shown in Figure 11. Whether the bacteria and their associated skin cells contributed to the dust count or vice versa is not known.

Absenteeism in the various schools and their average relative humidities and recirculation rates are shown in Table 6. These are the studies of the Grade 3 classroom in each school that had about 20 pupils each. There was a small but not significant decrease in absenteeism with increase in recirculation rate. There was no significant difference in absenteeism due to the different relative humidities in the various schools. The sample size of 20 students per class is not large enough for statistically significant results. An analyses of the entire population of the schools over several years will have to be undertaken to establish the effect of relative humidity and recirculation rate on absenteeism in schools.

DISCUSSION

Occupancy is the major factor in determining the number of viable airborne bacteria (cfu/m^3) in occupied spaces. The high dispersal rate of viables (10^7 per day per person) was demonstrated in the rapid rise of cfu/m^3 immediately after the students entered the classroom and by the rapid decrease of the counts when the students left the classroom. During the occupied period, the level of airborne bacteria (cfu/m^3) was determined mainly by the recirculation rate of air supplied to the room.

Dilution with outdoor air (measured outdoor air counts were -3.8°C, 52 cfu/m^3; 22°C, 26 cfu/m^3) where the counts were usually from 25 to 75 cfu/m^3 resulted in only a small reduction in bacteria because the outdoor air rate was about 10% to 15% of the recirculation rate.

Filters. The filter reduced the airborne bacteria count from 90% to 95% of the upstream value. The filters combined with a high recirculation rate are very effective in reducing the number of airborne bacteria.

Luciano (Luciano 1984) points out that recirculating rates of 50 AC/m were used in hospital operating rooms to reduce airborne counts to very low values. HEPA filters are not necessary, because the airborne bacteria are much larger than the 0.3 micron that this filter will remove at 99.97% efficiency. He gives bacteria retention efficiencies of greater than 99% for ASHRAE 95 DOP, 95 ASHRAE, and 85 ASHRAE, while 90 ASHRAE is rated at 98%. These findings are highly significant for air-conditioning applications, where pathogenic bacteria such as legionella and other bacteria that develop in water sprays and humidifiers (Green 1982) can be delivered from the air stream. Von Reckzeh and Warner, in their papers (Reckzeh and Dontenwill 1974; Wanner 1974) found that airborne bacteria were effectively removed with filters from the airstream of air washers.

Relative Humidity. Absolute values of the airborne bacteria in cfu/m^3 decreased as the relative humidity decreased in the classroom, and the logorithmic decay rate increased with lower humidities. Thus, the survival of the airborne bacteria detected in this study tended to be lower in the winter months. Several species of the airborne viables were grown in cultures and nebulized into a controlled relative humidity chamber, and as the relative humidity was decreased, the survival time of the airborne species was reduced. The laboratory experiments therefore confirmed the classroom determinations. In general, the reduction in cfu/m^3 with reduced humidity was not great, confirming the findings of Simard et al (Simard, Trudel, Pagnette, Payment 1983).

This finding is the opposite of Sale (Sale 1972), who showed a large decrease in the survival of airborne bacteria with higher relative humidities. His work must be suspect in that there was no determination of the ventilation or recirculation rate in his buildings.

The argument that the observed reduction in absenteeism or respiratory illness with increased relative humidity is caused by the reduced survival time at midhumidities, presented by Sale (Sale 1972), Green (Green 1974), and others, is not borne out by this study because the airborne bacteria decreased with decreasing relative humidity.

In this study, the airborne bacteria were nearly entirely nonpathogenic and were generally the same species as found by other investigators (Personal communication; Simard, Trudel, Pagnette, Payment 1983). Pathogenic bacteria, β Streptococcus and Staphylococcus, aureus were found by these investigators also. These pathogens were not found in this study in the airborne state until a severe cold period occurred in December. In the hundreds of samples taken, they were found infrequently and in small numbers in the winter period coincides with the increase in respiratory illnesses. The low numbers may not be of sigificance, as airborne sampling only recovers less the 5% of the total airborne viable particles in chamber tests.

The finding of the pathogens only in the winter months may mean that they have a different survival pattern with relative humidity than do the airborne bacteria found. This is quite possible, as many bacterial and viral pathogens do exhibit the lower survival times at midhumidities. Most of the midwinter infections are not bacterial infections but are viral infection and this investigation was not instrumented to isolate them. Simard et al (Simard, Trudel, Pagnette, Payment 1983) sampled 48 m^3 of air in an apartment exhaust duct every week for 20 weeks with a large volume sampler and did not detect a single virus.

CONCLUSIONS

The investigation of the effect of relative humidity and ventilation on the airborne bacterial content of air in schools revealed the following:

1. The number of airborne bacterial colony-forming units per cubic meter of air in schools is highly dependent on the number of occupants in the classroom. Therefore, any study of the effect of room environment on airborne bacteria must take into account the variation of them with the number of occupants.

2. The cfu/m^3 number of airborne bacteria in the classroom were mostly removed by filtration of recirculated air.

3. Ordinary filters with high air recirculation rates are highly effective in removing airborne bacteria from rooms. They may constitute a means for protecting building occupants from bacterial pathogens produced by sprays, humidifiers, and other conditioning equipment that could produce illness by causing airborne bacteria.

4. A decrease in indoor relative humidity reduced the number of cfu/m^3 in the air. Other studies that showed the opposite did not take into account the variation in number of occupants and the effect of ventilation and air recirculation.

5. This study did not substantiate the hypothesis that the reduction in absenteeism and respiratory illnesses in winter with increased indoor relative humidity is caused by the reduction in airborne microorganisms with increased humidity.

6. Pathogenic bacteria were only found in the midwinter season.

While this investigation revealed many aspects of airborne bacterial contamination in schools that may be significant to all buildings, further investigations will have to be undertaken to substantiate the findings.

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TABLE 1
Investigation of Effect
Of Relative Humidity on Absenteeism

INVESTIGATION	LOCATION	POPULATION	AVERAGE RELATIVE HUMIDITY %	TEST DATES
Serati Wuthrich	BERN, SWITZERLAND	100 WOMEN, OFFICE WORKERS	40 (31)	REPLICATED NOV - JAN. 1964-65 NOV - JAN. 1965-66
Colperin	MISSOURI, U.S.A.	800 MEN, ARMY RECRUITS	40(20)	REPLICATED OCT - DEC 1970 JAN.-MARCH 1971
Goberin Dong Sweetman	GENEVA, SWITZERLAND	812 MEN, OFFICE WORKERS	52(30-33)	JAN - MARCH 1976
		509 WOMEN, OFFICE WORKERS	55(30-33)	
Green	SASKATOON, CANADA	2400 HOSPITAL STAFF	30(20)	REPLICATED OCT.-APRIL 1974-75, 1975-76, 1976-77
Ritzel	BASEL, SWITZERLAND	KINDERGARTEN, 210 CHILDREN	49(40)	ABSENCE DUE TO COLDS - 9 WEEKS JANUARY - MARCH 1966
Green	SASKATOON, CANADA	1-8, 3600 CHILDREN	27-33 (22-26)	ALL ABSENCES - 2 YEARS OCTOBER - APRIL 1960, 1970
Sataloff Menduke	ARDMORE, PA	1-3, EST. 130 CHILDREN	29(26)	ABSENCE DUE TO ILLNESS - 17 WEEKS 1960
Sale	NORFOLK, VA	NURSERY, 263 CHILDREN	51(35)	ALL ABSENCES - 17 WEEKS NOVEMBER - MARCH 1972

( ) NONHUMIDIFIED %

TABLE 2
School Heating and Ventilating Systems

School	Heating System	Humidifying System	Outdoor Air Per Person	Recirculation Rate Ac/Mr	Room Vol.+ Per Student	
					m^3	ft^3
C	Natural Gas Warm - Air	Air Washer	1.5 L/sec 3 cfm	2.6	15	525
HC	Natural Gas Warm - Air	Air Washer	1.5 L/sec 3 cfm	3.0	8.2	287
KG	Steam Radiators	Air Washer	5.0 L/sec 100 cfm	All Fresh Air 1.22	15	525
NP	Hot Water Radiators	None	1.5 L/sec 3 cfm	3.00	13	455
QE	Unit Ventilators	None	*	0.63	13.6	476
W	Unit Ventilators	None	*	0.63	15	527

* Unit ventilator controls were set with minimum fresh air when heating was required opening to admit outdoor air as cooling was required.

\+ 20 students was average in all schools

TABLE 3
Bacterial Species Isolated

VENTILATION DUCTS APARTMENTS		SWISS OFFICE	SASKATOON SCHOOLS
Airborne bacteria	C.f.u./m^3 of air		
Micrococcus spp.	7.28	*Micrococcus*	
Staphylococcus spp.	3.21		
Staphylococcus aureus	0.08	*Staphylococcus aureus*	*S. Aureus*
Aerococcus viridans	2.37		
Streptococcus (group D)	0.89		
S. (group viridans)	0.55	*Streptococcus* spp.	*Streptococcus* spp.
S. spp. (other groups)	1.54		
Bacillus cereus	0.26		
B. Subtilis	0.19	*Bacillus* spp.	*Bacillus* spp.
B. spp. (other groups)	1.17		
Corynebacterium xerosis	0.25		
C. ulcerans	0.12		
C. haemolyticum	0.03	*Corynebacterium* spp.	*C.* spp.
C. spp. (other groups)	0.10		
Enterobacter agglomerans	0.06		
Acinetobacter calcoaceticus	0.86		
Pseudomonas vesicularis	0.22		
P. spp. (groups CDC)	0.26		
P. putrefasciens	0.07		
P. picketti	0.06		
P. paucimobilis	0.03		
P. spp. (other groups)	0.06		
Moraxella osloensis	0.34		
Branhamella catharrhalis	0.31		
Flavobacterium meningosepticum	0.13		
Other non-fermentative gram-negative bacilli	0.31	Gram-negative bacilli	Gram-negative bacilli
Neisseria spp.	0.07		*Neissera* spp.
Total	21.82 c.f.u./m^3		

TABLE 4
Pathogenic Bacteria

ROOM ISOLATIONS

	Haemolytic Streptococci	Straphylococcus Aureus
Dec	5/910	1/910
Jan	13/705	2/269
	3/512	1/745
Feb	1/299	1/1313
	1/705	
	1/1482	
	1/255	
Mar	1/332	1/247

TABLE 5
Unoccupied CFU

	Carpeted	Bare Floor	School
High Nap	200-250	30-50	W
Low Nap (Outdoor Carpet)	35-88	31-66	HC

TABLE 6
Air Change Rate Relative Humidity and Absenteeism

Schools	Attendance (RH)							
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Churchill ACR = 2.61	97.74 (38)	95.29 (34)	97.98 (35)	98.66 (28)	97.63 (22)	96.84 DNA	93.89 DNA	96.86
Queen Eliz. ACR = 0.63	98.92 (30)	97.20 (31)	94.1 (27)	90.18 (9)	97.84 (31)	96.95 DNA	95.18 DNA	95.77
King George ACR = 1.86	94.30 (48)	99.07 (30)	93.39 (29)	93.70 (29)	93.75 (24)	94.74 DNA	90.13 DNA	94.15
Howard Coad ACR = 3.0	99.2 (41)	98.5 (33)	95.7 (44)	92.13 (27)	96.35 (30)	97.48 DNA	97.14 DNA	96.64
Wilson ACR = 0.62	97.47 (30)	97.76 (32)	97.39 (31)	91.83 (18)	91.19 (21)	90.76 DNA	93.43 DNA	94.26
North Park ACR = 3.0	94.79 (41)	96.99 (27)	97.99 (20)	98.95 (11)	96.58 (11)	98.81	93.42	

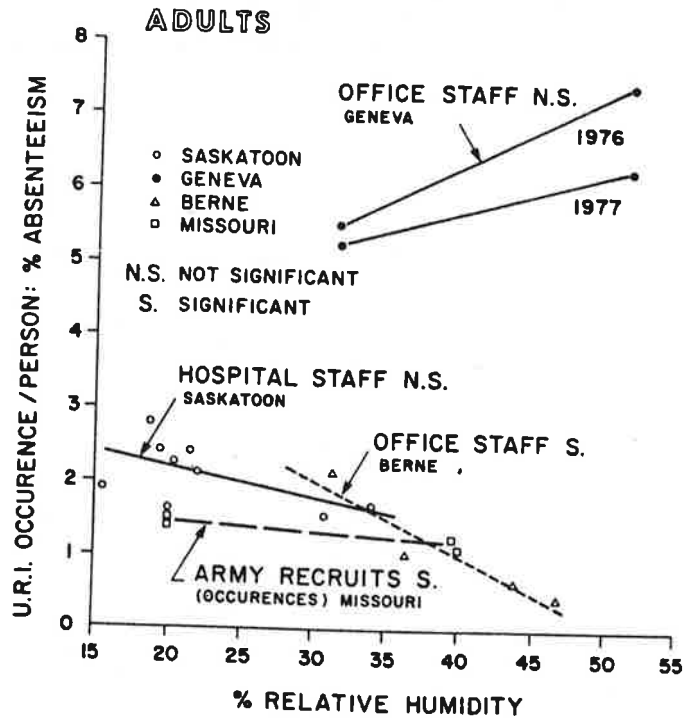

Figure 1. Effect of relative humidity on absenteeism of adults

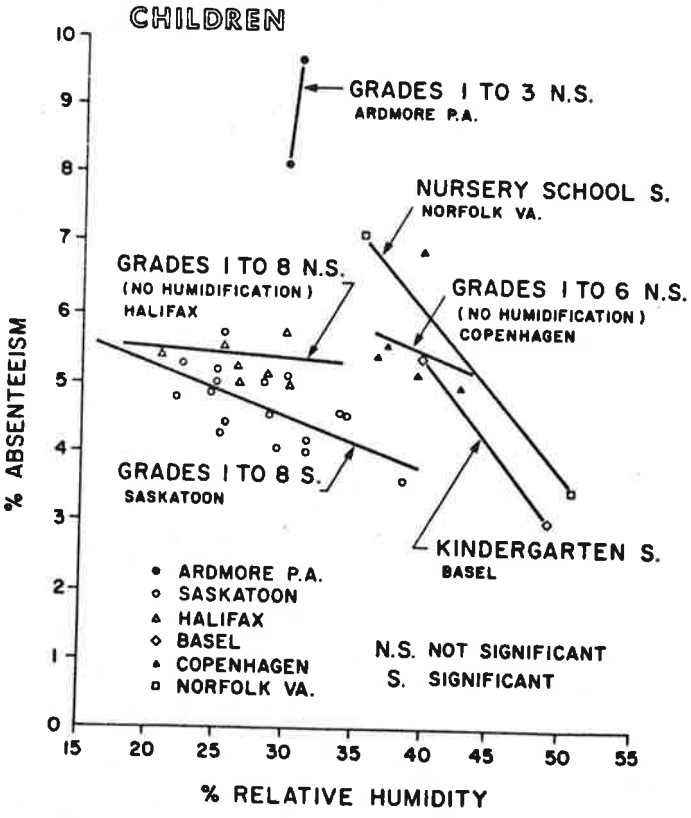

Figure 2. Effect of relative humidity on absenteeism of children

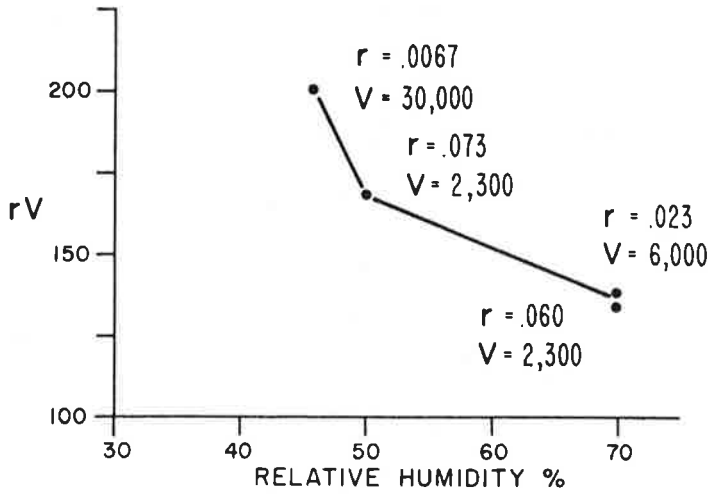

Figure 3. Airborne transmission of Influenza Virus infection in mice, r, effective transmission rate; v, airflow cc/min

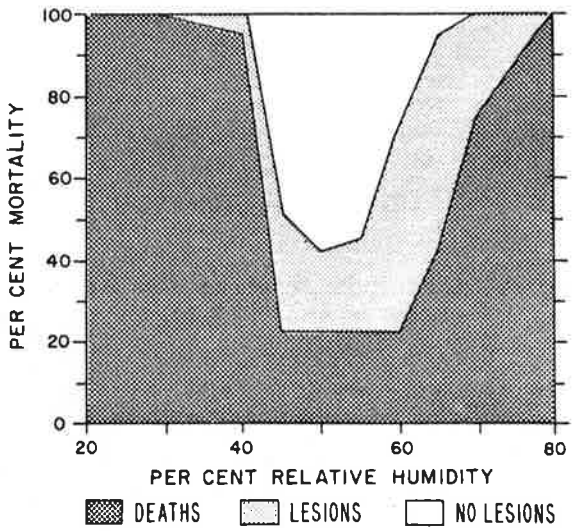

Figure 4. Morality of white mice exposed to Influenza Virus at various relative humidities

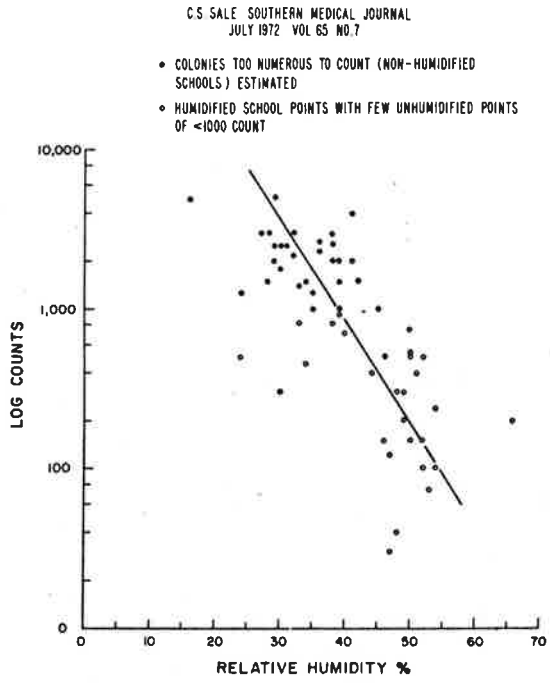

Figure 5. Airborne bacteria counts versus indoor relative humidity

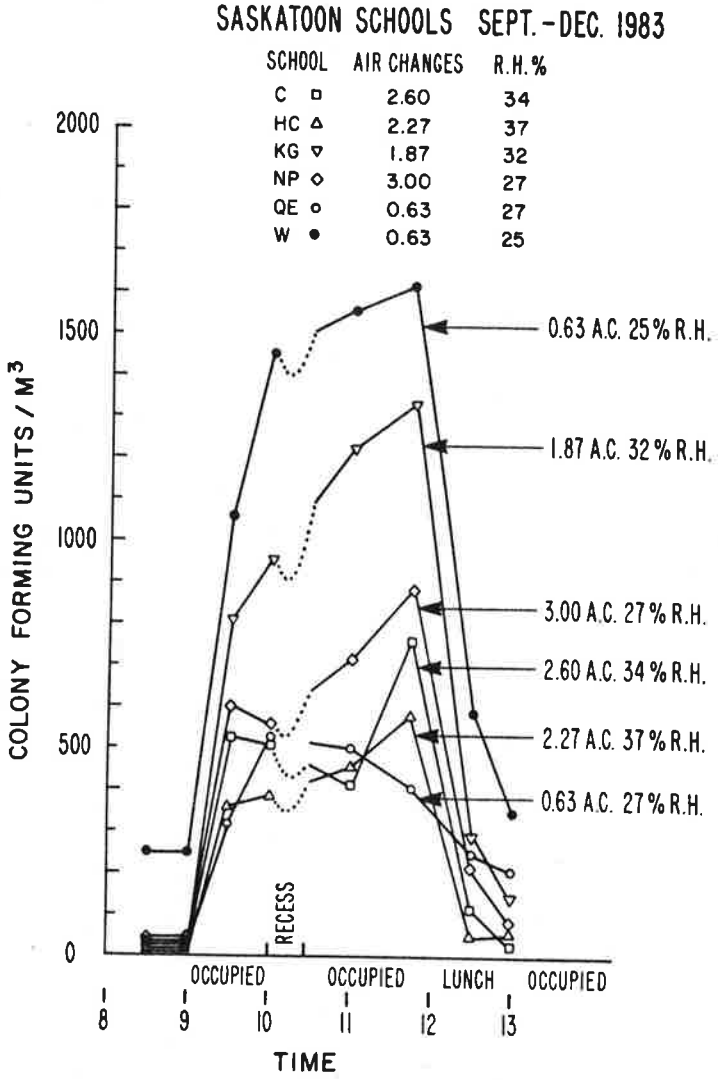

Figure 6. Airborne microorganisms, variation with time in schools

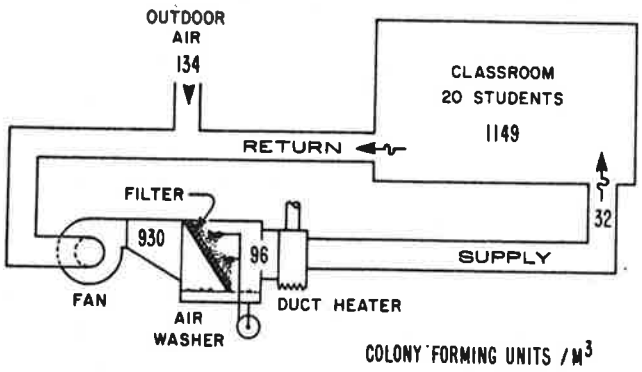

Figure 7. Typical values of cfu/m^3 in air-handling system with air washer off

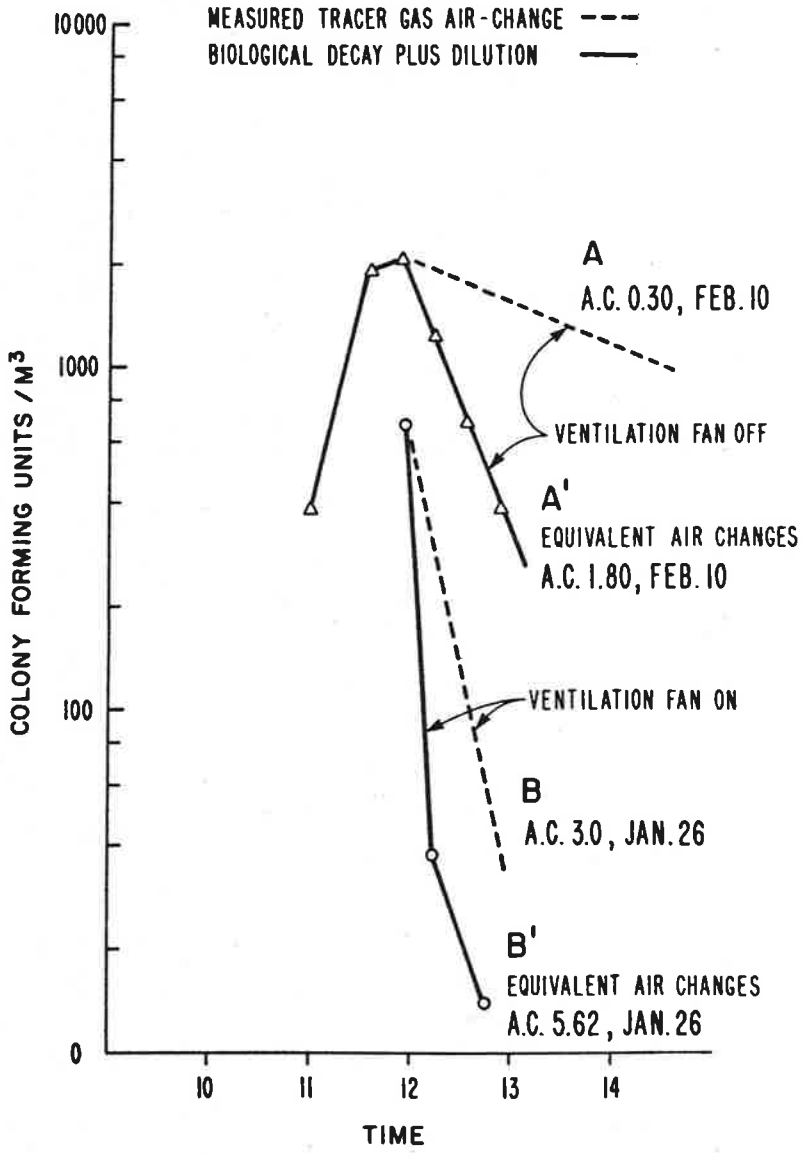

Figure 8. Decay rate of microorganisms and air change rates

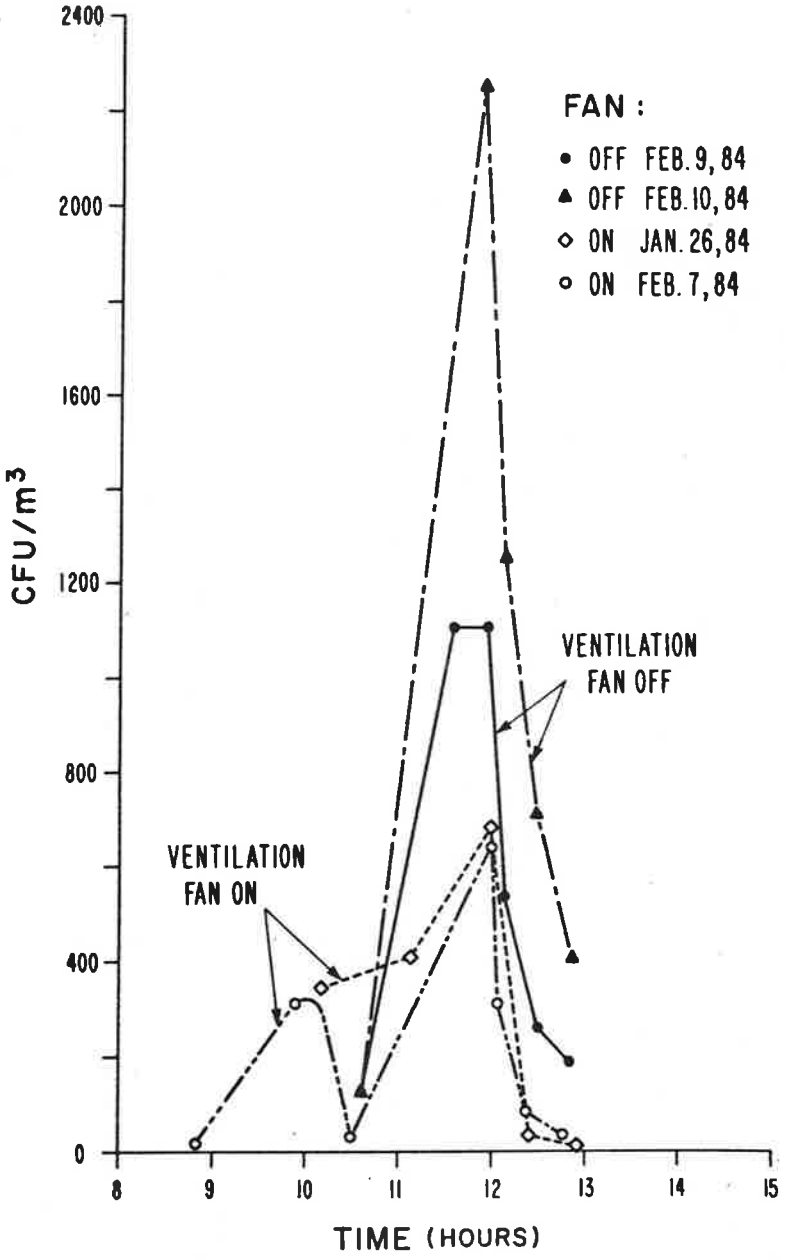

Figure 9. Effect of ventilation rate on airborne bacteria concentration

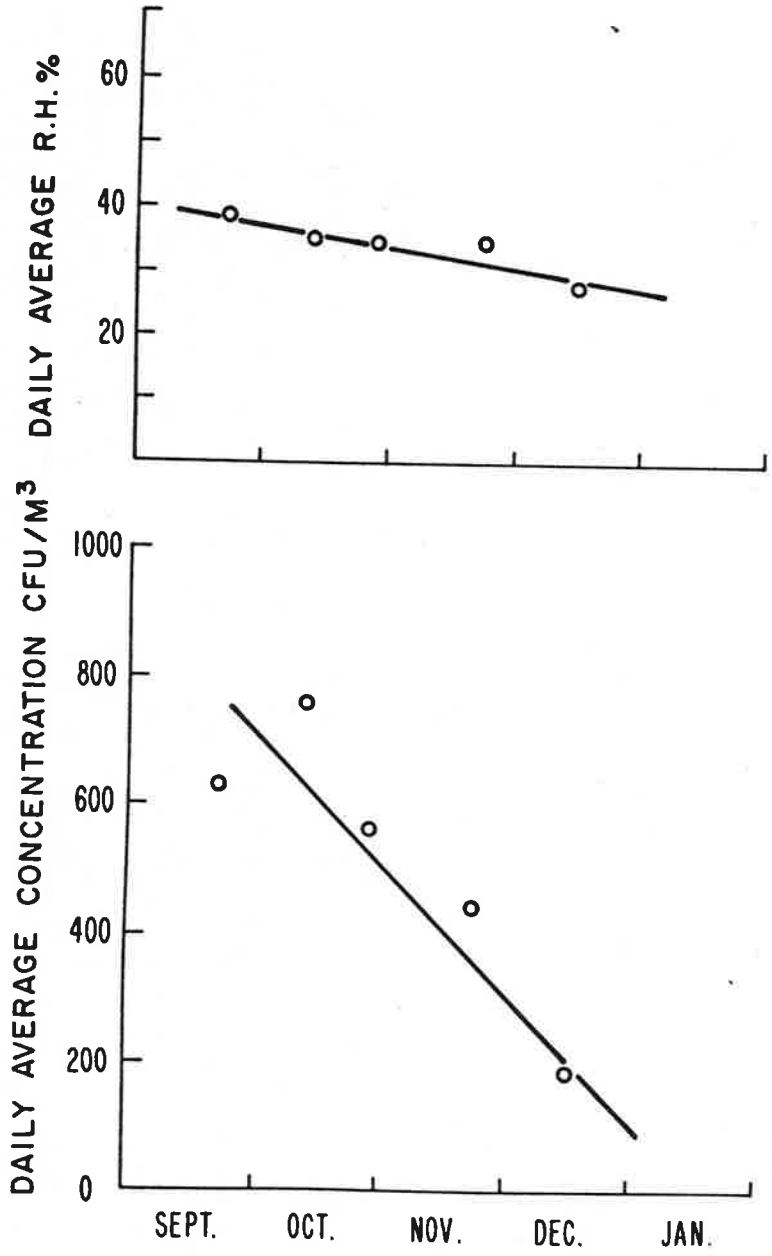

Figure 10. Effect of indoor relative humidity on airborne bacteria concentration

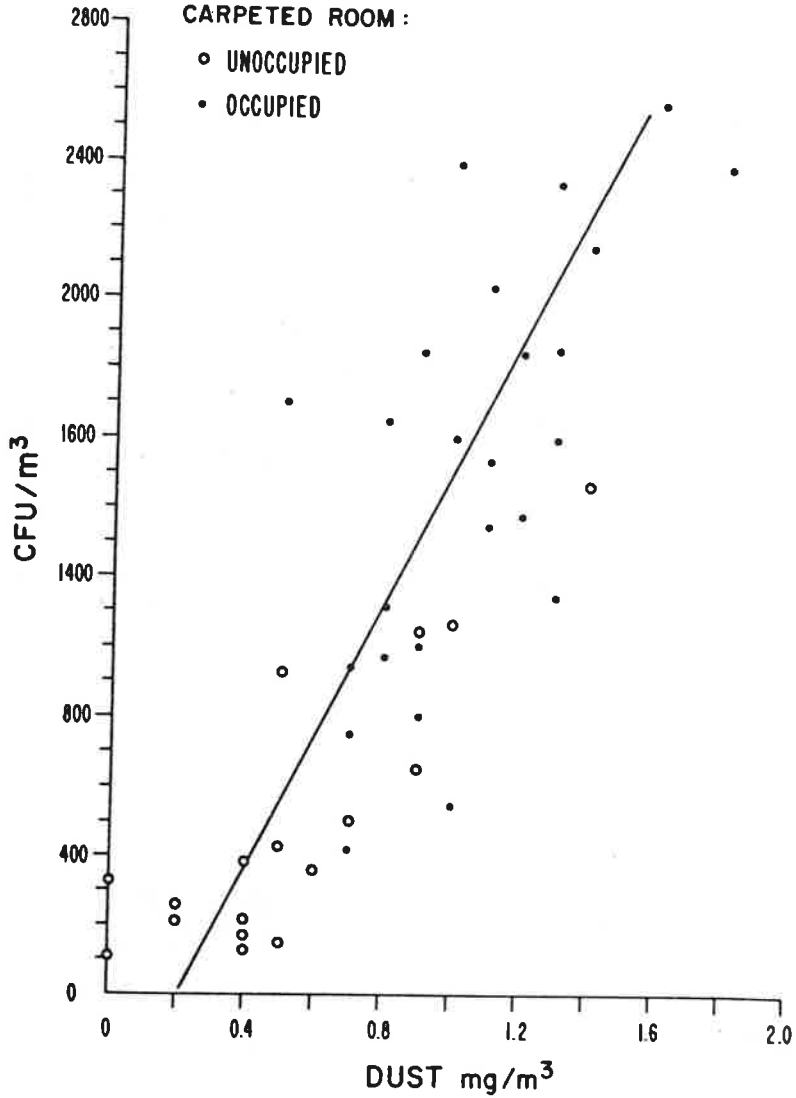

Figure 11. Respirable dust concentration versus airborne bacteria concentration

Discussion

P.R. MOREY, Niosh-CDC, Morgantown, WV: A water spray system (air washer) was utilized to provide humidification. In some office buildings air washers have been shown to be strong sources of airborne thermophilic actinomycetes, fungi, and protozoa (Kreiss and Hodgson 1984, Indoor Air Quality, CRC Press; Morey, Hodgson, Sorenson, Kullman, Rhodes, and Visvesvara 1984, Environmental Studies in Moldy Office Buildings: Biological Agents, Sources and Preventive Measures, Vol. 10). Did you attempt to collect any of these agents? Did you look for signs of illnesses, such as humidifier fever? Are air washer humidification systems widely used in schools in Saskatchewan?

MOREY: According to your presentation, the level of airborne bacteria decreased by about one log order when air was moved through the air handling unit containing an air washer. Were bacteria removed by the filter bank, by the scrubbing action of the air washer itself, or both? What was the atmospheric dust spot efficiency of the filter bank? What type of preventive maintenance program is used to prevent the air washer from acting as a source of microorganisms (eg., disinfection or control of microorganisms in air washer pump waters, filter replacement schedule)?