Ultra-violet Light Control of Air-borne Infections in a Naval Training Center*

Preliminary Report

S. M. WHEELER, Lt. (MC) USNR, F.A.P.H.A.,
H. S. INGRAHAM, Lt. (MC) USNR, F.A.P.H.A.,
ALEXANDER HOLLAENDER, Ph.D.,
N. D. LILL, Lt. Comdr. (MC) USNR,
J. GERSHON-COHEN, Lt. Comdr. (MC) USNR, and
E. W. BROWN, Capt. (MC) USN

Department of Epidemiology, U. S. Naval Medical School, Bethesda, Md.; U. S. Naval Training Center, Sampson, N. Y.; Bureau of Medicine and Surgery, U. S. Navy, Washington, D. C.; and National Institute of Health, Bethesda, Md.

THIS study was designed to test the efficiency and practicality of ultra-violet irradiation as a method of reducing the spread of respiratory infection in Navy barracks. In a more general sense it was also hoped that a controlled study of this type on a large scale might give information on the amount of irradiation required for effective control and the differential effect exerted on various diseases of viral and bacterial origin.

While considerable information is now available as to the effect of ultra-violet light in reducing cross-infections in hospital wards, curtailing the incidence of epidemic respiratory diseases in schoolrooms and sterilizing the air about the patient in operating rooms, systematic studies of the effect of ultra-violet irradiation of military barracks has not heretofore been reported.

Such semi-isolated military communities offer advantages for controlled epidemiological studies which are not to be found in most civilian groups. The population under observation can be very large, yet at the same time accurate figures are available as to its precise strength from day to day. Also, in such controlled populations all illnesses from the dispensary visits for minor complaints to more serious cases requiring hospitalization are known and classified by the medical officers of the unit, and complete data on respiratory morbidity in the study population can be recorded and analyzed. Finally, the nature of such semi-enclosed recruit communities

* Presented before a Joint Session of the Epidemiology, Health Officers, Laboratory, Engineering, and School Health Sections of the American Public Health Association at the Seventy-third Annual Meeting in New York, N. Y., October 4, 1944.

The views expressed in this report are those of the authors and do not necessarily reflect the policies of the Navy Department.

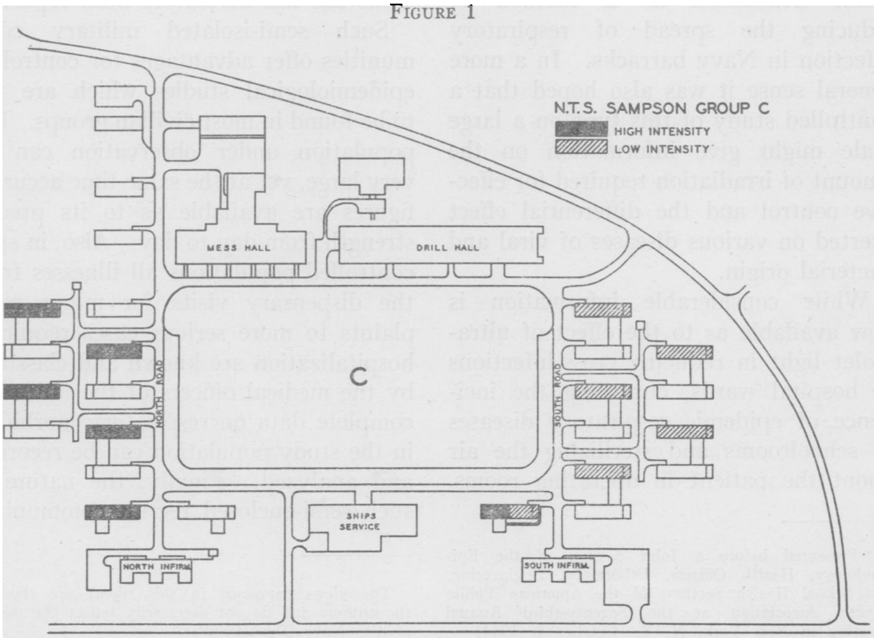
tends to restrict the sources of exposure to infection from outside the compound to a minimum.

While in the present study ultra-violet fixtures were installed only in the barracks, it is obvious that all exposure to respiratory infection did not take place in the sleeping quarters. In general, however, the recruit companies housed one company to a floor in the various barracks kept together with the men in their own company in their daily life on the drill fields, in the classrooms, mess halls, and other places of work and recreation. It was assumed that the prolonged exposure during the hours of sleeping in the barracks was the most important for the transfer of respiratory infection and that ultra-violet irradiation of the air of the barracks would be the most effective and practical means of interrupting the exchange of infectious material among the recruits.

Since the purpose of the study was to evaluate the practicality as well as effectiveness of ultra-violet lights in naval units, irradiation of all the indoors environments where the men might be congregated in their daily activities was not attempted. Lights were not installed in the large drill halls, mess halls, and gymnasiums where the size of these buildings would have made irradiation of the large volume of air in sufficient intensity impractical both from the standpoint of cost and from the number of fixtures which would have been required.

The present study was carried out at the U. S. Naval Training Center, Sampson, N. Y. At this camp naval recruits are received from civilian induction centers and are given their recruit training here before assignment in outgoing units for other stations in the Navy at sea or ashore. At the time of the study, in the winter and spring of 1943–1944, the training period was from 4 to 6 weeks in length. This short period of training and the frequency of incoming drafts made for a very rapid overturn of the population during this period.

FIGURE 1



One or two days were spent after the arrival of the recruits in the camp in physical examinations, the issuance of equipment, and the formation of recruit companies. These companies were then quartered in the units where they spent the entire remaining period of training (Figure 1). These self contained training units consisted of the barracks, mess hall, ships service stores, dispensaries, drill hall and other buildings surrounding the drill field. The usual complement of such units was 4,800 recruits housed in twenty-two 2 story barracks, each containing two companies of 112 men with one company to a floor. During the training period, liberty away from the particular unit and contacts with men from other units was at a minimum.

Unit C at Camp Sampson was the training area designated for the ultra-violet study. No other control measures such as sulfadiazine prophylaxis were employed in this area. In this unit the barracks were distributed in two groups of eleven buildings at either end of the drill field. Ultra-violet lights of relatively low intensity were installed in alternate barracks at the south end of the drill field. The intervening barracks at this end of the field which were not equipped with lights served as the low intensity controls. At the north end of the field there was similar experimental design of lighted and control barracks but the intensity of irradiation in each barrack was higher than at the south end. These were designated as the high intensity barracks group and the high intensity controls. Of the eleven irradiated barracks five were installed throughout with high intensity and five with low intensity lights, and one barrack had low intensity lights, on the lower deck and high intensity on the upper. For purposes of analysis the barracks groups and the contained recruit companies were divided into four epidemiological units of five and one half barracks, or eleven companies each. These were designated high intensity irradiated, high intensity control, low intensity irradiated, and low intensity control. Companies formed from incoming drafts moved into these groups in orderly sequence as graduation of companies into outgoing units took place after 4 to 6 weeks in training. This process made for a constant overturn of the study populations.

The barracks were wooden structures consisting of a large dormitory sleeping quarters on each floor with washroom and toilet facilities. Two rows of double decker wooden bunks were ranged down each side of these dormitories. The bunks were separated by a central aisle, and at the center of the room was a cleared space with tables and chairs and separated from the bunks by a row of clothes lockers.

Ultra-violet lights were installed at similar locations in all the lighted barracks. Suspended overhead fixtures provided indirect irradiation directed to the upper air of the barracks. Similar ceiling fixtures were installed in the washrooms. Lights were also installed under the bunks with irradiation directed downward to the floors to achieve a maximum of bactericidal effect on the floors and lower air where bacteria laden dust particles are found to be the most numerous (Figure 2).

More detailed information on the physical aspects of the ultra-violet installation are as follows:

The ceiling lamps were installed 7′ 9″ from the deck in such a way that only the upper third of the room was irradiated. At the high intensity side 21 ceiling lamps of 30 watts were used per room, supplying about 133,500 milliwatts. At the low intensity side each barrack room had 42 lamps of 15 watts, giving about 75,000 milliwatts per room (ceiling).

For deck irradiation 26 (15 watt) under-bunk lamps were used in the high and low intensity barracks, supplying at the high intensity side 78,000 milliwatts, and at the low

FIGURE 2

intensity side 46,000 milliwatts per floor. Besides these fixtures in the main barracks, heads and showers were equipped with ceiling lights 5 (30 watt) lamps at the high intensity and 9 (15 watt) lamps at the low intensity side). The current used by these lamps is relatively low, very similar to the amount of current used by fluorescent lamps. Bunk lights were installed in such a manner that no direct radiation could be seen by the men sitting on adjacent or other lower bunks. Since only every second bunk was equipped with a lamp, the reflectors threw the light over an area covering the deck under two bunks. The deck of the barracks was virtually covered by a heavy blanket of ultraviolet radiation.

The intensity of scattered ultra-violet radiation was on the average not higher than the levels set by the Council of Physical Therapy of the American Medical Association, and practically no complaints were received of detrimental effect on the eyes. The amount of visible light given out by these lamps was low enough so that there was no difficulty encountered when sleeping under these lamps. The light appeared to the people in the barracks similar to bright moonlight.

When the lamps were first started a certain amount of ozone was produced by them. However, the lamps were burned for not less than fifty hours when men were not present in the barracks. After this time only a very little ozone could be detected, depending on the atmospheric conditions. The amount of breakage of the lamps was small and probably could be entirely avoided by the proper construction of under-bunk lamp fixtures.

The organization of medical services in these recruit units was well adapted for an accurate analysis of respiratory morbidity. All men complaining of illness were seen by the staff of the unit dispensary who administered treatment and arranged for admission to the sick bay or the Naval Hospital if the fever or other symptoms seemed to warrant it. Minor ailments were diagnosed, treated, and returned to duty, but there was no provision for illness requiring bed rest other than admission to the sick bay or hospital.

During the period of observation the names of all recruits in the ultra-violet study area were recorded on individual cards along with other pertinent epidemiological data. These cards were kept on file in the dispensary and information as to all visits to the sick call and admissions to the sick bay or hospital was recorded on them. Since all illness whether mild or serious was first seen at the dispensary, and since a complete card file was kept on all recruits whether or not they became sick, these card files gave information as to the total population as well as the number and kind of respiratory illnesses occurring within this population. When respiratory diseases were admitted, further information as to the course of the illness was derived from the clinical records. In addition to being seen by the ward medical officer, every admission for respiratory disease was visited and examined by one of the medical officers of the epidemiology unit who made a throat culture to determine the presence of group A streptococci or of meningococci.

In addition to throat cultures on all admissions for respiratory illness there were weekly throat culture surveys of representative samples of recruits from the various barracks and periodic culturing of the men with minor respiratory complaints in the sick call line. Further laboratory work in connection with this study consisted in bacterial counts of air samples from the air of irradiated and control barracks and in the culturing of dust samples collected from dry sweepings.

RESULTS

The total number of admissions for respiratory illness by principal diagnoses and average number of men per 1,000 admitted during their period of training can be seen in Table 1. In this study admission signifies hospitalization for at least 24 hours. The greatest difference in rates for all these respiratory infections can be seen to occur between lighted and control barracks of the high intensity groups.

The commonest diagnosis in this series is " catarrhal fever," which represents in Navy terminology any febrile upper respiratory infection not specifically localized and without distinguishing diagnostic criteria such as rash or tonsillar exudate. It is also apparent from this table that specific bacterial infections such as scarlet fever and meningococcus meningitis, or specific virus diseases such as German measles were relatively scarce both in irradiated and control barracks during the months of observation in the winter and spring of 1943–1944.

This scarcity of streptococcal illness was reflected in low carrier rates for

TABLE 1

Respiratory Admissions in Irradiated and Control Groups of Barracks
Unit " C " Camp Sampson, N. Y., December 15, 1943–June 1, 1944
Rates Expressed as the Number of Recruits per 1,000 Admitted During the Period of Training (Average 4.7 Weeks)

	High Intensity Barracks Group				*Low Intensity Barracks Group*			
	Irradiated		*Control*		*Irradiated*		*Control*	
Diagnosis	*Cases*	*Rate*	*Cases*	*Rate*	*Cases*	*Rate*	*Cases*	*Rate*
Catarrhal Fever	398	70.4	539	91.6	443	81.5	434	76.0
Streptococcal Infections	79	14.0	92	15.8	93	17.1	95	16.6
German Measles	11	1.9	6	1.0	5	0.9	8	1.4
Meningococcus Meningitis	1	0.2	3	0.5	2	0.4	1	0.2
All Other Respiratory Infections	23	4.1	32	5.4	20	3.7	23	4.0
Total Respiratory Admissions	512	90.4	672	114.3	563	103.6	561	98.1

TABLE 2

Results of Throat Cultures for Group A Hemolytic Streptococci in Weekly Surveys of Samples of Barracks Populations and All Admissions for Respiratory Disease from Irradiated and Control Barracks

	High Intensity Group				*Low Intensity Group*			
	Irradiated		*Control*		*Irradiated*		*Control*	
Culture Group	*No. of Cultures*	*No. Pos.*	*No. of Cultures*	*No. Pos.*	*No. of Cultures*	*No. Pos.*	*No. of Cultures*	*No. Pos.*
Weekly Surveys Barracks Populations	659	3.8%	642	3.7%	655	2.1%	634	3.2%
Admissions for Respiratory Illness	512	5.9%	672	5.7%	563	5.7%	561	5.6%

the Group A hemolytic streptococcus both in samples of the normal recruit population and among admissions for respiratory disease (Table 2). It is also apparent from this table that carrier rates at this low level were not further lowered among recruits in irradiated barracks.

The rates for total respiratory admissions in the various groups represented in time series by calendar fortnights can be seen in Figures 3 and 4. For the high intensity groups the difference in rates is obviously greatest in the first two months of the study. During this period the reduction was in excess of 35 per cent. At this time the incidence of respiratory disease throughout the camp was still at a relatively high level following the influenza epidemic of November and December, 1943. In Figure 4 such differences in

FIGURE 3

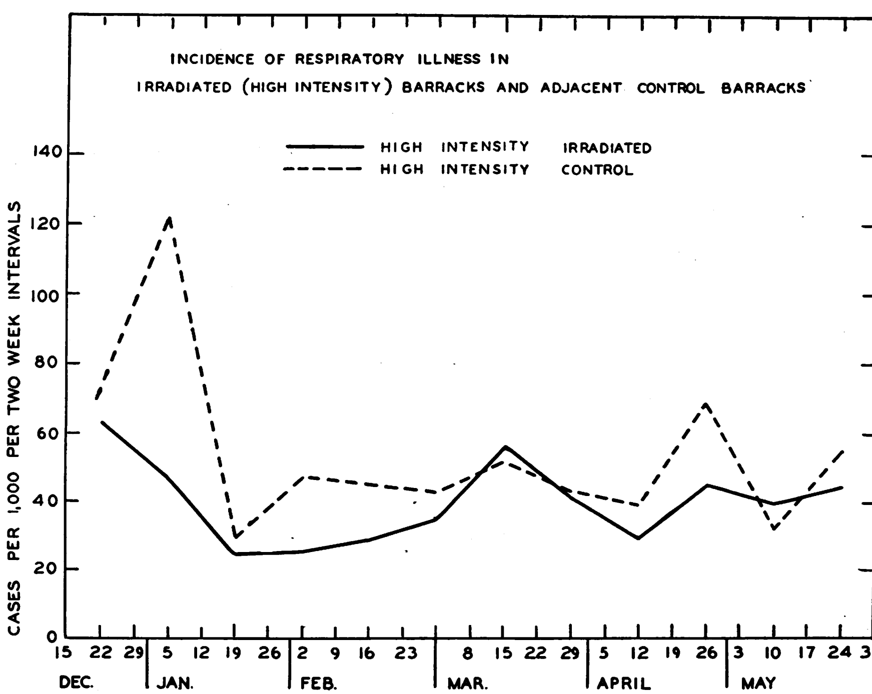
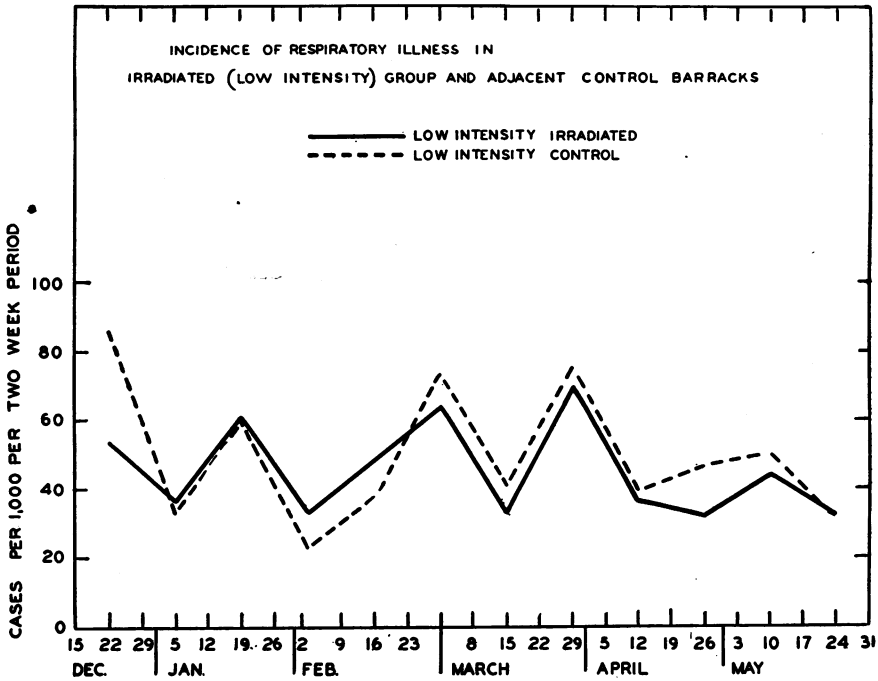


FIGURE 4



rates in the low intensity group between irradiated and non-irradiated barracks would seem likely to lie well within the limits of chance variation.

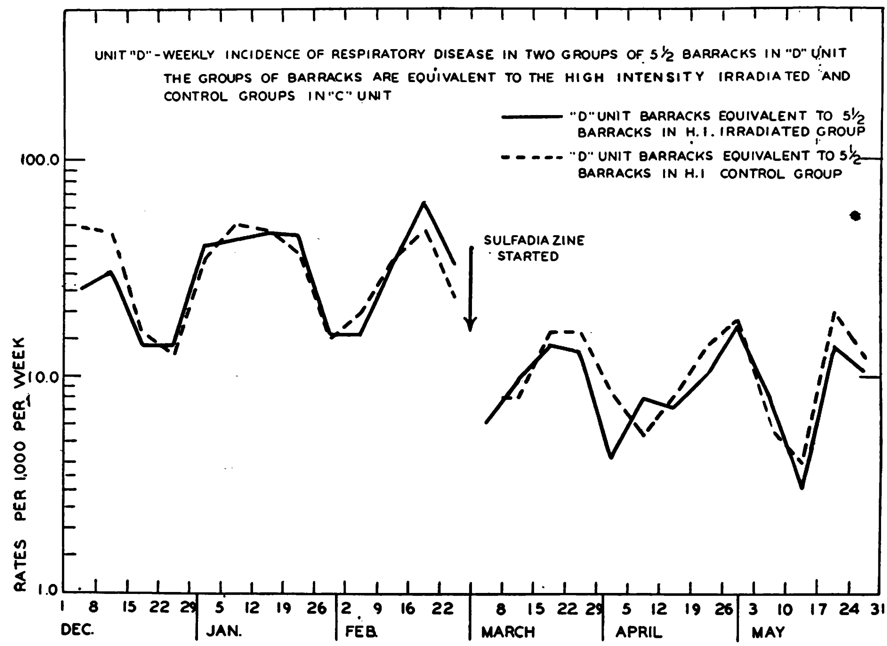
The striking similarity of the morbidity curves for low intensity irradiated and control groups affords an unexpected additional control to the results as found in the high intensity barracks. The marked difference in curves between the high intensity and its control group suggests that the dissimilarity is due to ultra-violet irradiation at an effective intensity.

Figure 4, showing the rates for the low intensity groups on a weekly basis shows a succession of peaks and dips in the morbidity curve which occur regularly at intervals of about 5 weeks. This phenomenon was observed generally throughout the camp when weekly rates were computed for similar groups in other units of barracks (Figure 5). The undulations here can be seen to have persisted even after the total rates were markedly reduced by sulfadiazine prophylaxis. An exception to this finding can be seen in a graph of the high intensity group of barracks where the regular undulations seem to have been abolished.

Study of this phenomenon suggested that it was a function of the orderly sequence of replacements through incoming companies occupying quarters in successive barracks vacated by graduations. As will be shown, the risk of infection is greatest in the middle weeks of training and that group of barracks with a majority of its occupants at this stage of training would show highest rates at this time. Similarly, lowest rates would occur when most of the recruits in the given segment of eleven barracks were at either the beginning or end of their training period.

This hypothesis was confirmed by a study of illness rates among recruits by number of weeks in training. In Figure

FIGURE 5



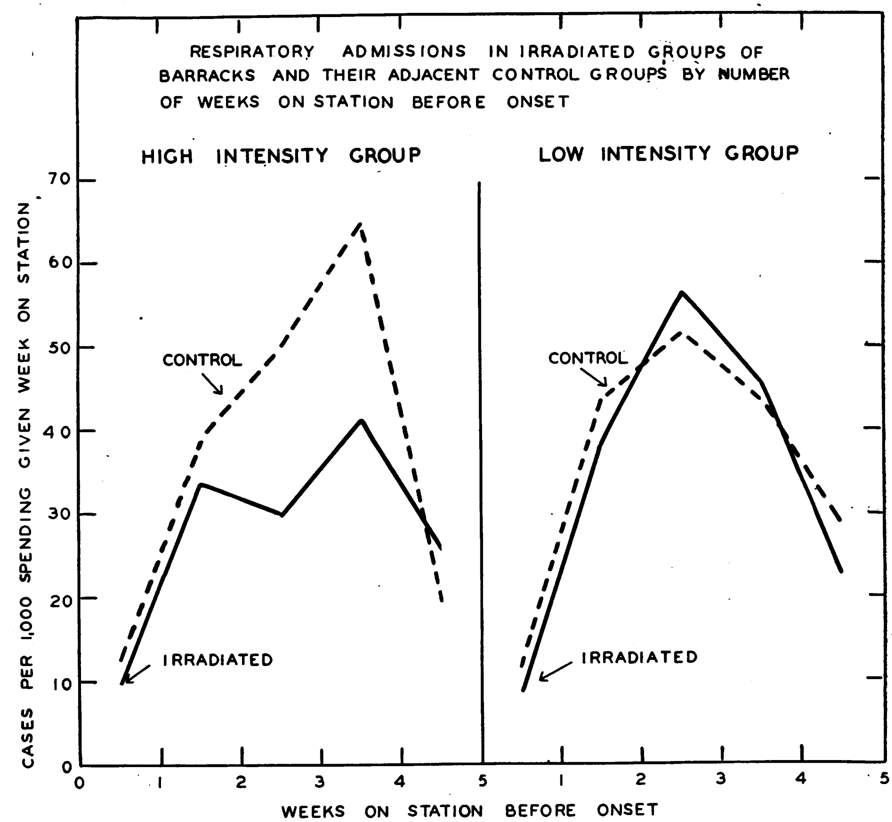
6 it can be seen that the rise and fall of incidence by weeks in training in the low intensity irradiated and control was nearly symmetrical with a peak in the third week. The curve for the high intensity irradiated barracks, however, is truncated and indicates the reason why this group fails to show the regular succession of peaks when rates are charted by calendar weeks.

In assessing the statistical significance of the differences in morbidity between the irradiated and control groups, consideration should be given to variations in disease incidence within units of the groups themselves. In this instance the company (comprising 112 men and occupying one floor of a barrack) was chosen as the basic epidemiologic unit. For each group of five and one-half barracks, irradiated or control, the average number of men per company admitted to the sick list for respiratory infections was computed. For each series of companies in the barracks groups the standard deviation about the average was calculated. The usual formulas were employed to estimate the likelihood of the differences observed in average rates for each group being due to chance.

This type of calculation was performed for all companies which were under observation 27 or more days during the course of the experiment. This requirement excludes a number of companies at the beginning or end of the experiment, but the exclusions are essentially equally divided among the groups. The number of admissions for each company was adjusted to the number of days' experience of the high intensity control group of companies, a figure slightly less than the average for all companies (Table 3).

By this method it appears justifiable to conclude that the 25 per cent reduction for the entire period of observation in respiratory illness observed in the high intensity irradiated group as compared with its control group or with the two control groups combined is prob-

FIGURE 6



ably due to irradiation and not due to chance. It is also obvious that the differences between the low intensity irradiated group and its control are such as could easily arise by chance alone. Further calculations not shown on Table 3 show a significant deviation between the high intensity irradiated and low intensity control. All other combinations of groups were found to be within the limits of chance variation.

TABLE 3

Mean Number of Admissions for Respiratory Illness per Company in Irradiated and Control Groups of Barracks, Significance of Difference Between Means for Irradiated and Control Groups

Company and Barracks Group	*No. of Companies in Group* *	*Mean No. of Admissions per Company* †	*Standard Error of Mean*	*x/σ*	*Probability of Occurrence by Chance Alone*
High Intensity Control	47	12.4	0.85	2.9	4 in 1,000
High Intensity Irradiated	46	9.3	0.64		
Low Intensity Control	47	11.4	0.59	0.1	1 in 2
Low Intensity Irradiated	45	11.3	0.77		
Low and High Intensity Control	94	11.9	0.50	3.2	1 in 1,000
High Intensity Irradiated	46	9.3	0.64		

* Includes only companies with 27 or more days' exposure during period of observation.
† Adjusted to 32.1 days' company experience.

Four surveys were conducted during the winter and spring on the bacteria of the air of irradiated and non-irradiated barracks. In these surveys extensive use was made of the open blood agar plate exposed at different levels from the floor. Also, more quantitative devices operating on the impingement or bubbler principle were used for estimates of the number of bacteria found in a given volume of air.

Total saprophyte counts in these surveys of air bacteria were consistently lower in the irradiated barracks compared to their controls. The overall reduction in these test units was 50 per cent or greater than the controls. The greatest reduction of bacterial colony counts was found under high intensity sources. A very definite and marked correlation was also found to exist in both irradiated and control barracks between bacterial counts and proximity of the exposed plates to the floor strongly suggesting the relationship of the number of bacteria isolated from the air and its dust content.

A small series of blood agar plates with gentian violet 1/500,000 incorporated were exposed for periods of 5 hours to determine the presence of hemolytic streptococci in the air. Samples of dust were also collected from the floors of irradiated and non-irradiated barracks, and cultured for the presence of beta hemolytic streptococci.

The number of these tests for hemolytic streptococci in the air was too small for the assessment of statistical significance but streptococci were found consistently and were relatively numerous in the air and dust of the control barracks, whereas streptococcal colonies were found infrequently and in small numbers from either dust or air of the irradiated quarters.

COMMENT

The type and location of ultra-violet sources were determined on the basis of the greatest expected measure of control in the exposed populations. For reasons already mentioned, sleeping quarters were chosen as the site of the installations. Within these quarters a combination of upper air and floor irradiation was employed. Irradiation of the lower air and floor was considered important because of many recent reports implicating the infected dust particle and lint as vehicles in the spread of respiratory infection. Direct observations have shown that dust and lint often carry pathogenic organisms and also that as the dust content of room air increases it is accompanied by a corresponding increase in the number of bacteria found in air samples. Whether dust particles stirred into the air by momentary turbulence created by bed making and other activities or whether organisms floating freely for indeterminate periods in the air of a room are of equal importance in the transmission of air-borne contagion, is not yet established. For this reason the present installation was directed both to the irradiation of dust in the lower air and on the floor and also to the more hypothetical droplet nuclei of the upper air of the sleeping quarters by overhead irradiation.

In this experiment the level of ultra-violet intensity seems to have been an important determining factor as to whether or not air-borne infections were effectively controlled. It is interesting that even in the low intensity barracks 121 watts of ultra-violet energy were produced in each dormitory, which is high for the volume of air irradiated in comparison with previously reported figures in other studies on the effect of ultra-violet light. Lurie (1944), in his recent experiments on the spread of tuberculosis in rabbit colonies, found that it was necessary to increase the intensity of ultra-violet barriers in order effectively to interrupt the spread of this infection in a controlled environment.

One of the many questions as yet unanswered in the present study is whether an even higher intensity of ultra-violet energy would have increased the effect on the spread of respiratory illness in the barracks. A moderate increase in the number of fixtures and total intensity furnished is planned for studies in the coming winter and may help to elucidate this question.

The slightly greater intensity of irradiation from lamps which are new may have been the cause of the markedly greater percentage reduction of respiratory illness in the high intensity group in the first 2½ months of the study than in its later stages. On the other hand, differences in the nature and amount of illness in the early and later stages of the study may account for the apparent difference in the effect of the ultra-violet sources. By this hypothesis ultra-violet irradiation is most effective in times of high disease incidence such as occurred at Camp Sampson in December, 1943, and January, 1944, during the later stages of the influenza epidemic. This is because under epidemic conditions airborne spread is considered to be an important factor. When disease rates drop below a certain minimum, infection is contracted by contact at close range with relatively greater frequency. Such a method of spread would not lend itself to control by ultraviolet sterilization of the air. The low rates encountered in the latter months of the study in the spring of 1944 may have represented an irreducible minimum as far as control through ultraviolet irradiation is concerned.

The unusually low illness rates in Unit " c " at Camp Sampson during the period of observation is revealed by comparison with similarly computed rates at the Naval Training Station, Newport, R. I., in 1940 and 1941 (Table 4).

In comparison with Newport the most notable lack of morbidity at Sampson can be seen to exist in German measles and streptococcal infections. This may have been due in part at Camp Sampson to the relatively short training period which averaged less than 5 weeks. This would serve to limit the amount of streptococcal illness which has been observed in other naval training stations to reach its peak of incidence from 6 to 8 weeks after the onset of training. It would also tend

TABLE 4

Respiratory Disease Among Naval Recruits
" C " Unit, Camp Sampson, N. Y., December 15, 1943–June 1, 1944
Compared with
Naval Training Station, Newport, R. I., November 1, 1940–July 1, 1941
Average Weekly Admissions per 1,000 During Training Period

	N.T.S., Newport, R.I. 1940–41		*Unit " C," Sampson, N. Y. 1943–44*		
Diagnosis	*Cases*	*Rate per 1,000 per Week*	*Cases*	*Rate per 1,000 per Week*	*Ratio of Rates, Newport to Sampson*
Catarrhal Fever Group	2,098	26.2	1,875	17.6	1.5 : 1
German Measles	355	4.7	38	0.36	13.0 : 1
Acute Streptococcal Infections:					
Scarlet Fever	175	2.3	6	0.06	38.3 : 1
Other Strept. Infections *	418	6.4	128	1.2	5.3 : 1
Total Respiratory Disease	3,111	39.6	2,047	19.2	2.1 : 1

* Predominantly tonsillitis and pharyngitis, by clinical diagnosis; not necessarily confirmed by throat cultures.

to prevent the appearance of many cases of contagious diseases, such as German measles, which have relatively long periods of incubation. In the coming winter training will be lengthened to about 10 weeks. This decreases the rate of overturn but may give a greater opportunity for these specific bacterial and virus diseases to develop during the period of recruit training. If such is the case a more definite assessment of the effect of ultra-violet irradiation will be possible.

SUMMARY

Ultra-violet irradiation of the floors and upper air of barracks housing naval recruits was accompanied by a 25 per cent reduction of respiratory illness in those barracks equipped with high intensity sources (235 watts of ultra-violet energy per dormitory sleeping quarters for 112 men) as compared with illness in the adjacent control barracks.

This effect was most noticeable in the early winter months when illness rates were at a generally high level throughout the camp. At this time the reduction of incidence in barracks irradiated with high intensity sources as compared to the controls was approximately 35 per cent.

Streptococcal illness and carrier rates were at a very low level. These low levels were not further reduced among men living in irradiated barracks.

Bacterial counts from air samples in irradiated barracks showed a definite reduction (50 per cent) in total saprophyte colony counts as compared with counts from non-irradiated control barracks.

Beta hemolytic streptococci isolated from air and dust were found more frequently and in greater numbers in control barracks than from irradiated sleeping quarters.

In view of the fact that reduction in morbidity rates was marked in the high intensity irradiated group only in the first months of the study period, the results of the experiment of 1943–1944 should be interpreted with caution. The final assessment of the limits of effectiveness of ultra-violet irradiation in barracks must await further observations during the coming winter of 1944–1945.

NOTE: The authors wish to express thanks and appreciation to Commodore H. A. Badt, U.S.N., commander of the United States Naval Training Center, Sampson, N. Y., whose aid and support made it possible to carry out this study, and to Captain T. A. Fortescue, (MC) U.S.N., Senior Medical Officer of the Training Center, who provided generously of all facilities and coöperated actively in the conduct of the project. The authors also acknowledge the generous coöperation and interest of the Preventive Medicine Division of the Bureau of Medicine and Surgery in the conduct of this investigation.