# Staff Meeting Bulletin
# Hospitals of the » » »
# University of Minnesota

## The Disinfection of Air

Volume XIX | Friday, March 12, 1948 | Number 19

STAFF MEETING BULLETIN
HOSPITALS OF THE . . .
UNIVERSITY OF MINNESOTA

Volume XIX | Friday, March 12, 1948 | Number 19

INDEX



Published for the General Staff Meeting each week
during the school year, October to June, inclusive.

Address communications:

Staff Bulletin
332-M University of Minnesota Hospitals
Minneapolis 14, Minnesota

# UNIVERSITY OF MINNESOTA MEDICAL SCHOOL
## CALENDAR OF EVENTS

Visitors Welcome

March 15 - March 20, 1948

No. 194

Monday, March 15

9:00 - 9:50 Roentgenology-Medicine Conference; L. G. Rigler, C. J. Watson and Staff; Todd Amphitheater, U. H.

9:00 - 10:50 Obstetrics and Gynecology Conference; J. L. McKelvey and Staff; Interns' Quarters, U. H.

9:15 - Fracture Rounds; A. A. Zierold and Staff; Ward A, Minneapolis General Hospital.

10:00 - 12:00 Neurology Ward Rounds; A. B. Baker and Staff; Station 50, U. H.

11:00 - 11:50 Roentgenology-Medicine Conference; Staff; Veterans' Hospital.

11:00 - 12:00 Cancer Clinic; K. Stenstrom and D. State; Eustis Amphitheater, U. H.

12:15 - 1:20 Obstetrics and Gynecology Journal Club; M-435, U. H.

12:30 - 1:50 Surgery Grand Rounds; A. A. Zierold, Clarence Dennis and Staff; Minneapolis General Hospital.

1:30 - 2:30 Pediatric-Neurological Rounds; R. Jensen, A. B. Baker and Staff; U. H.

4:00 - 5:00 Pediatric Seminar; Streptomycin; Warren Anderson; 6th Floor Seminar Room, U. H.

5:00 - 6:00 Urology - Roentgenology Conference; D. Creevy and H. M. Stauffer and Staffs; M-515, U. H.

Tuesday, March 16

8:30 - 10:20 Surgery S minar; Lyle Hay; Small Conference Room, Bldg. I, Veterans' Hospital.

9:00 - 9:50 Roentgenology Pediatrics Conference; L. G. Rigler, I. McQuarrie and Staff; Eustis Amphitheater, U. H.

10:30 - 11:50 Surgical Pathological Conference; Lyle Hay and Robert Hebbel; Veterans' Hospital.

12:30 - 1:20 Pathology Conference; Autopsies; Pathology Staff; 102 I. A.

2:00 - 2:50 Dermatology and Syphilology Conference; H. E. Michelson and Staff; Bldg. III, Veterans' Hospital.

| | |
|---|---|
| 3:15 - 4:20 | Gynecology Chart Conference; J. L. McKelvey and Staff; Station 54, U. H. |
| 3:30 - 4:20 | Clinical Pathological Conference; Staff; Veterans' Hospital. |
| 4:00 - 5:30 | Surgery-Physiology Conference; O. H. Wangensteen and M. L. Visscher; Eustis Amphitheater, U. H. |
| 4:00 - 5:00 | Pediatric Rounds on Wards; I. McQuarrie and Staff; U. H. |
| 5:00 - 5:50 | Roentgenology Diagnosis Conference; J. Richards Aurelius, and Staff of Ancker Hospital; M-515, U. H. |

Wednesday, March 17

| | |
|---|---|
| 8:00 - 8:50 | Surgery Journal Club; O. H. Wangensteen and Staff; M-515, U. H. |
| 8:30 - 12:00 | Neurology Rehabilitation and Case Conference; A. B. Baker and Joe R. Brown; Veterans' Hospital. |
| 11:00 - 11:50 | Pathology-Medicine-Surgery Conference; Hypertensive Heart Disease; O. H. Wangensteen, C. J. Watson and Staff; Todd Amphitheater, U. H. |
| 4:00 - 5:00 | Infectious Disease Rounds; Todd Amphitheater, General Hospital, Veterans' Hospital. |

Thursday, March 18

| | |
|---|---|
| 8:15 - 9:00 | Roentgenology-Surgical-Pathology Conference; Walter Walker and H. M. Stauffer; M-515, U. H. |
| 8:30 - 10:20 | Surgery Grand Rounds; Lyle Hay and Staff; Veterans' Hospital. |
| 9:00 - 9:50 | Medicine Case Presentation; C. J. Watson and Staff; Todd Amphitheater, U. H. |
| 10:00 - 11:50 | M dicine Ward Rounds; C. J. Watson and Staff; E-221, U. H. |
| 10:30 - 11:50 | Surgery-Radiology Conference; Daniel Fink and Lyle Hay; Veterans' Hospital. |
| 11:00 - 12:00 | Cancer Clinic; K. Stenstrom and D. State; Eustis Amphitheater, U. H. |
| 1:00 - 1:50 | Fracture Conference; A. A. Zierold and Staff; Minneapolis General Hospital. |
| 4:30 - 5:20 | Ophthalmology Ward Rounds; Erling W. Hansen and Staff; E-534, U. H. |

Friday, March 19

| | |
|---|---|
| 8:30 - 10:00 | Neurology Grand Rounds; A. B. Baker and Staff; Station 50, U. H. |
| 9:00 - 9:50 | Medicine Grand Rounds; C. J. Watson and Staff; Todd Amphitheater, U.H. |
| 10:00 - 11:50 | Medicine Ward Rounds; C. J. Watson and Staff; E-221, U. H. |

10:30 - 11:20 Medicine Grand Rounds; Staff; Veterans' Hospital.

10:30 - 11:50 Otolaryngology Case Studies; L. R. Boies and Staff; Out-Patient Department, U. H.

11:00 - 12:00 Surgery-Pediatric Conference; C. Dennis, A. V. Stoesser and Staffs; Minneapolis General Hospital.

12:00 - 1:00 Surgery Literature Conference; Clarence Dennis and Staff; Minneapolis General Hospital, Small Class Room.

1:00 - 1:50 Dermatology and Syphilology; Presentation of Selected Cases of the Week; H. E. Michelson and Staff; W-312, U. H.

1:00 - 2:50 Neurosurgery-Roentgenology Conference; W. T. Peyton, Harold O. Peterson and Staff; Todd Amphitheater, U. H.

Saturday, March 20

7:45 - 8:50 Orthopedics Conference; Wallace H. Cole and Staff; Station 21, U. H.

8:00 - 9:00 Pediatric Psychiatric Rounds; Reynold Jensen; 6th Floor West Wing, U. H.

8:00 - 9:30 Psychiatry and Neurology Grand Rounds; Staff; University Hospitals.

9:00 - 10:30 Pediatric Grand Rounds; I. McQuarrie and Staff; Eustis Amphitheater, U. H.

9:00 - 9:50 Surgery-Roentgenology Conference; O. H. Wangensteen, L. G. Rigler, and Staff; Todd Amphitheater, U. H.

9:00 - 9:50 Medicine Case Presentation; C. J. Watson and Staff; M-515, U. H.

10:00 - 11:50 Medicine Ward Rounds; C. J. Watson and Staff; M-515, U. H.

10:00 - 12:50 Obstetrics and Gynecology Grand Rounds; J. L. McKelvey and Staff; Station 44, U. H.

\- - -

NOTICE

The DeVilbiss Company is showing a film "Occupation Health Problems" on Tuesday, March 16th at 2:30 P.M. in Eustis Amphitheater. Among the subjects covered in this film are:

The Common Cold in Industry

Basic Principles of Aerosol Therapy

Care of Industrial Dermatitis

The Treatment of Burns

Anyone interested is invited to attend.

Florence Julian,
Chairman, Supervisor-Head Nurse Group

## II. THE DISINFECTION OF AIR

Gaylord W. Anderson
Harold A. Whittaker

Air hygiene has been a subject of concern to scientists and to public health workers for more than a century.

Many theories have been expounded on air as a vector in the spread of disease including the early fallacious belief that "miasma" was responsible for the dissemination of a long list of diseases including some of intestinal origin.

As late as 1849 Sir William Farr, an early epidemiologist, presented information to show that a cholera epidemic in London was air-borne but another epidemiologist, Dr. John Snow, produced more conclusive evidence to prove that the epidemic was water-borne.

A large amount of research has been undertaken since the early theories were abandoned which research has led to a better understanding of the problems associated with air-borne infection. It would appear that air hygiene presents two fundamental questions:

1. Is air-borne infection a significant mode of transmitting disease?

2. Have effective and practical methods been developed to prevent or minimize the spread of air-borne infection?

An attempt is made in the discussion that follows to present a summary of information which may be helpful in formulating an opinion on the present status of these questions.

The possibility of control of respiratory diseases through disinfection of air must of necessity rest on the assumption that air is an important vehicle for the transmission of infection. If it is an important vehicle, measures which will either sterilize the air or at least markedly reduce its degree of contamination will undoubtedly bring about a significant reduction in the incidence of such infections. On the contrary if air is not important as a vehicle for the dissemination of respiratory infection, little can be expected through air sanitation.

It is necessary at the outset to define what is meant by "air-borne infection". There is a general assumption, based not on scientific experiment but on general deduction, that the organisms of many diseases enter the body through the respiratory tract; in other words that they are inhaled. Such an assumption, which has been accorded universal acceptance, does not of necessity imply indirect spread through contaminated air as a vehicle. On the contrary close respiratory association may result in an almost immediate transfer of microorganisms from the nose and throat of one person to the nose and throat of another. If anyone has any doubt of the existence of such immediate exchange of infection, he need only observe a group of students on the University Campus on a subzero day to witness one student's face enveloped in the visible exhalations of his associates. Identical, though less obvious, phenomena surround us constantly and are favored by crowding. Such transfer of infection represents a direct spread of organisms, which pass almost instantaneously from person to person; it thus constitutes direct spread and is not to be thought of as air-borne.

Nor is such direct exchange through association likely to be affected by measures for air disinfection or sterilization. To be effective under such circumstances, the measures would of necessity require instantaneous germicidal action in order to kill organisms in the few seconds or even the fraction of a second that elapse after the organisms leave the body of the donor and before they enter the body of the recipient of the infection. This would require either a very high concentration of germicidal aerosol or location of irradiation in such a manner as to reach all vaporized nasal and throat secretions under all circumstances. It is not far fetched to point out that the latter could be achieved only by hanging an ultra-violet light or similar radiant device on our respective, and we hope, respectable noses.

The term "air-borne infection" implies that the organisms are discharged into the air where they remain suspended for an appreciable period of time, later to be inhaled by a person who has not necessarily had any contact or association with the person who, through his exhalations, contaminated the air. Those of us who are together in this room may well exchange infection directly as we crowd the exits at the end of this conference, but this would not necessarily represent air-borne infection; on the contrary most of it would represent direct spread through association. On the other hand, we have all through our mere presence in this room contaminated the air through our exhalations. Any of our organisms breathed in by those who follow us in this room, and who have had nothing in common with us other than the fact that they have occupied the room that we have vacated, will be truly air-borne, and infections so acquired can truly be classified as air-borne infections. The distinction is thus basically a matter of the time that elapses before the transfer is completed, yet the possibilities of control are vastly different.

The concept of air-borne infection, like so many other concepts, is not a new one. During the latter part of the last century, there was a general assumption that diseases could be spread great distances through the medium of air. This assumption was given tangible expression in our insistence that the communicable disease hospitals, commonly referred to as pest houses, be placed well outside the city limits and on the side of the city away from the prevailing winds so that the emanations would not be wafted toward the community.

Although many of these practices had been begun in the prebacteriological era of miasmata, they were retained as a part of the bacteriological concept until discarded around the turn of the century through the work of Flueggo and Chapin. The former demonstrated to his and other's satisfaction that bacteria exhaled from either nose or throat followed the laws of ballistics and fell to the earch according to mathematically deducible trajectories. It was assumed, therefore, that they would not remain suspended in the air. About the same time Chapin emphasized the role of carriers and missed cases as sources of infection. On this basis, it was not necessary to postulate air transmission to account for the development of infection in a person who had had no apparent association with a previous case. Association with an unrecognized case or carrier provided a satisfactory explanation. The hypothesis of air-borne infection accordingly fell into disrepute, undermined alike by the laboratory and the epidemiologist. The previously outcast pest-house became a respectable city resident, and cases of diverse respiratory infections were treated in open wards with no further precautions than aseptic nursing technique.

This comfortable era of disbelief in air-borne infection persisted to the early 1930's in spite of certain disquieting observations as to the inadequacies of the concept. Experience showed that certain virus infections such as measles and chickenpox could not be hospitalized in open wards and cared for through mere aseptic nursing technique without some cross infections. Furthermore periodic episodes such as the 1930 outbreak of psittacosis at the old Hygienic Laboratory of the U. S. Public Health Service showed clearly that infection might spread within a building to persons whose closest contact with infected animals or material was their passing a locked door behind which such material was kept or even their employment two floors distant from this room. Such observations suggested clearly that under certain circumstances air might serve as a vehicle of at least some infections. Subsequent experience with Q-fever has been equally suggestive of air-borne infection.

In the early 1930's the work of Wells, made possible through the development of an air centrifuge for the collection of air samples, demonstrated clearly that bacteria and viruses can survive in air for considerable periods of time. Wells showed that whereas certain of the organisms follow the trajectories of Fluegge, others remain suspended in the air for many hours (even 24 hours), moving hither and yon with the air currents. Nor do such organisms become dry and, therefore, lose their viability. It was shown that they are surrounded with a thin film of moisture, closely adherent through capillary attraction and, therefore, subject to extremely slow evaporation. Whereas the larger particles do obey the law of ballistics, these finer particles, referred to as droplet nuclei and possibly consisting of single organisms with protective coating of moisture, remain suspended and viable for long periods and can, therefore, be inhaled by a new host. Extensive studies were made of the factors regulating the degree of air contamination. Basically this is conditioned by the crowding of those contaminating the air, the duration of their presence, the violence of their exhalation and the incidence of upper respiratory tract infection. Wells and his colleagues as well as other students of aerobiology further demonstrated that air so contaminated could be disinfected by ultra-violet irradiation. Robertson later introduced the concept of chemical sterilization through fine disinfectant mists or aerosols, a concept strangely reminiscent of the antiseptic mists of Lister.

The observations so recorded were facts, well substantiated by repeated laboratory observations. Unfortunately there followed a rather hasty assumption that since microorganisms were recoverable from air, this air must of necessity be an important vehicle for the transmission of respiratory tract infections. In other words, it was assumed that the role and importance of air as a vehicle of transmission had been demonstrated. It was furthermore assumed that since air could be disinfected, control of respiratory infections through air disinfection was an obvious corollary. Medical journals were joined by the Sunday supplements and commercial advertisers in predictions of the era in which respiratory infections would be controlled through air disinfection in exactly the same manner as the spread of certain intestinal infection has been controlled through water disinfection. In many circles it was hardly popular to hold contrary views.

It does not, however, follow that because viable pathogens can be isolated from the air, any appreciable number of infections can be or are so acquired. There is, as always, a vast difference between a bacteriologic possibility and an epidemiologic probability. Even if it is granted that certain infections can be spread through the medium of air, it does not follow that this is the usual mode of transfer or that the bulk of these infections are so transmitted in contradistinction to spread through direct association. Before we can determine the possibilities inherent in air disinfection, it is necessary to know how much infection is so spread and under what conditions it is spread.

Unfortunately there is no simple way to demonstrate the mode of spread of such infections or to measure directly the relative amounts spread through air and through association. If someone in this room should develop an infection as a sequel to this meeting, he will not know if it was acquired through contaminated air breathed while he was sitting here quietly or through direct association with someone who on the way out of the room breathed, spoke or coughed directly into his face. The only evidence that we have so far been able to acquire is through the measurement of the incidence of infection under controlled conditions which decrease or eliminate air contamination, comparing this group with a control group which has had no such protection. If the group are otherwise comparable we can assume that the reduction in incidence is due to the air sanitation measures and that that portion of the total disease so eliminated is that which was truly air-borne. These studies are based on the well demonstrated fact that such methods as ultra-violet irradiation and dispersion of aerosols can totally or partially disinfect air, and that use of floor oils or oil impregnation of bedding can reduce the degree of dust and bacterial contamination of air.

Neither time nor space permit a comprehensive review of a large and confusing literature. A few examples will, however, suffice to show the current status of our knowledge of the extent to which infections can be and are airborne, and the relative importance of this mechanism as contrasted with other modes of spread.

1.) Operating room infection--
Numerous observers, and notably Deryl Hart, have shown that the incidence of wound infection can be substantially reduced by air sterilization. This is particularly evident in connection with chest surgery in which extensive incisions are usual, thus exposing a large open area to possible air contamination. Tables I and II, extracted from one of Hart's publications, show the extent to which such infection may be reduced through air disinfection.

Table I

Effect of Irradiation of Air on Infections Following Chest Surgery

| | With Irradiation | Without Irradiation |
|---|---|---|
| Operations | 132 | 110 |
| Infections | 5 | 36 |
| % infected | 3.8 | 33.0 |
| Mortality from infection | 0 | 4 |

Table II

Effect of Irradiation of Air on Temperature Elevations following Chest Surgery

| Before Operation | | | | | After Operation | | | |
|---|---|---|---|---|---|---|---|---|
| With Irradiation | | Without Irradiation | | Temperature | With Irradiation | | Without Irradiation | |
| No. | % | No. | % | | No. | % | No. | % |
| 114 | 86.4 | 97 | 88.2 | $37^\circ$-$37.5^\circ$ | 30 | 67 | 2 | 32 |
| 15 | 11.4 | 12 | 10.8 | $37^\circ$-$38^\circ$ | 58 | | 33 | |
| 3 | 2.2 | 1 | 1.0 | $37^\circ$-$39^\circ$ | 38 | | 58 | |
| 0 | 0 | 0 | 0 | $37^\circ$-$40^\circ$ | 5 | 33 | 16 | 68 |
| | | | | $37^\circ$-$41^\circ$ | 1 | | 1 | |

These similar findings of other investigators have been well substantiated and accepted. They admit of little controversy but possibly some interpretation. It should be pointed out that these results were obtained with exposed tissue from which the natural mechanical barriers to infection had been removed. Thus a small dose of organisms such as might be found in air may be of far greater significance in open wounds than in the nose or throat where the usual defensive barriers are intact and a larger dose may be required to set up an infection. Furthermore, the victim is immobilized, his wound is theoretically exposed to only one source of infection, viz., air, and this source is subject to control. Inferences drawn from the successful reduction of wound infection are obviously not transferable to infection of the respiratory tract of a person circulating freely within the community.

2.) Institutional Care of Patients Confined to Bed --
This group of patients resembles the former in that it is confined to a small space in which the contacts can be carefully limited and in which the air can be strictly controlled. Several groups of this character have been studied from which the following examples of apparently successful control of respiratory tract infection through air disinfection are selected:

a.) Premature babies -- Table III, adapted from the work of Elizabeth Robertson and her colleagues in Toronto, shows the effect of ultra-violet irradiation of air in protecting premature infants.

Table III

Respiratory Infections in Premature Infants

| | No. of Babies | Number Infected | % Infected |
|---|---|---|---|
| Irradiated wards | 28 | 8 | 29 |
| Control wards | 24 | 12 | 50 |

Stand.dev. of diff. in rates = 13.4

Act. diff. = 21 $\frac{21}{13.4} = 1.6$

- - -

These results, which are not the best that have been reported, suggest some protection even though the data are not statistically significant. They indicate clearly, however, that air sterilization does not remove all possibility of infection and that either the methods of irradiation are defective or that there are other important sources of infection than the air itself.

b.) Other children-- Numerous reports of attempts to reduce the incidence of cross infections in the pediatric nursery through air sterilization are available. Robertson and her associates (Table IV) found a substantial and statistically significant reduction.

Table IV

Respiratory Infection in Pediatric Ward

| | No. of Babies | Number Infected | % Infected |
|---|---|---|---|
| Irradiation | 56 | 12 | 21 |
| Control | 60 | 36 | 60 |

Stand. dev. diff. = 8.4
Act. diff. = 39 $\frac{39}{8.4} = 4.6$

Harris and Stokes in a comparable study of various aerosols (propylene and triethylene glycols) found even more striking results in presumably comparable but unspecified and, therefore, statistically unanalyzable groups of older children (Table V):

Table V

Incidence of Respiratory Infections

| | Glycol used | Aerosol Wards | Control Wards |
|---|---|---|---|
| 1941-42 | Propylene | 2 | 16 |
| 1942-43 | Propylene | 5 | 100 |
| 1943-44 | Tri-ethylene | 6 | 16 |
| | | 13 | 132 |

- - -

Numerous other reports suggest comparable results though failures to achieve a reduction have also been reported. It would seem fair to conclude, however, that so long as these patients are confined to limited areas through enforced bed rest, some reduction in incidence of respiratory infections may be achieved through air sterilization.

3.) School group -- Studies of school children bring into play a most important factor that has been eliminated in the foregoing studies, viz., periods of exposure outside of a controlled environment. The hospital patient can be kept constantly in a zone of disinfected air. Consequently one should expect to obtain in these the maximum results if air-borne infections is a factor of importance. The child attending a school with irradiated classrooms is, however, in this regulated environment for only a portion of the day. Even if the air of the home were also regulated, there would remain the contacts on the playground and elsewhere outside of the controlled area.

Wells, Wells and Wilder studying the schools of Germantown and Swarthmore, Pa., have reported favorable results in control of measles through irradiation of school rooms. (Table VI) The results are statistically significant if one can assume that valid comparison can be made between groups so obviously dissimilar in their age compositions. Taken at their face value, the data suggest that irradiation of the air may well have reduced that portion of the measles

Table VI

Measles 1941 - Germantown & Swarthmore

| | Susceptible | % Attacked |
|---|---|---|
| Irradiated | | |
| Germantown 1-4 | 110 | 21.8 |
| Swarthmore 1-6 | 191 | 24.6 |
| Control | | |
| Germantown 5-12 | 141 | 62.4 |
| Swarthmore 7-12 | 137 | 54.7 |

\- - -

infections spread within the school. Even if one were to assume that it eliminated all of this type of spread, it remains apparent that about an equal quantity is spread through home and community contacts even in choice residential suburbs. Under more usual urban conditions, an even greater proportion of extra-school infections might be expected. Inasmuch as measles is a disease to which one acquires no latent immunization and in which there is no effective means of artificial immunization, one can seriously question the ultimate value of delaying an attack until after school age in view of the increased seriousness of the infection in adult life.

The more recent studies of Perkins, Bahlke and Silverman cast further doubt on the possibility as well as value of measles control in a school group. In studies of irradiation of air in consolidated schools of an up-state New York area they found that no actual reduction in the ultimate incidence of measles was achieved through irradiation, but that there was a prolongation of the outbreak. In other words, the outbreak in the irradiated school was less explosive than in the non-irradiated school but the ultimate attack rate was quite comparable, 81% in the non-irradiated school rooms and 86% in the irradiated. Furthermore, the slight benefit achieved through the irradiation appeared to be offset through exposures within the school bus (Table VII) None of the differences are statistically significant so one may seriously question if under such circumstances the truly air-borne classroom infections potentially controllable through irradiation were really important as contrasted with the uncontrollable infection through direct

Table VII

Measles Attack Rates, Port Byron, N.Y.
Kindergarten thru 6th Grade

| | Classroom Not Irradiated | | Classroom Irradiated | |
|---|---|---|---|---|
| | Susceptible | % Attacked | Susceptible | % Attacked |
| Bus riders | 88 | 83 | 104 | 90 |
| Non-bus riders | 31 | 77 | 26 | 69 |

\- - -

association.

4.) Military group -- Numerous studies of such groups were carried on during the past war but all yielded very inconclusive clinical results though in all cases the method of reducing the bacterial content of air achieved significant bacteriological results.

a.) Oiling of floors -- In a study carried on at Fort Bragg by the Commissions on Acute Respiratory Diseases and Air-Borne Infections it was suggested that the reduction of air contamination by oiling of floors might reduce slightly the incidence of serious infection in non-epidemic periods but not during outbreaks of respiratory infection. A series of complicated but illuminating tables is summarized in Table VIII.

Table VIII

Incidence Rates, Respiratory Infection, Selected Batteries, Ft. Bragg 1944 & 1945
Control through Oiling of Floors

| | Mean Strength | Rates /1000/week Duty | Quarter | Hospital |
|---|---|---|---|---|
| Batt.E (6 weeks) | | | | |
| Oiled floors | 322 | 124 | 78 | 28 |
| Control | 322 | 121 | 99 | 71 |
| Batt.F (8 weeks) | | | | |
| Oiled floors | 416 | 130 | 149 | 190 |
| Control | 409 | 142 | 161 | 232 |
| Batt.N (9 weeks) | | | | |
| Oiled floors | 420 | 164 | 190 | 274 |
| Control | 435 | 170 | 186 | 267 |

Further studies of carrier rates showed no consistent and significant differences in the pneumococcus and streptococcus carrier rates.

b.) Irradiation of air -- Studies of Wheeler and his associates at the Naval Training Center at Sampson (Table IX) showed results equally conclusive with those through oiling of floors at Ft. Bragg.

Table IX

Respiratory Admissions, Camp Sampson
12/15/43 - 6/1/44
Admission Rates per 1000

| | High Intensity Irradiation | | | | Low Intensity Irradiation | | | |
|---|---|---|---|---|---|---|---|---|
| | Irrad. | | Control | | Irrad. | | Control | |
| | Cases | Rate | Cases | Rate | Cases | Rate | Cases | Rate |
| Catarrhal Fever | 398 | 70.4 | 539 | 91.6 | 443 | 81.5 | 434 | 76.0 |
| Strept. Infection | 79 | 14.0 | 92 | 15.8 | 93 | 17.1 | 95 | 16.6 |
| Germ. Measles | 11 | 1.9 | 6 | 1.0 | 5 | 0.9 | 8 | 1.4 |
| CS Men. | 1 | 0.2 | 3 | 0.5 | 2 | 0.4 | 1 | 0.2 |
| Other resp. | 23 | 4.1 | 32 | 5.4 | 20 | 3.7 | 23 | 4.0 |
| Total | 512 | 90.4 | 672 | 114.3 | 563 | 103.6 | 561 | 98.1 |

It is quite apparent from these tables that the most that could be attributed to irradiation was a slight reduction in the so-called "catarrhal fever" cases in the barracks exposed to high intensity irradiation.

The prevalence rate of carriers as determined by surveys of the barracks population and by culturing all cases diagnosed as having a respiratory tract infection showed no essential difference between the irradiated and the non-irradiated group (Table X).

Table X

Prevalence of Streptococcal Carriers
Camp Sampson 12/15/43 - 6/1/44

| | High Intensity Irradiation | | | | Low Intensity Irradiation | | | |
|---|---|---|---|---|---|---|---|---|
| | Irrad. | | Control | | Irrad. | | Control | |
| | Cultured | Carrier Rate | Cultured | Carrier Rate | Cultured | Carrier Rate | Cultured | Carrier Rate |
| Barracks Surveys | 659 | 3.8% | 642 | 3.7% | 655 | 2.1% | 634 | 3.2% |
| Respiratory Admissions | 512 | 5.9% | 672 | 5.7% | 563 | 5.7% | 561 | 5.6% |

One may conclude from these studies that no significant reduction in the incidence of respiratory infection through irradiation of air was demonstrable in spite of the fact that bacteriological studies of the air and dust showed strikingly lower counts in the irradiated barracks than in the control barracks. Two possible explanations of these results are apparent. Either the residual microorganisms that escaped destruction through these means of irradiation were adequate to produce as high an attack rate as did the larger number in the control barracks or the recruits suffered so many exposures outside of the controlled area that the reduction of air contamination in the irradiated barracks was of no practical importance. If this latter explanation is the correct one (and I suspect it is in this instance), one may conclude that the truly air-borne infections within the barracks constituted an insignificant fraction of all respiratory infections to which these recruits were exposed.

## Conclusions

Aside from the conclusions that may be drawn from the above studies regarding the effectiveness of air sanitation in control of respiratory tract infections, there are certain implications regarding the apparent importance of air as a vehicle of infection. Bacteriological studies in all of the above cases showed a significant reduction in the bacterial content of the air. It can be assumed, therefore, that those in the experimental group were breathing in fewer organisms than were those in the control group. In those studies in which the patient was confined to the controlled environment and in which the opportunities for direct spread through respiratory association were reduced to a minimum, the best results were achieved. Even these, however, were not perfect, representing either some partial failure of air sterilization or the effect of concomitant direct spread through association. The fact that the results became progressively better with increasing age and resistance suggests the latter explanation. Those groups of persons who were in the controlled environment only a portion of the day and were, therefore, exposed to the highest risk of direct association spread showed the least protection and even this was questionable at best. Such data would strongly suggest that under conditions of isolation where direct association may be kept to a minimum, the amount of infection that is truly air-borne may be significant but that in the general community where there is ample opportunity for association outside of the controlled or controllable environment, these latter contacts are of such significance in the spread of respiratory tract infection as to offset the slight benefit that comes from elimination of the air-borne infection for a portion of the day.

The data hold one further suggestion regarding the type of infection in which spread through the medium of air is of some importance. The inadequacy of aseptic nursing techniques in preventing the spread of measles and chickenpox within isolation wards, and the repeated occurrence of psittacosis and Q-fever outbreaks within a building suggest that air may actually be an important vehicle for the spread of certain diseases. There are epidemiological if not bacteriological grounds for suspecting that these are all conditions in which the disease may be established by very small doses of infection in contradistinction to the relatively large doses required to produce certain bacterial infections. It is, therefore, possible that the small doses carried by air may be significant in the spread of such virus or rickettsial infections but not in the production of bacterial infections. If this were correct we might reasonably anticipate that air sterilization would be of value in controlling the virus and rickettsial diseases under conditions where no other mechanism for spread was possible, yet be ineffective in reducing bacterial infection simply because the dosage of the latter in the air is usually inadequate to produce disease. Neither type of disease would be controllable through air sanitation if the associations outside of the controlled area are sufficiently numerous. It would appear that under conditions of usual community life, these associations are so numerous and uncontrollable that they offset any protection achieved through the elimination of air-borne infection. In other words, the truly air-borne infections appear to constitute so small a fraction of all respiratory-spread infection that little is accomplished through their control until we find a means of simultaneously controlling those spread directly from person to person through respiratory association.

Many mechanical methods have been tried to prevent or minimize the spread of air-borne infection in enclosed spaces but the methods that have attracted the most attention recently include disinfection of air with ultra-violet irradiation and glycol vapors, and the suppression of dust by the application of oil to floors, blankets and bedding.

The bactericidal properties of ultra-violet light have been known for three quarters of a century and in 1933 Wells and Fair[9] applied its use to the disinfection of air. Since that time many improvements have been made in ultra-violet irradiation equipment, among them the development of low pressure mercury tube, the better design of fixtures and the manufacture of a meter to measure accurately the intensity of ultra-violet light.

There are certain precautions that should be taken in the use of ultra-violet light for air sterilization. Protection against over-exposure to the light must be provided because direct irradiation of sufficient intensity to destroy organisms may injure the eyes and skin. Installations should be designed to irradiate the upper air in the room above the head of the individual or to use baffles that will protect the person against rays of dangerous intensity.

The Council on Physical Therapy of the American Medical Association[10] has adopted regulations for the acceptance of ultra-violet lamps for use in connection with the disinfection of air. After setting up certain physical requirements for lamps and the permissible intensity of ultra-violet light, the Council makes this statement, "How to design the lamp installation to meet the requirements for adequate disinfection of a room and at the same time protect the occupants is a problem for solution by a sanitary engineer."

Certain glycols have also been recognized as bactericidal agents for many years but Robertson and his associates[11] were the first to use pure glycols for the disinfection of air. Propylene glycol has been used extensively in experimental work on air disinfection, but it now appears that triethylene glycol has certain advantages for the disinfection of air.

Robertson[12] has found for example in regard to triethylene glycol that "Concentration of 1 gram of this glycol in 200,000,000 cc. or less of air causes pronounced and rapid killing of such microorganisms as pneumococci and streptococci." These studies have further shown that glycols are most effective at relative humidities between 40 and 60 per cent. Vaporization of this chemical should be done at temperatures below 260° F., otherwise it will disintegrate and form acrolein.

The toxic effects of triethylene glycol on monkeys and rats after nearly a year's exposure in a saturated atmosphere of this chemical appeared not to be harmful. One advantage of the glycol method is that assuming effective dispersion the chemical should permeate the atmosphere of the room under treatment.

Several types of equipment have been developed for vaporizing glycols including apparatus for controlling the quantity of chemical dispersed into the air and in one design[13] for also maintaining constant relative humidity in the space receiving treatment.

Dust suppression by oiling floors, blankets, bedding and certain kinds of clothing, as a large scale operation in hospitals, institutions, barracks, etc. is coming rapidly into use. There is experimental evidence[14] to show the marked reduction in total bacterial count in the air of rooms where dust suppression procedures are routinely applied. These reductions range as high as 80 per cent.

Specifications covering the use of oil and oil emulsions for the purposes mentioned are available and in use.

Methods have been described for applying a petroleum distillate clear paraffin oil to floors after thoroughly cleaning and drying. Wood floors can be oil treated with a cloth mop or a hair broom. This procedure cannot be used for concrete, linoleum or waxed surfaces but it has been suggested that the daily use of oiled sawdust or oiled mops during sweeping is quite effective. Methods have been devised for impregnating blankets and bedding with oil that can be applied in practically any modern laundry.

There is evidence to suggest that the combination of dust suppression measures with either ultra-violet irradiation or glycol vapor treatment gives more satisfactory results. Each of the methods mentioned has its advantages, disadvantages and limitations but the results of recent studies with all of these methods are encouraging.

The results of important research on the methods discussed in this paper to control of air-borne infection are admirably summarized in two reports, one[17] by the Subcommittee for the Evaluation of Methods to Control Air-Borne Infection of the Committee on Research and Standards of the American Public Health Association, January 1947, entitled "The Present Status of the Control of Air-Borne Infection" and the other[16] by the Committee on Sanitary Engineering of the Division of Medical Sciences of the National Research Council entitled "Recent Studies on the Disinfection of Air in Military Establishments".

In general, these reports indicate some of the present concepts on air-borne infection, review the results of experimental work on control measures and offer conclusions and recommendations on the present status of the application of mechanical methods to the control of air-borne infection.

The conclusions of the report of the Subcommittee for the Evaluation of Methods to Control Air-Borne Infection of the Committee on Research and Standards of the American Public Health Association are as follows:

"The subcommittee offers the following five points to summarize its group judgment concerning the present status of the application of engineering methods to control air-borne infection:

1. The oiling of floors, blankets, and bedding has now developed to the point of practical application in the suppression of dust. Such measures constitute good housekeeping. They reduce bacterial contamination of the air, but there is as yet insufficient evidence that they prevent disease. Dust suppression should be applied wherever practicable in conjunction with ventilation, ultra-violet irradiation, and disinfectant vapors, when the latter methods are employed.

2. The available evidence strongly indicates that methods of air disinfection (ventilation, ultra-violet irradiation, and glycol vapors) are useful adjuvants to aseptic techniques in the reduction or elimination of air-borne infections in operating rooms and in contagious disease and pediatric wards. Installations are indicated under conditions where there has been demonstrated or there exists potentially a significant incidence of cross-infection or a serious risk to patients. It is essential that competent engineering supervision be available to insure the adequacy of the original installation, to maintain its continued effectiveness, and to protect both personnel and patients.

3. It is not yet possible to compare the relative efficiency of ultra-violet irradiation and glycol vapors. Only the former method has been developed to a point of practical application. Recent designs of glycol vaporizers and automatic control devices give promise that adequately controlled studies may be conducted in the near future. The relative merits of the two procedures will involve such problems as cost, safety, and the consistency of effective operation based upon long experience.

4. The general use of ultra-violet irradiation or disinfectant vapors in

schools, barracks, and in specialized industrial environments is not justified at the present time. There is great need for further carefully controlled field studies to define the mechanisms of the spread of infectious disease among these types of populations.

5. There is no justification for the indiscriminate use of ultra-violet light or other methods for disinfecting air in homes, offices, or places of public congregation."

(This report is accompanied by eighty-nine references).

Subcommittee members:
James E. Perkins, M.D., Chairman
F. W. Gilcreas
Alexander Hollaender, Ph.D.
Alexander D. Langmuir, M.D.
O. H. Robertson, M.D.
William F. Wells
George M. Wheatley, M.D.
C. P. Yaglou

The discussion and recommendations of the Committee on Sanitary Engineering of the Division of Medical Sciences of the National Research Council are as follows:

"It appears from the foregoing review that a first step in the disinfection of air in barracks, wards, and similar places of assembly in military establishments is suppression and removal of dust and lint particles. The oiling of floors and blankets and, in hospital wards, of sheets and pillow cases, has been shown to be a practical, cheap, and effective measure. It reduces the bacterial content of the air, and there is evidence that it may in some degree reduce the risk of transmission of certain bacterial infections, particularly those due to hemolytic streptococci, Group A. A reduction in the risk from virus infections has not been demonstrated, although some experimental work with influenza virus suggests this possibility. On the basis of present studies, both the Army and the Navy have accepted the oiling or related treatment of floors for dust control and the oiling of bed clothing under appropriate circumstances as recommended sanitary practice.

Experimentally, it has been established that, under ideal laboratory conditions, bacteria and viruses suspended in the air as finely dispersed particles can be rapidly inactivated by exposure to adequate concentrations of triethylene glycol vapor. In the glycolization of the air of barracks, hospital wards, and similar places of assembly, under actual conditions of use and occupancy, however, there were a number of factors that limited its effectiveness. It has been shown that under the most favorable circumstances, triethylene glycol vapor will reduce the total number of bacteria (or the number of bacteria of a pathogenic species, such as the hemolytic streptococci, Group A) in the air by as much as 90 per cent. However, this is not a measure of effectiveness in reducing the spread of respiratory infections. Under natural conditions dispersed aggregates of bacteria and viruses carried by air currents represent only one of the channels by which infection travels from person to person. Others exist, too. Infective particles may pass directly from one individual to another in face-to-face contact. The heavier infective particles, including lint from contaminated blankets, bedding, clothing, and handerchiefs, may accumulate in dust in the immediate environment of an infected individual and will then constitute an important channel for short range transmission of infection. The possibility of indirect transmission of infection by the handling of contaminated objects cannot be ignored. Undoubtedly the relative importance of these channels varies with the ability of different pathogenic agents to survive in the external environment and with the conditions of occupancy, the extent of crowding, and the kind of activity carried on. Examples are, hospital wards in which patients are confined to their beds or in which patients are ambulatory, classrooms, moving-picture theaters, dispensaries, and drill halls.

Up to the present, studies of the value of ultra-violet light and of triethylene glycol vapor in reducing the incidence of respiratory infections have been largely confined to barracks and hospital wards. The data available suggest that under some circumstances these both may have a measurable effect upon the attack rate from certain respiratory diseases, but experience is not sufficient to justify drawing definite conclusions.

The two primary conditions for the successful application of ultra-violet light to the disinfection of air are: (a) supplementing irradiation with dust suppression meaaures, since ultra-violet light is not efficient against bacteria and virus protected by dust; and (b) attaining a radiation of sufficient intensity but not so high as to affect the eyes or skin of occupants.

The use of triethylene glycol, too, must be supplemented with dust control measures if it is to be successful. The glycol concentration should be just below the saturation level with low rather than high temperatures. The glycol must be pure, made especially for air disinfection, and the vaporizing device must operate at relatively low temperatures. Glycolization of air at high temperatures is undesirable and impractical.

Admittedly, both ultra-violet light and glycols have their merits and demerits. Present knowledge is too limited to make any definite claims or predictions concerning their ability to reduce air-borne infection. The design and operation of apparatus for air disinfection is still on an empirical basis and the use of these disinfecting agents is not without danger (to the user). Extravagant claims for promotion of sales of disinfecting apparatus at this time may well retard progress and injure the industry.

The committee does not recommend the general use of these disinfecting devices for the present. Much research and development work by qualified personnel remains to be done."

(This report is accompanied by thirty-eight references.)

Committee members:
- Abel Wolman, Chairman
- G. M. Fair
- W. A. Hardenbergh
- R. E. Lawrence
- K. F. Maxcy
- W. D. Tiedeman
- H. A. Whittaker
- C. P. Yaglou, Consultant

It is also of interest to quote a public statement by Dr. R. E. Dyer[17], Director of the National Institute of Health of the U. S. Public Health Service, summarizing the conclusions of the two committee reports.

"Committees of the National Research Council and the American Public Health Association have studied and reviewed the data on such installations. Within the past several weeks, these two Committees separately have submitted reports. Both of these Committees feel that the use of either glycol vapors or ultraviolet radiation is still purely in the experimental stage and that the data collected so far do not warrant the installation of such equipment in public buildings and industry in the hope of cutting down upper respiratory infection. The U. S. Public Health Service, through its research organization, the National Institute of Health, has conducted rather extensive studies on both glycol vapors and ultraviolet radiation and fully concurs in the reports and recommendations made by the Committees of the National Research Council and the American Public Health Association. It must be emphasized that direct unshielded ultraviolet radiation of sufficient intensity to kill microorganisms in the air is also harmful to the eyes and exposed skin of humans. These observations are not intended to indicate that the future will or will not disclose new public health values in the application of either glycols or ultraviolet radiation. Much experimentation is needed, however, before a decision can be made as to whether such application may or may not be warranted."

In conclusion, it is urged that every possible encouragement be given to further research to answer more completely both of the questions raised in this paper.

Mechanical control of air-borne infection offers an intensely interesting field of research and the solution of this problem will require the combined efforts of the engineer, the biophysicist, the bacteriologist, the chemist, the clinician and the last but not the least important, the epidemiologist to prove the validity of the control methods in preventing disease.

References

1. Am.Assoc.Adv.Sci.:
Aerobiology '42.

2. Hart, Deryl:
Sterilization of the Air in the Operating Room with Bactericidal Irradiation.
J.Thor.Surg. 7:525-35 (June) '38.

3. Robertson, Elizabeth Chant; Doyle, M. Elizabeth; and Tisdall, Frederick F.
Use of Ultraviolet Radiation in Reduction of Respiratory Cross Infections.
J.A.M.A. 121:908-914 (Mar.20) '43.

4. Harris, T. N. and Stokes, Joseph Jr.
Air-Borne Cross-Infection in the Case of the Common Cold.
Am.J.Med.Sci.206:631-636 (Nov.) '43.

5. Wells, W. F., Wells, M. W., and Wilder, T. S.
The Environmental Control of Epidemic Contagion. I. An Epidemiologic Study of Radiant Disinfection of Air in Day Schools.
Am.J.Hyg.35:97-121 (Jan.) '42.

6. Perkins, James E., Bahlke, Anne M., and Silverman, Hilda Freeman.
Effect of Ultra-Violet Irradiation of Classrooms on Spread of Measles in Large Rural Central Schools.
Am.J.Pub.Health 37:529-37 (May) '47.

7. Commission on Acute Respiratory D iseases and Commission on Air-Borne Infections:
A Study of the Effect of Oiled Floors and Bedding on the Incidence of Respiratory Disease in New Recruits.
Am.J.Hyg.43:12-144 (Mar.) '46.

8. Wheeler, S M., Ingraham, H. S., Hollaender, Alexander, Lill, N. D., Gershon-Cohen, J., and Brown, E. W.
Ultra-violet Light Control of Air-Borne Infections in a Naval Training Center.
Am.J.Pub.Health 35:457-68 (May) '45.

9. Wells, W. F. and Fair, G. F.
Viability of B.Coli exposed to Ultra-Violet Radiation in Air.
Science, 82:280 (Sept.) '35.

10. American Medical Association Council on Physical Therapy:
Acceptance of Ultra-Violet Lamps for Disinfecting Purposes.
J.A.M.A. 122:503 (June) '43.

11. Robertson, O. H., Bigg, E., Puck, T. T. and Miller, B.
The Bactericidal Action of Propylene Glycol Vapor on Micro-organisms Suspended in Air.
Jan.Exper.Med., 75:593 (June) '42.

12. Robertson, O. H.
Sterilization of Air with Glycol Vapors.
The Harvey Lectures, 1942-43.

13. Bigg, E. and Jennings, B. H.
The Introduction of Glycols for Air Sterilization by a New Vaporization Method.
Jr.of Ind.Hyg.& Tox.26:307-312 (Nov.) '44.

14. Report of Commission on Air-Borne Infection to the Board for the Investigation of Epidemic Diseases.
U.S.Army (April) '45.

15. American Public Health Association Report of Subcommittee on Evaluation of Methods to Control Air-Borne Infection, Committee on Research and Standards.
A.J.P.H. 37:13-23 (Jan.) '47.

16. National Research Council Report of Committee on Sanitary Engineering, Division of Medical Sciences.
A.J.P.H. 37:189-199 (Feb.) '47.

17. Minnesota's Health.
Statement by Dr. R. E. Dyer, U.S. Public Health Service.
1:3-4 (Mar.) '47.

- - -