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STUDIES OF SEWAGE PURIFICATION [1]

XV. EFFECTIVE BACTERIA IN PURIFICATION BY TRICKLING FILTERS

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In studies of the activated sludge process of sewage purification, it was shown (*1*) that the predominant bacteria in activated sludge belonged to a group represented by zoogleal formations. Subsequently it was demonstrated (*2*) that these bacteria are the active agents in activated sludge, being capable in pure culture of producing

[1] From the Division of Public Health Methods, National Institute of Health. Preceding papers in this series are:

Theriault, E. J., and McNamee, P. D.: Studies of sewage purification. I. Apparatus for the determination of dissolved oxygen in sludge-sewage mixtures. Pub. Health Rep., 50: 480 (1935). Reprint 1680.

Butterfield, C. T.: Studies of sewage purification. II. A zoogloea-forming bacterium isolated from activated sludge. Pub. Health Rep., 50: 671 (1935). Reprint 1686.

Theriault, E. J.: Studies of sewage purification. III. The clarification of sewage. A review. Sewage Works J., 7: 377 (1935). Pub. Health Rep., 50: 1581 (1935). Reprint 1715.

Smith, Russell S., and Purdy, W. C.: Studies of sewage purification. IV. The use of chlorine for the correction of sludge bulking in the activated sludge process. Sewage Works J., 8: 223-230 (1936). Pub. Health Rep., 51: 617 (1936). Reprint 1746.

McNamee, P. D.: Studies of sewage purification. V. Oxidation of sewage by activated sludge. Sewage Works J., 8: 562 (1936). Pub. Health Rep., 51: 1034 (1936). Reprint 1774.

Butterfield, C. T., Ruchhoft, C. C., and McNamee, P. D.: Studies of sewage purification. VI. Biochemical oxidation by sludges developed by pure cultures of bacteria isolated from activated sludge. Sewage Works J., 9: 173 (1937). Pub. Health Rep., 52: 387 (1937). Reprint 1812.

Ruchhoft, C. C., McNamee, P. D., and Butterfield, C. T.: Studies of sewage purification. VII. Biochemical oxidation by activated sludge. Sewage Works J., 10: 661 (1938). Pub. Health Rep., 53: 1690-1718 (1938). Reprint 1967.

Butterfield, C. T., and Wattie, Elsie: Studies of sewage purification. VIII. Observations on the effect of variations in the initial numbers of bacteria and of the dispersion of sludge flocs on the course of oxidation of organic material by bacteria in pure culture. Pub. Health Rep., 53: 1912 (1938). Reprint 1999.

Ruchhoft, C. C., Butterfield, C. T., McNamee, P. D., and Wattie, Elsie: Studies of sewage purification. IX. Total purification, oxidation, adsorption, and synthesis of nutrient substrates by activated sludge. Sewage Works J., 11: 195 (1939). Pub. Health Rep., 54: 468 (1939). Reprint 2050.

Ruchhoft, C. C., and Smith, R. S.: Studies of sewage purification. X. Changes in characteristics of activated sludge induced by variations in applied load. Sewage Works J., 11: 409 (1939). Pub. Health Rep., 54: 924 (1939). Reprint 2074.

Ruchhoft, C. C., Kachmar, J. F., and Moore, W. A.: Studies of sewage purification. XI. The removal of glucose from substrates by activated sludge. Sewage Works J., 12: 27 (1940). Pub. Health Rep., 55: 393 (1940). Reprint 2142.

Ruchhoft, C. C., Kachmar, J. F., and Placak, O. R.: Studies of sewage purification. XII. Metabolism of glucose by activated sludge. Pub. Health Rep., 55: 582 (1940). Reprint 2149.

Lackey, James B., and Wattie, Elsie: Studies of sewage purification. XIII. The biology of *Sphaerotilus natans* kutzing in relation to bulking of activated sludge. Pub. Health Rep., 55:975 (1940). Reprint 2166.

Ruchhoft, C. C., and Kachmar, John F.: Studies of sewage purification. XIV. The role of *Sphaerotilus natans* in activated sludge bulking. Pub. Health Rep., 56: 1727 (1941). Reprint 2309.

not only activated sludge but also possessing the powers of oxidation and purification inherent in natural activated sludge.

In the trickling filter process of sewage purification, also biological in nature, the fundamental set-up of the process would suggest that the active agents might be the same organisms as those of activated sludge. That is, with both processes the success of the purification depends on the presence of three essential elements, (1) bacterial masses or flocs, (2) food supply for these bacteria, i. e., polluting material, and (3) a continuous source of oxygen. The process is also dependent upon a physical means of keeping these three elements dispersed and continuously in contact with each other. In the activated sludge process the contact and mixing is brought about by an agitation of the sludge-sewage mix with compressed air which also provides a continuous source of oxygen. In the trickling filter the sludge mass is held dispersed on a framework of stones, or other material, while the sewage trickles over the surface of the sludge. The interstices of this framework provide an ample air reservoir and the circulation of this contained oxygen is aided, in part, by the flow of liquid through the system. With intermittent flow, time is provided for the sludge to utilize the adsorbed substances. Moreover, the successful perpetuation of both processes is dependent on the frequent or continuous removal of excess, and frequently detrimental, byproducts. Soluble fractions of such byproducts are removed with the effluent in both processes. Suspended matter is removed continuously in the activated sludge process by the withdrawal of excess sludge, while in the trickling filter such withdrawals are accomplished by a continuous but moderate unloading and by a periodic sloughing off of the accumulations on the filter stones. With both processes the removal of excess material is probably aided by successive growths of various biological forms. The latter factor is probably more significant in the trickling filter where such biological growths are more varied and more abundant.

While the two processes are fundamentally similar, it does not necessarily follow that the active bacterial agents are the same or even belong to the same group or genus. Consequently, it appeared desirable to study the bacterial flora of trickling filters, to isolate the predominant bacteria in a few instances, to determine the ability of these organisms in pure culture to carry on the trickling filter process, and if such bacteria appeared to be similar to those obtained from activated sludge, to make a comparative pure culture study of the two types employing both activated sludge and trickling filter set-ups.

OPERATION OF EXPERIMENTAL UNIT

An experimental trickling filter, 30 inches square and 6 feet deep, constructed in three equal sections to allow for the collection of samples

served as an immediate source of material for this study. The filter was fed with settled natural sewage in standard fashion (in intermittent cycles), usually at a rate of 3 million gallons per acre per day continuously throughout the 24-hour period. The sewage employed was from Third Street sewer, Cincinnati, Ohio, which carries principally a domestic sewage from a residential section.

From the start of the flow of sewage through this filter frequent macroscopic and microscopic examinations (the latter of both wet and dry stained preparations) were made of composite samples of material scraped from the stones of the filter. Results of these examinations indicated a very marked similarity between the growths on the stones of the trickling filter and the growths of activated sludge previously studied and reported (*1*). This agreement was particularly apparent in the bacterial section of the biological elements involved. With regard to biological forms, other than bacteria, the presence of flies and fly larvae (which are never found in activated sludge) and of certain varieties of worms (only rarely observed in activated sludge) in the growths of the trickling filter has been noted. These observations have been confirmed repeatedly by the results of a study of the material on stones obtained from two municipal trickling filter plants.

PURE CULTURE ISOLATIONS

As soon as this trickling filter had developed a normal purification rate, as measured by the reduction in the biochemical oxygen demand (B. O. D.) of the sewage passing through the filter, an intensive bacteriological study was instituted of the growths which had developed on the stones. This study involved the isolation, in pure culture, of the predominant bacterium present in the growths and in some instances an attempt to determine the relative number of such bacteria per ml. of growth. In making these observations, two methods were followed. With both methods a number of stones, with their adherent growth, were selected at random from various sections of the filter. After a gentle preliminary washing with sterile dilution water to remove extraneous and loosely attached material and organisms, the adherent growths were carefully scraped from the stones with sterile instruments and the removed material accumulated in a sterile petri dish. From this point one of the following two methods was applied.

Method No. 1.—The accumulated growth was mixed thoroughly, and a one-tenth ml. portion was withdrawn and examined carefully under low power magnification. Typical massed bacterial formations, which appeared to represent the predominant type of bacteria in the mixture, were selected, picked with sterile capillary pipettes and carefully washed by passing them, with appropriate agitation, through a series of sterile dilution waters. When these massed formations of bacteria had been presumably washed relatively free of extraneous

bacteria and adherent material, the bacteria in the masses were dispersed by pressure between two sterile glass surfaces. Simultaneously, sterile dilution water was added and a fairly thorough separation of the clumped bacteria was obtained. The organisms, thus dispersed, were planted in serial dilution in tubes of broth and synthetic sewage. The tubes were incubated at 20° C. and examinations were made at 24-hour intervals for 96 hours. Usually growth occurred in all dilutions up to and including the 0.00001 dilution and all growths above the 0.01 dilution appeared to be pure and of the same type of organism. Isolations made from the highest dilutions were subjected to additional purification and held for further study.

Method No. 2.[3]—The accumulated growth, referred to above, was mixed thoroughly and a 1 ml. or larger portion was removed and placed in a 1-ounce sterile ground-glass stoppered bottle with glass beads. Sterile dilution water was then added to make 10 ml. and the mixture was shaken at full speed in the shaking machine for 10 minutes. Immediately afterward the now finely divided mixture was diluted further and planted in serial dilution in tubes of broth or synthetic sewage. Tubes thus inoculated were incubated at 20° C. for 96 hours. Growth usually occurred in all dilutions up to the 0.00001 or 0.000001 dilution and judging from microscopic observations all growths from tubes above the 0.01 to the 0.001 dilution contained pure cultures. To insure the purity of these cultures transfers were made from the highest dilutions showing growth. After these transfers had been incubated for 6 to 8 hours (i. e., after some growth had occurred but before sufficient growth had taken place to produce any crowding or clumping of cells) they were planted out in serial dilution on dilute nutrient agar plates. (While these organisms do not grow well on standard nutrient agar they will produce colonies of about 1.0 mm. diameter after incubation for 4 to 6 days at 20° C. on dilute (1–3) nutrient agar.) Selecting plates which contained not more than 20 to 30 colonies per plate, transfers were made from typical colonies. This process of short-time incubation in liquid media followed by planting on solid media was repeated two or three times for each isolation. Colony appearance, microscopic examination of stained smears, and additional chemical tests have

[3] Method No. 1 outlined above was the procedure followed in the original work with activated sludge as reported in reference *1*. Shortly after this article appeared a fair and just criticism was voiced to the effect that this method of selection of the portion of sludge for examination introduced a personal equation in the selection which might materially affect the result. That is, a mass might be selected which did not represent the predominant organism in the mixture. However, this presumption does not appear probable when it is considered that the worker responsible for the selection had been making daily intensive microscopical study of the material over a period of several months. A study of means of dispersing bacteria massed in the gross mixture, which may be reported later, resulted in the development of method No. 2. It should be noted here that the work reported in reference *1* has since been repeated employing method No. 2 without any variation in the type of organism isolated as the predominant bacterium in activated sludge. Method No. 2 is not presented as a perfect procedure, as it has many inherent errors. However, it does avoid some of the errors of procedure No. 1, and the fact that the same type of bacterium is obtained by both methods goes far toward establishing the results presented.

indicated the purity of the cultures thus obtained. Such cultures were held for further study.

Four such cultures of the presumably predominant bacteria in the growths on the stones of the experimental trickling filter have been isolated and subjected to study. In addition, cultures have been isolated from two municipal sewage trickling filter plants.

These four isolations from the experimental filter were made from samples collected at various periods during the year as follows: (1) One in March when temperatures were near freezing and the filter was overloaded; (2) two in June when the temperature was about the average for the year and the filter was being fed at a normal rate of about 3 million gallons per acre per day; and (3) one in August when the highest temperatures of the year prevailed and the flow of sewage to the filter was at a normal rate. The average purification efficiency of the filter for each month in which these cultures were isolated, expressed in terms of the percentage of the 5-day biochemical oxygen demand removed, was 50.4 percent for the first samples, 92.8 percent for the second, and 93.9 percent for the third.

The results obtained while these cultures were being isolated show that these bacteria are present in the filter growth at least to the extent of 300,000,000 per ml. of growth. This figure is cited as representing a minimum number, for it is not reasonable to presume that an accurate enumeration was obtained. As it was not possible to make direct counts of the bacteria present in such a mass, recourse had to be made to procedures which would disperse the bacteria so that plate counts or most probable number estimations based on growth in serial dilutions could be made. To make an accurate enumeration by such a procedure, two assumptions must be made: (1) That all clumps or masses of bacteria were completely broken up, and (2) that no cells were killed, or injured sufficiently to prevent growth, by the dispersion procedure. While the latter assumption cannot be tested, microscopic examination of the treated sample showed definitely that the dispersion of the massed organisms was not complete. Consequently, it is known that the 300 million count given is a low figure and does not represent the maximum number of this type of bacterial cells. In this connection, it is noted that pure culture trickling filter growths free from detritus or any other material yielded a count of 880,000,000 bacteria per ml. of accumulated growth. The accuracy of this count is subject to the same two assumptions.

CONSTRUCTION AND OPERATION OF PURE CULTURE FILTER

The development of apparatus to explore the ability of these bacteria, under pure culture conditions, to reproduce the trickling filter process of sewage purification required considerable time and was accom-

panied by numerous failures before a fair measure of success was attained. The apparatus employed in the studies here reported is shown diagrammatically in figure 1. As the assembled set-up was

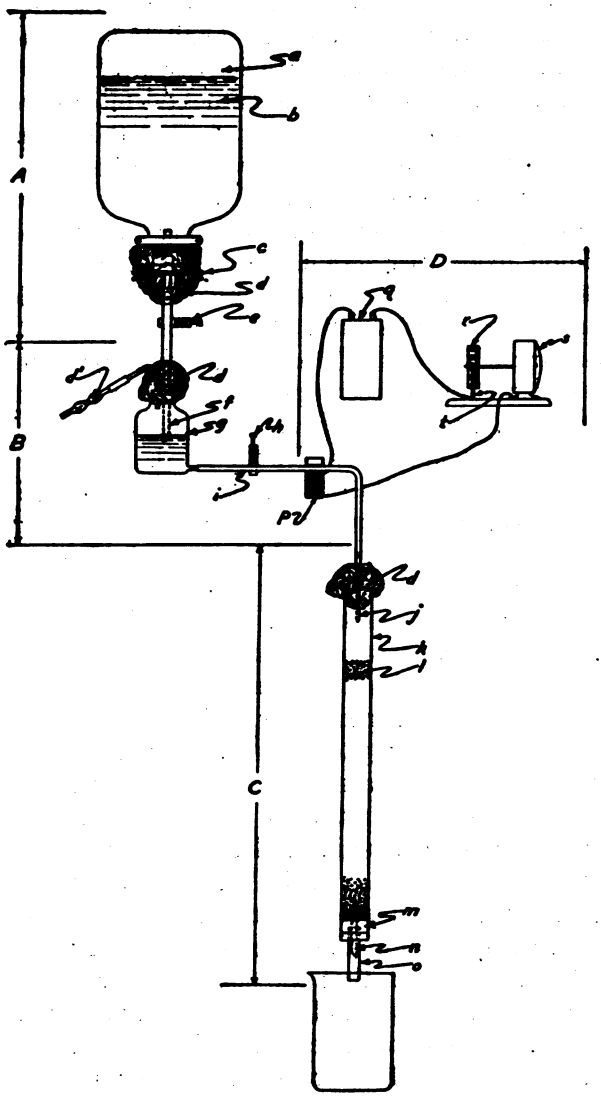


FIGURE 1.—Sketch of pure culture trickling filter set-up.

too large to be sterilized intact, provision was made for a division into sections for sterilization. These sections, unit A, stock supply of sterile synthetic sewage; unit B, equalizing reservoir for maintaining approximately a constant pressure on the feed line; unit C, trickling filter with provision for inflow and outflow of liquid, and unit D, control device for intermittent flow, are indicated in the figure. Units A, B, and C were sterilized by autoclaving, with their tubes for sub-

sequent interconnections adequately protected by cotton packing from contamination. Unit D, which did not come in direct contact with the filter or feed material, was not subjected to sterilization.

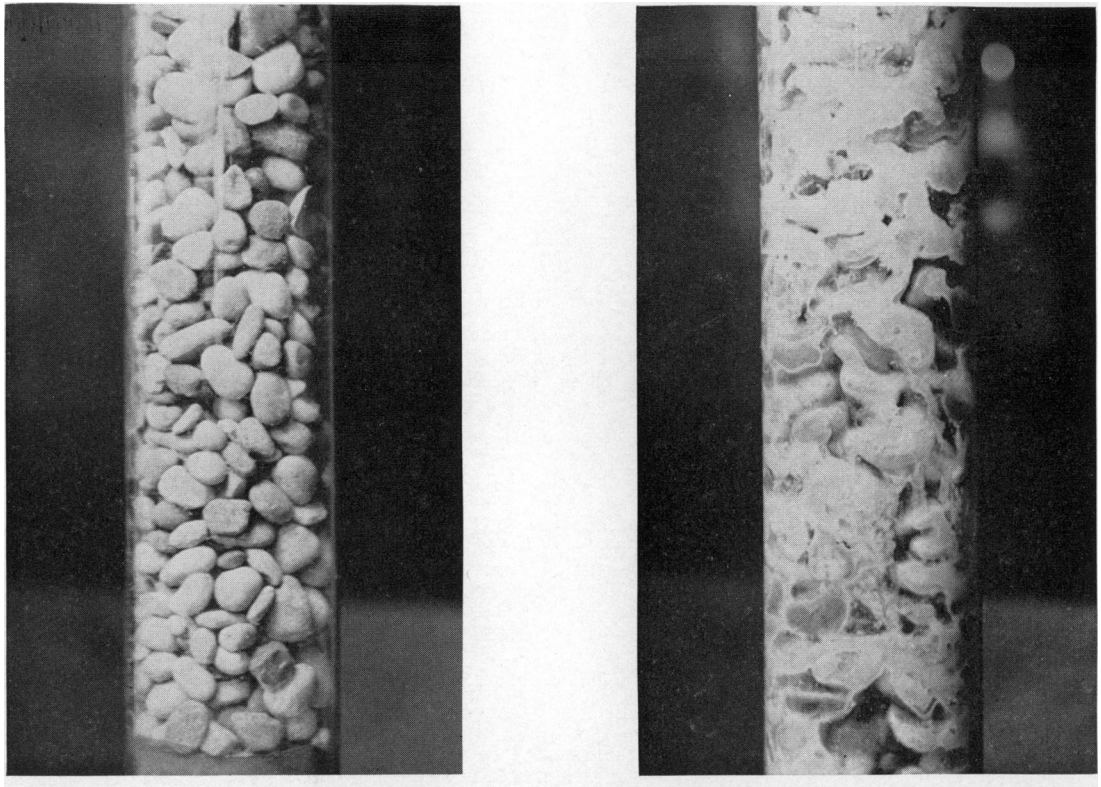
As far as is known this is the first time that an effort has been made to operate a trickling filter under pure culture conditions. Consequently, a detailed description of the various parts of the apparatus and their function may be of interest. Referring to the designations as given in figure 1, the component parts of the set-up may be described as follows: (a) Five gallon pyrex carboy; (b) 16 liters of sterile synthetic sewage (for composition, etc., see Butterfield and McNamee (*3*)); (c) metal collar and clamp arranged to hold rubber stopper with its glass tube outlet firmly in place; (d) at this and other points, cotton packing so placed as to prevent the entrance of extraneous bacteria, molds, etc.; (d^1) filters of 6 to 12 inches of loosely packed cotton in all air lines; (e) screw clamp on rubber hose connection (this clamp was left open during sterilization to allow free exchange of air and steam when carboy was upright, but was closed during the assembling of the apparatus until the time of sampling the synthetic sewage, the connecting of it to unit B and the starting of the flow through the system; (f) pyrex glass tube constant level siphon (this tube must have its lower end beveled to facilitate the flow of air to (a) when the level of the sewage in (g) drops and sewage begins to flow into (g); (g) this is a 500 ml. pyrex bottle with side delivery outlet at the bottom, fitted with a two-holed rubber stopper, one hole for inlet sewage tube, the other hole for filtered air intake as sewage is discharged; (h) metal screw clamp on rubber tubing (i) to regulate the rate of flow of synthetic sewage; (j) pyrex glass tube with constricted tip to aid in regulation of flow; (k) pyrex glass cylinder 30 inches long and 2 inches in diameter. The overall length of tube (k) was limited to 30 inches, providing for a filter depth of about one-third that of a normal trickling filter, because no greater lengths could be placed in the autoclave and sterilized. For pure culture set-ups such sterilization was essential. (l) Gravel of ¼ to ½ inch diameter which filled tube (k) to a depth of 22 inches; (m) tight-fitting rubber stopper forced entirely into lower end of (k); (n) effluent tube extending through (m) with lower end beveled to aid flow and air-liquid interchange; (o) large glass tube used as a shield for (n). The annular ring of rubber in the rubber stopper between (n) and (o) was left in place to aid in holding tube (o) firm and rigid. (p) An electromagnet which when activated closes on tube (i) collapsing it and stopping the flow of sewage; (q) a 2.0 volt cell connected to electromagnet through a make and break circuit; (r) commutator wheel provided with ten equally spaced contact segments fastened on the extended axis of the hour hand shaft of a clock, thus providing in each 1-hour period ten 3-minute periods in

which sewage was distributed to the filter at the established rate and ten 3-minute periods in which no sewage flow occurred (variations in the flow and rest periods of the filter may be provided by varying the number and size of contact segments on this commutator (r)); (s) the clock which motivated the commutator (r); and (t) a sliding contact for the segments of (r) in the circuit of the 2-volt cell.

METHODS OF DEVELOPING GROWTH

In the development of appropriate growths on this experimental trickling filter two methods were tried for the initial seeding of the stones. In method No. 1 a small amount, 10 ml., of a broth culture of the organism under trial was dropped slowly onto the top stones of the filter and allowed to trickle through. The filter then stood from 1 to 2 hours before the flow of sterile synthetic sewage was started. This interval permitted the added bacteria to become somewhat more firmly attached to the stones. Initial flow of sewage for the first day or two was always carried on at a slow rate of less than 1.0 million gallons per acre per day. Such low flows provided ample food for the small numbers of bacteria present and did not produce any violent washing action to carry away bacterial growth before it had become established. With this method 1 week was required to obtain a satisfactory growth throughout the filter and 2 weeks were required for the filter to reach maximum efficiency.

With seeding method No. 2, 8 liters of sterile synthetic sewage were inoculated with the test organism and aerated at 20° C. for 48 to 96 hours. Under such conditions a heavy, flocculent growth of these bacteria would develop. This 8 liter amount of growth was passed slowly through the gravel of the experimental trickling filter by means of a sterile siphon, while the filter drainage was carefully regulated by valves. By watching the location of the accumulation of growth added in this manner and making appropriate variations in the rate of flow, a very even distribution of the bacterial masses throughout the filter could be obtained. With this procedure also the seeded filter was allowed to stand quiescent for an hour or two after seeding before the initial slow flow of sewage was started. Using method No. 2 as much growth could be obtained in one day on the filter as in a week with method No. 1. Moreover, with method No. 2 maximum efficiencies would be obtained in a week. A photograph of a portion of this experimental filter with and without a fully developed growth of these bacteria in pure culture on the gravel of the filter is shown in figure 2. It is noted that the stones and adjoining sections of the retaining walls are covered heavily with growth. This growth is spongy and contains large amounts of moisture. Microscopic examinations indicated that it was composed entirely of bacterial cells. As observed above, this growth mass yielded a minimum bacterial count of 880 million per ml. of moist growth mass.



A. Unseeded sterile filter.

B. Filter 7 days after seeding.

FIGURE 2.—Sections of pure culture trickling filter.

TESTING PROCEDURES

The extent of purification of the synthetic sewage accomplished as it passed through these pure culture trickling filters was measured by comparing the 5-day biochemical oxygen demand of the influent with the corresponding 5-day B. O. D. of the filter effluent. These B. O. D. determinations were made in accordance with the standard procedure. Each pair of samples (influent and effluent) was put up for this determination in appropriate dilution and seeded. The seed used (1 ml. per liter of dilution) in each case consisted of settled domestic sewage after aeration for 24-hours at room temperature.

Rates of flow of the synthetic sewage through these pure culture filters were varied from less than 0.5 to 6.0 or more million gallons per acre per day. In the zone of 1.0 to 3.0 million gallons per acre per day tests made were repeated with greater frequency. These repetitions were made at various times during the life of the filter to provide observations on any variations in growth or in the condition of the filter as it aged. In all cases when a change in rate of flow was made, the filter was allowed to run at the new rate for a period, at least overnight, to allow for an adjustment to the new conditions of flow before a test was made.

RESULTS WITH PURE CULTURE TRICKLING FILTER

Results obtained in this manner by pure culture trickling filters developed (1) by culture 87 isolated as the predominant organism in the growth mass on the stones of a trickling filter fed with natural sewage, and (2) by culture 86, a typical zoogleal bacterium, isolated as the predominant organism in activated sludge, are presented in table 1. The same results are shown graphically in figure 3.

TABLE 1.—*Relative purification produced by pure culture trickling filter growths developed in an experimental trickling filter*

Range of flow in million gallons per acre per day	A. With culture 86 [1]			B. With culture 87 [2]		
	Average flow for period	Number of tests included in average	Percentage of 5-day B. O. D. removed	Average flow for period	Number of tests included in average	Percentage of 5-day B. O. D. removed
0.0–0.49	0.34	1	71.1	0.39	1	78.6
0.5–0.99	.92	3	52.1	.75	5	62.7
1.0–1.49	1.21	10	57.1	1.22	5	50.0
1.5–1.99	1.80	10	49.1	1.78	3	35.8
2.0–2.49	2.22	10	43.1	2.25	5	40.5
2.5–2.99	2.68	8	38.6	2.73	6	35.6
3.0–3.49	3.17	5	32.6	3.28	2	29.8
3.5–3.99	3.70	1	22.7	3.78	4	31.0
4.0–4.99	4.51	3	23.2	4.51	2	24.5
5.0–5.99	5.37	1	14.2	5.00	1	29.2
6.0–6.99	6.26	1	16.0	6.07	1	27.6
7.0–7.99	7.46	1	21.2			

[1] A predominant bacterium in activated sludge.
[2] A predominant bacterium in trickling filters.

Three observations may be made regarding the results presented. First, a marked purification of the synthetic sewage occurs as it passes through the filter. Second, there is a definite correlation between the rate of flow and the extent of purification. And third, the purification accomplished by the two pure culture systems is quite similar. That is, judging from the results obtained, these two organisms, one predominant in trickling filters, the other in activated sludge, may be used interchangeably in pure culture trickling filters without apparent variation in purification efficiency. Certain conditions affecting these observations will be considered.

With regard to the over-all purification accomplished by these pure culture trickling filter systems, it was planned at the start of the work

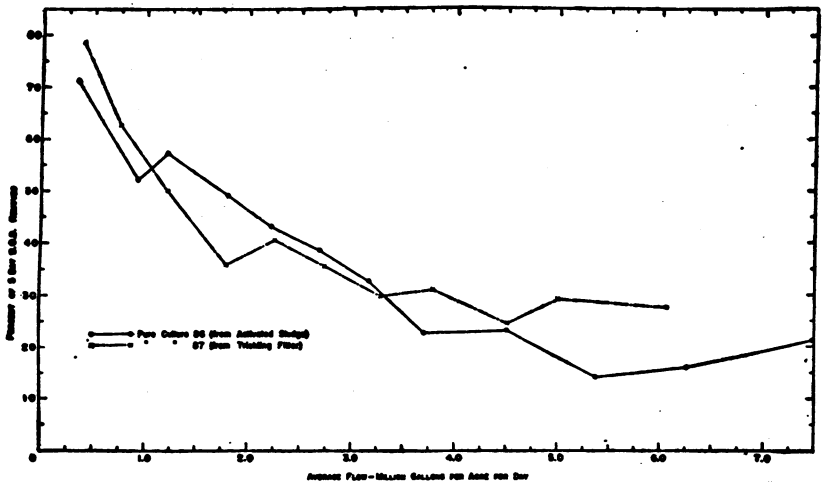


FIGURE 3.—Over-all purification by pure culture trickling filters with varying flow.

to make direct comparison of the results obtained with those observed in plant size units operated under natural conditions with all the flora and fauna of domestic sewage. The requirements for a pure culture set-up established limits which prevented such a direct comparison. For instance, as noted above, the depth of gravel in the pure culture filter was limited to 22 inches by the sterilization facilities while the depth of stone in a normal filter is about 60 to 72 inches. Correspondingly the time of flow through the stones of the pure culture filter was less than 1 minute (about 55 seconds) while flow through a normal filter requires 3 to 4 minutes.

Consequently, the extent of purification in a similar filter fed with raw domestic sewage containing all of its normal flora and fauna was determined. In each case the purification with the pure cultures approached that observed with a similar filter containing the normal flora and fauna.

While definite evidence is not available to show that the extent of

purification in a trickling filter varies directly with the depth of the filter or with the time the sewage is in contact with the growth on the filters, presumptive evidence suggests that this is the case. Therefore, the purification accomplished by the filter of 60 to 72 inches depth might be assumed to be about three times as great as that observed with a 22-inch filter. That is, on this basis, the purification of about 33 percent observed with the 22-inch filter at a flow of 3 million gallons per acre per day would be expected to be 90 to 100 percent with a filter of normal depth. Or, considered from another angle, the 22-inch filter flowing at a rate of 1 million gallons per acre per day might be expected to accomplish the purification of a normal depth filter flowing at a rate of 3 million gallons per acre per day. On the latter basis, the percentage of the 5-day biochemical oxygen demand removed would be in the range of 50 to 60 percent. With such allowances the degree of purification accomplished by these pure culture filters would be of almost the same order of magnitude as observed in a normal filter. Thus the purification accomplished by the pure culture trickling filters developed by the predominant bacteria isolated from a natural activated sludge equalled that accomplished by a similar trickling filter developed by the predominant bacterium in a trickling filter.

PURE CULTURE TRICKLING FILTER OPERATED AS CONTACT FILTER

At the conclusion of each run, when operating the pure culture filter as a trickling filter, it was operated for a time as a contact filter to compare the purification brought about by these two methods. To carry out this procedure the outlet (n) of the filter (see fig. 1) was closed by attaching a short piece of sterile rubber tubing with a clamp. The filter was then slowly filled to the top level of the stones and allowed to stand thus for 1 hour. The effluent was then slowly drained off and the filter allowed to rest for at least 3 hours before the test was repeated. The degree of purification was determined by comparing the 5-day B. O. D. of the influent with the corresponding B. O. D. of the effluent. This test as a contact filter was repeated 7 times using synthetic sewage, 11 times with sterilized natural sewage, and 5 times with raw natural sewage. The latter tests were conducted on the same day at the end of the run so that the additional inoculum introduced with the raw sewage would not have time to develop sufficiently to affect the results materially. The averages of the results obtained from these runs as a contact filter are given in table 2.

The amount of sewage required to fill this unit as a contact filter was a quantity that would provide an hour's flow at a rate of about 3.35 million gallons per acre per day. Consequently, as the sewage was held in contact for 1 hour the extent of purification may be

compared with the trickling filter results when operated at 3.35 million gallon rate. This rate of operation as a trickling filter (see fig. 3) had given an average reduction of the 5-day B. O. D. of about 30 percent. The purification accomplished by the contact process, with synthetic sewage in which all components are in solution, is approximately the same as the average obtained by the sprinkling procedure. However, the purification accomplished by this process with sterilized natural sewage and with raw sewage is considerably greater than with synthetic sewage. This may be explained by assuming for the contact method a 100 percent wetting of all of the active biological surfaces while with the sprinkling method some of the surfaces may escape such contact. The more reasonable explanation is that with natural sewage, sterilized or raw, a considerable portion of the 5-day B. O. D. is contained in colloidal and suspended matter. This fraction would be removed effectively by the filter, while in synthetic sewage no such suspended solids were present. It was not possible to make these observations satisfactorily with natural sewage on the pure culture trickling filter as the particles present in the sewage interfered with the establishment of a continuously uniform flow at the low rates required.

TABLE 2.—*Pure culture trickling filter (culture 86, table 1) operated as a contact filter with various feeds*

Nature of influent	Number of tests	Average contact period, hours	Percent of purification as measured by 5-day B. O. D. of influent and effluent
Synthetic sewage	7	1	28.2
Sterilized natural sewage	11	1	51.3
Raw natural sewage	5	1	61.1

RESULTS WITH PURE CULTURE ACTIVATED SLUDGE

Using the same pure cultures, No. 87 isolated from a trickling filter, No. 86 isolated from activated sludge, and a new culture, No. 103, isolated from a trickling filter, pure culture activated sludges were developed and their over-all purification efficiency using synthetic sewage was determined by the methods described by Butterfield (*1*). The results obtained from these tests are presented in table 3.

For purposes of comparison, the average results from a previous similar study (*2*) with activated sludge bacteria, zoogleal cultures Nos. 1, 4, and 9, are included in this table. This gives an opportunity to compare the results obtained with the older pure culture sludges (with a much heavier growth, 1,793 p. p. m. vs. 877 p. p. m. of suspended solids), with the newer sludge developed with culture 86.

TABLE 3.—*Over-all purification by pure culture activated sludges developed by bacteria isolated from various purification systems*

Designation	Cultures used	Source of culture	Amount of sludge in p. p. m.	Number of tests made	Percent of 5-day B. O. D. removed after aeration of:			
					1 hr.	3 hrs.	5 hrs.	24 hrs.
A	86	Activated sludge	877	4	34.9	52.0	62.2	61.0
B	87 and 103	Trickling filter	760	4	43.4	66.7	75.8	80.3
C	1, 4, and 9	Activated sludge	1793	5	34.6	78.1	82.1	88.8
Average of A and C					34.8	65.0	72.2	74.9

The amount of purification accomplished by the pure culture activated sludges produced by cultures 87 and 103, isolated as the predominant organisms of trickling filters, exceeds that accomplished by the activated sludge produced by culture 86, isolated from activated sludge, but does not equal the earlier results obtained with activated sludge cultures Nos. 1, 4, and 9. It must be noted, however, that these previous sludges were developed until they contained a much larger number of bacteria as measured by the amount of sludge produced. The average over-all purification accomplished by pure culture sludges produced by activated sludge bacteria cultures 1, 4, 9, and 86 (that is, the average of A and C as given in table 3) approximately equals that accomplished by the activated sludges produced by trickling filter bacteria, cultures 87 and 103. Thus it is observed that the predominant bacteria of a trickling filter can produce a pure culture activated sludge which functions at least as effectively as a similar sludge produced by the normal activated sludge bacteria.

RESULTS WITH BACTERIA-ONLY TRICKLING FILTERS AND ACTIVATED SLUDGES DEVELOPED BY SEVERAL STRAINS OF ZOOGLEAL BACTERIA

Detailed studies of the characteristics of the zoogleal bacteria isolated from activated sludges and from trickling filters have yielded interesting information. For instance, the various strains were identical with regard to certain major characteristics. They were all aerobic, gram-negative rods, producing capsules, not forming chains, forming zoogleal flocs or huge colonies in liquid media under aeration, and failing to ferment the ordinary sugars with gas production. They differed in certain minor characteristics such as the digestion of casein, the production of indol, and the utilization of nitrates.

These differences in activity suggest that while the extent of purification produced by sludges developed by these bacteria, each in pure culture, was approximately the same, the substances utilized by the various sludges may have varied in quality if not in quantity. This suggests further that a bacteria-only activated sludge or trickling filter produced by the combined growths of several of these strains of

bacteria would bring about a more complete purification. If these bacteria were the active agents, this purification would approach more uniformly, even with a feed whose constituents varied, the purification produced by a normal trickling filter, or activated sludge.

Accordingly, an experiment was carried out to determine the purification accomplished by a bacteria-only growth in a trickling filter and in activated sludge when the bacteria involved were a mixture of pure strains of zoogleal organisms. Nine pure culture strains were selected for this purpose: Cultures 53, 83, 85, 86, and 88 which had been isolated from activated sludges, and cultures 87, 100, 102, and 103, which had been obtained from the growths on the stones of trickling filters. In producing such growths each of 9 flasks containing 100 ml. of broth was inoculated with one of these strains in pure culture. They were held at 20° C. for 48 hours. By this time all 9 flasks had developed a heavy flocculent growth. The entire contents of each of the 9 flasks were then introduced into an aeration bottle containing 8 liters of synthetic sewage and aeration was started with storage at 20° C. While it was not possible to follow the relative growth of each of the 9 strains present in the aeration bottle, it was felt that the massive initial inoculation employed would give each strain an excellent opportunity to be well represented in the final growth subjected to test. Sludges produced in this manner will be referred to as "mixed pure culture" growths.

The 8 liter portion of synthetic sewage, thus inoculated and incubated at 20° C. under aeration, was fed daily with fresh synthetic sewage by the fill-and-draw method. That is, once daily, aeration was stopped, the bacterial sludge was allowed to settle for 30 minutes, 5 liters of clear supernatant were removed under aseptic conditions with a sterile siphon, 5 liters of sterile synthetic sewage were added, and aeration was resumed. When necessary, adjustments were made with sterile solutions to keep the hydrogen ion concentration in the range of pH 6.6 to 7.4. After a period of about 30 days, when bacterial sludge had developed to the extent of about 1,500 p. p. m. in terms of suspended solids (dry weight at 105° C.) the 8 liters were thoroughly mixed and divided into two equal portions. The sludge of one portion was transferred at once to a sterile trickling filter set-up, using method No. 2 described above, for observations on its efficiency in purifying synthetic sewage under these conditions. (For results see table 4, experiment 1X.) Tests were made on the purification accomplished with various rates of flow during the next 7 days. The other portion of this "mixed pure culture" activated sludge was continuously maintained as an activated sludge with daily feedings as described above.

Tests were made of its purification efficiency as an activated sludge on the first (experiment 1A), third (experiment 1B), and seventh (experiment 1C) day of feeding from the time the portion was withdrawn to start the trickling filter set-up. (See table 5 for results.)

After the sludge of 1X had been in service for 13 days as a trickling filter sludge it was completely removed from the stones with aseptic precautions and put on test at once as an activated sludge. The results of the test with this sludge, 1X, are presented in table 5. It is noted that in this experiment practically none of the bacterial sludge was lost either as it was added to or removed from the trickling filter set-up. This is shown by approximately the same suspended solids content for portions 1C and 1X.

These observations with activated sludge and trickling filter purification by "mixed pure culture" growths were repeated under identical procedures in experiments 2A, 2B, and 2X. The only variation noted in experiment 2 is that apparently about one-third of the bacterial sludge was lost either in transferring the portion of sludge to, or removing it from, the trickling filter. This is shown by the variation in suspended solids content—1,666 for 2B and 904 for 2X. The results obtained in these two experiments, with averages, are presented in tables 4 and 5.

TABLE 4.—*Purification accomplished by a trickling filter developed by the growth of a mixture of 9 pure cultures of zoogleal bacteria*

Experiment 1X [1]				Experiment 2X [2]			
Hours from start	Rate of flow (million gallons, per acre per day)	Percent of 5-day B.O.D. removal	Remarks	Hours from start	Rate of flow (million gallons, per acre per day)	Percent of 5-day B.O.D. removal	Remarks
20	0.74	80.6		48	0.87	65.2	
44	1.78	78.0		72	1.47	66.6	
48	2.13	88.0		74	1.43	66.9	
68	2.88	86.6		76	1.43	66.2	
70	1.09	89.4		96	3.72	23.6	Flow suddenly increased at sampling period.
72	.93	91.2		98	1.36	27.9	
117	1.10	77.6		120	1.02	58.1	Ponding observed at intervals.
119	.68	84.2	Rate increased as soon as sampled.	124	1.12	58.0	
121	4.14	44.6		144	.88	54.5	
140	5.04	31.3		148	1.02	68.5	
142	3.41	12.8	Ponding complete, filter stones stirred up.	168	1.12	61.4	
164	2.89	70.2		216	1.80	28.4	Ponding complete, filter stones stirred up.

[1] See table 5 for purification accomplished by aliquot portions of the same mixed bacterial growths under conditions of activated sludge operation. Test 1A made at 20-hour period, 1B at 68-hour period, 1C at 164-hour period, and 1X with sludge washed from the growth on the stones of this filter.

[2] See table 5 for purification accomplished by aliquot portion of the same mixed bacterial growths under conditions of activated sludge operation. Test 2A made at 72-hour period, 2B at 168-hour period, and 2X with sludge washed from the growth on the stones of this filter.

TABLE 5.—*Purification accomplished by activated sludge[1] developed by the growth of a mixture of 9 pure cultures of zoogleal bacteria*

Experiment No.	Amount of sludge, p. p. m.	Percentage of 5-day B. O. D. removed after aeration for:				Percentage of 5-day B. O. D. oxidized after aeration for:			
		1 hr.	3 hrs.	5 hrs.	24 hrs.	1 hr.	3 hrs.	5 hrs.	24 hrs.
1A [2]	1536	34.3	40.8	36.4	90.7				
1B	1628	64.9	82.1	83.9	88.7				
1C	1558	53.7	77.7	81.2	81.5	38.4	62.2	67.9	84.6
1X	1598	57.9	84.3	79.8	81.4	23.6	43.0	52.9	63.6
2A		67.7	83.5	89.2	87.3				
2B	1666	50.5	85.1	89.7	85.1	23.3	43.7	48.6	59.7
2X	904	31.2	64.3	65.4	71.0	15.5	34.7	42.5	58.5
Average, 1A, 1B, 1C, 2A, and 2B		54.2	73.8	86.1	86.7	30.8	52.9	58.2	72.2
Average, 1X and 2X		44.6	74.6	72.6	76.2	19.6	38.8	47.7	61.0

[1] Sludges produced by the mixed growth of nine pure cultures of zoogleal bacteria, cultures 53, 83, 85, 86, 87, 88, 100, 102, and 103.

[2] Sludges 1A, 1B, 1C, 2A, and 2B produced and continuously maintained under aeration as an activated sludge. Sludges 1X and 2X developed as an activated sludge for about 30 days as an aliquot portion of 1A and 2A, then at the time tests of 1A and 2A were made sludge portions 1X and 2X were put on sterile trickling filters and used as a trickling filter for 13 days, then growth on stones of filter was washed off and tested at once as an activated sludge in 1X and 2X.

DISCUSSION OF RESULTS

Considering first the findings from the trickling filter studies, it is noted, as has been observed in the preceding experiments with pure culture trickling filters, that excellent results were obtained until partial or complete ponding of the filter occurred. Correction of this difficulty, by stirring the gravel in the ponded area, usually, but not always, restored normal operation after a few days. When normal results were not obtained it was assumed that the ponding action had blocked off certain portions of the growth in the filter even though an apparently normal resumption of flow had occurred. Such an effect might materially reduce the opportunity for contact between some of the bacterial masses and the inflowing bacterial food and at the same time would have a tendency to create anaerobic areas.

When the results presented in table 1 are compared with those in table 4, it is at once apparent that in the trickling filter set-up the "mixed pure culture" growth was more effective than the growth of any one pure culture. This difference was definitely in the favor of the "mixed pure culture" growth when the rate of flow was approximately 3 million gallons per acre per day. However, when the flow was near the rate of 1 million gallons per acre per day the increased efficiency of the "mixed pure culture" growth was the more marked. This latter rate of flow, as was noted above, is probably about the optimum for shallow filters of the depth required for the production of a set-up under pure culture conditions. Thus the results obtained with the "mixed pure culture" growth, reaching a maximum efficiency of removing approximately 90 percent of the 5-day B. O. D. of the influent, approach very closely the conditions of a normal trickling

filter. This suggests very definitely that these bacteria are the active agents in this purification process.

The results presented in tables 3 and 5 provide a similar comparison when the growths of these same organisms, in pure culture and in "mixed pure culture," are used as an activated sludge. Again it is observed that the "mixed pure culture" growth is the more effective. The maximum difference, about 40 percent, is found in the averages for the results obtained at the 1-hour aeration period. The differences observed at the 3-, 5-, and 24-hour aeration periods were considerably less but the "mixed pure culture" sludge consistently produced a higher percentage of B. O. D. removal.

In the averages presented in table 5 an interesting difference is observed between the purification produced by sludges 1A, 1B, 1C, 2A, and 2B (which had been produced and continuously maintained under aeration as an activated sludge) and the purification brought about by sludges 1X and 2X (which, while originally produced as an activated sludge, had been in service on a trickling filter for the 13 days immediately preceding these tests). With but one exception the sludges continuously maintained as activated sludges produced the higher degree of over-all purification. The one exception, the 3-hour period, was probably caused by one unusually high result in experiment 1X in this period. This difference between the activity of the two diversely treated sludges was more marked when measured by the portion of the 5-day B. O. D. oxidized [3] during the various aeration intervals. The "mixed pure culture" sludge in each instance produced a greater amount of oxidation, the greatest difference being observed during the first hour of aeration.

This difference in activity between the activated and trickling filter sludges is probably brought about by the condition of the sludges. The sludges which had been maintained under continuous conditions of activation were fed by the fill-and-draw method. At the time of test, 24 hours had elapsed since the last feeding and these sludges were probably relatively free of adsorbed material. The other sludges used in trickling filters immediately prior to these tests under conditions of activated sludge operation had been fed continuously up to the time of removal from the filters. These sludges were probably moderately loaded with adsorbed material when aeration was started. Their gradual improvement in purifying power at each subsequent aeration interval supports this assumption

[3] It may be pertinent to distinguish here the differences between the terms B. O. D. removed and B. O. D. oxidized, which are explained in detail in reference 2. When an activated sludge or a trickling filter is fed with sewage the initial but continuous step in the purification process is adsorption followed by oxidation and by synthesis of the adsorbed material into new bacterial protoplasm through growth and reproduction of cells. The B. O. D. removed is a measure of the over-all, or total, purification produced by the combined activities of adsorption, oxidation, and synthesis. The B. O. D. oxidized includes only that portion of the over-all purification which has been produced by actual oxidation.

Perhaps the most interesting observation made in this study of the bacteria of trickling filters is that the zoogleal organisms found to be predominant in trickling filters and in activated sludge floc may be used interchangeably in pure culture set-ups without any material variations in the purification efficiency obtained. This interchangeability in pure culture trickling filters is shown quite definitely in the results presented in table 1 and in figure 3. The same interchangeability in purification by the activated sludge process is shown in table 3.

The interchangeability of these zoogleal bacteria in activated sludge is shown more clearly in figure 4. Here the average purification ac-

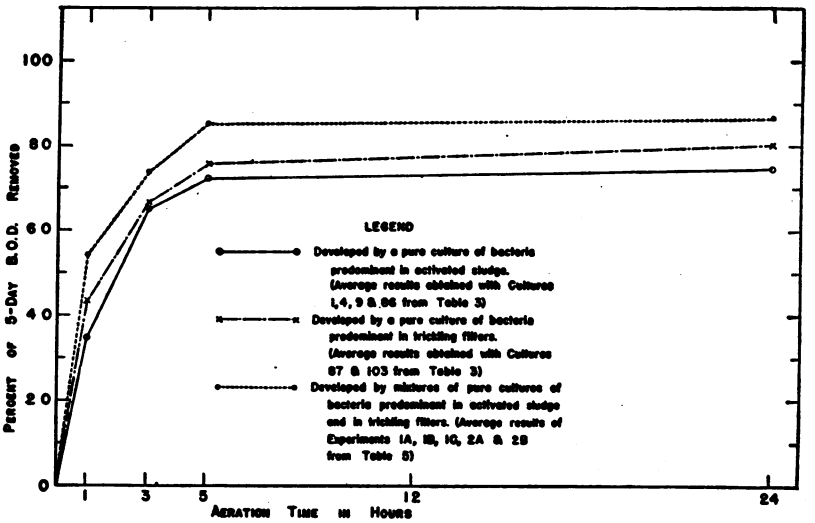


FIGURE 4.—Over-all purification produced by activated sludge developed by pure cultures of zoogleal bacteria.

complished by activated sludges, each developed by a pure culture of zoogleal bacteria isolated from natural activated sludge, is contrasted with the purification obtained with activated sludges each developed by a pure culture isolated from a normal trickling filter. In the average for sludges developed by bacteria isolated from activated sludge 9 experiments are included, 2 with culture No. 1, 1 with culture No. 4, 2 with culture No. 9, and 4 with culture No. 86, while 4 experiments, 2 with culture No. 87 and 2 with culture No. 103, are included in the average for sludges developed by bacteria isolated from normal trickling filters. Remarkable agreement at all aeration intervals is noted between the purification accomplished by the pure culture activated sludges developed by the zoogleal bacteria from the two sources, activated sludges and trickling filters. Moreover, the slight difference in purification noted, which is within the limits of variation observed between different cultures, favors the activated sludges developed by bacteria isolated from trickling filters.

The results obtained with the mixture of 9 pure cultures of these zoogleal bacteria, 4 isolated from trickling filters and 5 from activated sludges, are also shown in figure 4. It is noted that this "mixed pure culture" sludge produced a more extensive purification at each aeration interval, with the greatest change taking place during the first hour.

SUMMARY

The isolation in pure culture of the predominant bacteria found in the growths on the stones of experimental and municipal trickling filter sewage plants is reported. These bacteria are present at least to the extent of 300 million per ml. of filter growth. The organisms thus isolated and studied are zoogleal in nature and are similar to the predominant bacteria found in activated sludge.

The construction, method of inoculation, and operation of a trickling filter unit under pure culture conditions is described in detail.

These bacteria in pure culture, in this trickling filter unit, produced a growth on the stones of the filter which simulated a normal trickling filter both in appearance and in purification properties.

The predominant bacteria of activated sludge in pure culture are shown to have the same ability to produce adherent growths on the stones of a filter which in gross appearance and in purifying power simulates a normal trickling filter.

Conversely, it is demonstrated that these bacteria, isolated as the predominant organisms in a trickling filter, will in pure culture produce a floc of the same general appearance as activated sludge. That is, these trickling filter bacteria also have the ability to grow in a liquid medium in a massed floc or colony bound together tenaciously enough to remain intact under the agitation of the aeration required to keep it suspended and to maintain aerobic conditions. This pure culture activated sludge during a 5-hour aeration interval removed about 76 percent of the 5-day B. O. D. of polluted waters.

A mixture of nine pure cultures of these zoogleal bacteria in both trickling filter and in activated sludge set-ups was more effective than any one strain in pure culture by itself. The extent of purification brought about by such a mixture was equivalent to that produced by a trickling filter or by an activated sludge containing all of the flora and fauna of normal sewage.

The results obtained show that the predominant zoogleal bacteria of trickling filters and of activated sludges may be used interchangeably without impairment of purification efficiency. These results also indicate very definitely that the members of this group of bacteria are the active agents in purification by biological processes and suggest that the maintenance of conditions favoring their growth would expedite such purification procedures.

ACKNOWLEDGMENTS

Appreciation is expressed to Principal Chemist C. C. Ruchhoft and the staff of the chemical laboratory of the Stream Pollution Investigations Station for their aid in carrying on the oxidation observations presented in table 5 and for making the determinations on suspended solids. Special consideration is due also to Senior Sanitary Engineer J. K. Hoskins for his most helpful suggestions and guidance throughout this investigation.

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ORNITHODOROS PARKERI AND RELAPSING FEVER SPIROCHETES IN UTAH [1]

By GORDON E. DAVIS, *Senior Bacteriologist, United States Public Health Service*

Previous to the present investigation, specimens of *Ornithodoros parkeri* have been collected in Utah as follows: By field crews of the Plague Laboratory at San Francisco, Calif., 6 larvae from a golden mantled squirrel (*Citellus* sp.), Wayne County, 1936; 1 larva and 2 nymphs from a ground squirrel (*Cit. grammurus*), Washington County, 1938; 1 nymph from a prairie dog (*Cynomys* sp.), Uintah County, 1938; 5 nymphs from a prairie dog burrow, Emery County, 1939; and by Medical Entomologist Cornelius B. Philip, 6 specimens, Grand County, 1939. All but 2 lots were received in alcohol.

Two cases of relapsing fever have been reported in Utah, one in 1928 and the other in 1930. Both were thought to have originated west of Salt Lake City.

The present survey covered the period August 31 to September 8, 1940, and included parts of San Juan, Grand, Emery, Carbon, Uintah, Duchesne, Utah, Sanpete, Sevier, Piute, Garfield, Kane, Washington, Iron, Beaver, and Millard Counties.

Forty-nine lots of ticks ranging from 1 to 59 specimens were collected. Species determinations were made by Dr. R. A. Cooley. All but 1 lot were *O. parkeri*. A single specimen collected in San Juan County was *O. turicata* and constitutes the first record for this

[1] From the Rocky Mountain Laboratory, Hamilton, Mont., Division of Infectious Diseases, National Institute of Health.

species in Utah. The total number of *O. parkeri* collected was 306, of which 235 survived for testing for spirochetes. Twelve lots were collected in Uintah County, 5 in Carbon, 20 in Grand, 7 in Emery, and 4 in Iron. Spirochetes were recovered from 1 lot from Uintah County, one from Carbon, 2 from Emery, and 3 from Grand. These findings were based on a single test feeding on white mice.

Table 1 gives the laboratory accession number, the dates of collection, lot number, number of lots, the number of ticks in each lot and the number tested, the habitat, the collector, and the results of testing for spirochetes.

TABLE 1.—*Ornithodoros parkeri and relapsing fever spirochetes in Utah*

Accession No.	County	Date collected	Lot No.	Number of ticks		Habitat	Collector	Spirochetes
				Collected	Tested			
16634	Emery	June 22, 1939	1	5	2	Prairie dog burrow	Plague laboratory.	Not found.
16141	Grand	Sept. 15, 1939	2	6	6	do	Philip	Present.
17130	San Juan	Aug. 31, 1940	3	[1] 1	1	Burrow	Davis	Not found.
17132	Grand	Sept. 1, 1940	4	5	2	Prairie dog burrow	do	Do.
17133	do	do	5	7	7	Burrow	do	Do.
17134	do	do	6	3	3	Prairie dog burrow	do	Do.
17135	do	do	7	2	2	Burrow	do	Do.
17136	do	do	8	9	9	Prairie dog burrow	do	Do.
17137	do	do	9	3	3	do	do	Do.
17138	do	do	10	8	8	Burrow	do	Present.
17139	do	do	11	10	9	Prairie dog burrow	do	Not found.
17140	do	do	12	2	2	do	do	Present.
17141	do	do	13	4	2	do	do	Not found.
17143	do	do	14	7	7	do	do	Do.
17144	do	do	15	2	2	do	do	Do.
17145	do	do	16	3	3	do	do	Do.
17146	do	do	17	9	6	do	do	Do.
17147	do	do	18	6	4	do	do	Do.
17148	do	do	19	9	7	do	do	Present.
17149	do	do	20	2	2	do	do	Not found.
17150	do	do	21	2	2	do	do	Do.
17151	do	do	22	42	38	do	do	Do.
17351	do	do	23	3	2	do	do	Do.
17356	Emery	Sept. 2, 1940	24	1	1	do	do	Do.
17357	do	do	25	3	3	do	do	Present.
17358	do	do	26	1	1	do	do	Not found.
17359	do	do	27	5	4	do	do	Do.
17360	do	do	28	4	3	do	do	Do.
17361	do	do	29	2	2	do	do	Do.
17367	do	do	30	10	10	do	do	Present.
17362	Carbon	Sept. 3, 1940	31	1	1	do	do	Not found.
17363	do	do	32	2	2	Burrow	do	Do.
17364	do	do	33	4	4	Prairie dog burrow	do	Do.
17365	do	do	34	3	3	do	do	Do.
17366	do	do	35	12	10	do	do	Present.
17368	Uintah	Sept. 5, 1940	36	4	4	do	do	Not found.
17369	do	do	37	6	6	do	do	Do.
17370	do	do	38	2	2	do	do	Do.
17371	do	do	39	3	3	do	do	Do.
17372	do	do	40	7	6	do	do	Do.
17373	do	do	41	1	1	do	do	Do.
17374	do	do	42	13	13	do	do	Present.
17375	do	do	43	2	2	do	do	Not found.
17376	do	do	44	4	4	do	do	Do.
17377	do	do	45	4	4	do	do	Do.
17378	do	do	46	10	10	do	do	Do.
17379	do	do	47	1	1	do	do	Do.
17381	Iron	Sept. 8, 1940	48	1	1	do	do	Do.
17382	do	do	49	1	1	do	do	Do.
17384	do	do	50	1	1	do	do	Do.
17385	do	do	51	59	11	do	do	Do.

[1] *O. turicata.*

Figure 1 shows the areas in which *O. parkeri* and the one specimen of *O. turicata* were collected. The recovery of spirochetes is indicated by "S". With the exception of Emery County, the exact locations of the collections made by the staff members of the Plague Laboratory are unknown to us.

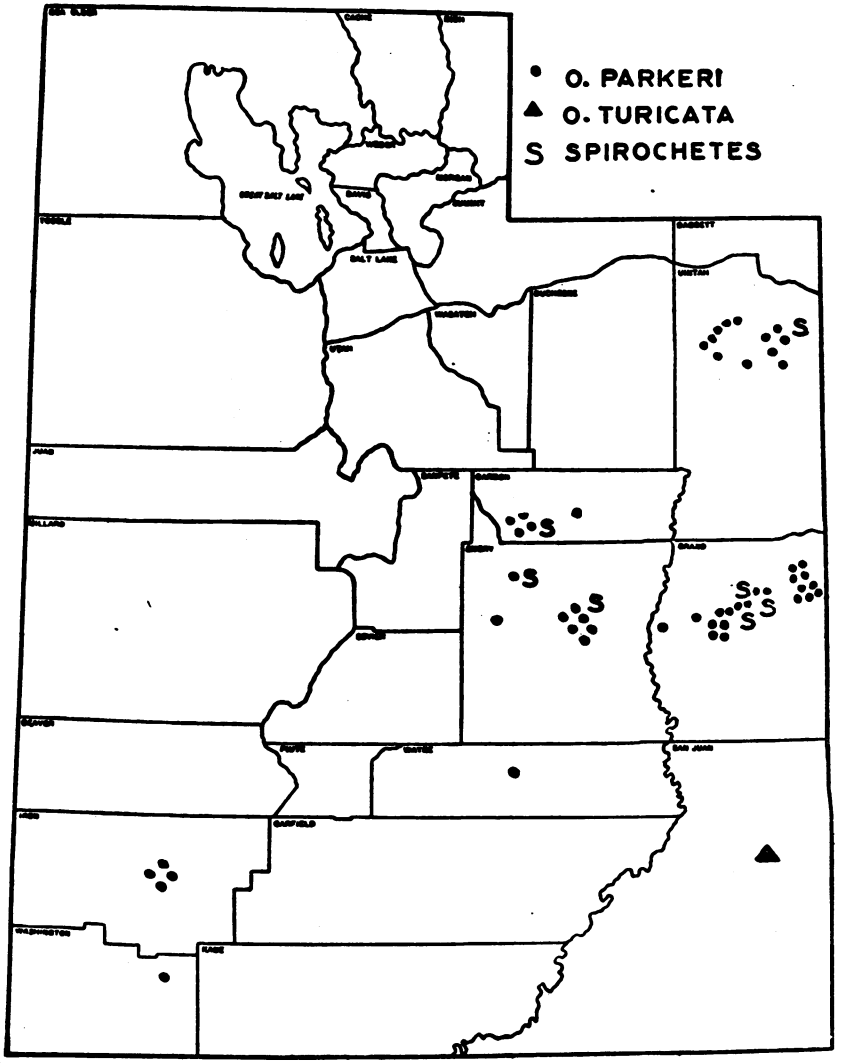

FIGURE 1.—*O. parkeri* and relapsing fever spirochetes in Utah.

DISCUSSION

As ground squirrels (*Citellus* sp.) were already in hibernation, the chief guide in the search for ticks was the presence of prairie dog burrows which could be seen easily from the highway. Doubtless,

this overemphasizes the presence of this species in these burrows, as *O. parkeri* has been collected from numerous other rodents and from burrowing owls.

The area southeast of the Colorado River is arid and the terrain for the most part bluffs and canyons. It was in this area that the one specimen of *O. turicata* was found. In the early morning, sandy areas revealed something of the "night life" in the innumerable tracks of small rodents, especially mice and kangaroo rats. Many of the small kangaroo rat burrows were examined and a number of these rats were taken in box traps but no ticks were found. Central Utah from northeast to southwest is, to a great extent, under cultivation. There were no indications of prairie dogs over large areas. In Duchesne County, three extensive prairie dog towns, one of which contained many animals, were examined but no ticks were found.

In Iron County, in southwestern Utah, a prairie dog "ghost town" was investigated. The absence of rodents and the condition of the burrows suggested that the town had been vacant for some time and aroused speculation concerning the possible presence of plague, a human case of which had occurred east of this area. The openings to the burrows were clogged by dried vegetation, and skeletal remains of prairie dogs were found in two burrows. However, *O. parkeri* was found in four burrows. The absence of early immature forms and of engorged ticks further suggested that hosts had not been recently present.

Although the openings to prairie dog burrows are often well protected against washing as the result of heavy rains, yet in one area, during a heavy shower, such washing was quite in evidence. In such instances many early unfed immature ticks must be entrapped in the mud flow.

One of the strains of spirochetes was studied in white mice, white rats, and guinea pigs. Relapses were observed in all three hosts. These tests were made by allowing a series of uninfected *O. parkeri*, in the first nymphal stage, to engorge on a white mouse infected with the strain of spirochetes under study and subsequently to engorge on normal animals. Eleven of this series of ticks were tested individually by feeding on white mice, 16 on white rats, and 8 on guinea pigs. Spirochetes were observed in the peripheral blood of mice up to 31 days following tick feeding, at which time the mouse observed for this period died, in white rats for as long as 26 days, and in guinea pigs up to 30 days. Temperatures of the guinea pigs were taken daily for 6 weeks. One guinea pig showed only 1 relapse, 6 showed 2 relapses, and 1 showed 3 relapses. The appearance of spirochetes closely paralleled a rise in temperature.

SUMMARY

During the late summer of 1940, 49 lots of *Ornithodoros* ranging from 1 to 59 specimens were collected in San Juan, Grand, Uintah, Carbon, Emery, and Iron Counties in Utah. There was a total of 306 ticks, 235 of which survived for testing for spirochetes. The one specimen collected in San Juan County was *O. turicata;* the rest were *O. parkeri.* Spirochetes were recovered from ticks collected in Uintah, Grand, Carbon, and Emery Counties. White mice, white rats, and guinea pigs were shown to be susceptible to one of the strains. Relapses occurred in all three host species. The appearance of spirochetes in the ear blood of guinea pigs closely paralleled a rise in temperature.

DISEASE OUTBREAKS FROM WATER, MILK, AND OTHER FOODS IN 1939—CORRECTION

In the article with the above title, by Senior Sanitary Engineer A. W. Fuchs, which appeared in the PUBLIC HEALTH REPORTS of November 28, 1941, table 5, page 2281, shows a water-borne outbreak involving 325 cases as occurring in the State of New Jersey. This table should be corrected by the addition of a footnote referring to this outbreak, as follows: In this outbreak, involving 325 cases of gastro-enteritis, ice was suspected as the vehicle. Attention is called to footnote 1 of table 3, which also refers to this outbreak.

DEATHS DURING WEEK ENDED DECEMBER 13, 1941

[From the Weekly Mortality Index, issued by the Bureau of the Census, Department of Commerce]

	Week ended Dec. 13, 1941	Corresponding week, 1940
Data from 87 large cities of the United States:		
Total deaths	8,407	8,631
Average for 3 prior years	8,539	
Total deaths, first 50 weeks of year	416,899	417,804
Deaths per 1,000 population, first 50 weeks of year, annual rate	11.7	11.7
Deaths under 1 year of age	566	565
Average for 3 prior years	521	
Deaths under 1 year of age, first 50 weeks of year	26,478	25,164
Data from industrial insurance companies:		
Policies in force	64,719,421	64,791,753
Number of death claims	10,750	11,293
Death claims per 1,000 policies in force, annual rate	8.7	9.1
Death claims per 1,000 policies, first 50 weeks of year, annual rate	9.3	9.6

PREVALENCE OF DISEASE

No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring

UNITED STATES

REPORTS FROM STATES FOR WEEK ENDED DECEMBER 20, 1941

Summary

General health conditions in the United States continue favorable, as indicated by reports of important communicable diseases and the mortality rate for a group of 88 large cities. None of the communicable diseases is epidemic for the country as a whole; in fact the incidence of most of these diseases reported currently to the Public Health Service is below the 5-year median expectancy. The current mortality rate for 88 large cities is slightly above the 3-year average, but the cumulative rate to date for these cities is the same as for the corresponding period last year.

The number of reported cases of influenza decreased as compared with last week (2,693 as compared with 2,995). Texas, with 1,320 cases, reported about half of the current cases. The 5-year median for the current week is 2,225, while 42,457 cases were reported for the corresponding week last year.

The incidence of poliomyelitis remains slightly above the 5-year median, due to 11 cases in Alabama (1 case last week), 7 in New York (8 last week), and 6 in Illinois (5 last week). No other State reported more than 3 cases for the current week.

Of 62 cases of endemic typhus fever, 22 occurred in Georgia, 14 in Alabama, and 7 in Texas. One case of tularemia was reported in each of the following named States: Kansas, Maryland, and North Carolina.

The crude death rate for 88 large cities for the current week was 12.2 as compared with 11.8 for the preceding week and with a 3-year (1938–40) average of 12.0.

Telegraphic morbidity reports from State health officers for the week ended December 20, 1941, and comparison with corresponding week of 1940 and 5-year median

In these tables a zero indicates a definite report, while leaders imply that, although none were reported, cases may have occurred.

Division and State	Diphtheria			Influenza			Measles			Meningitis, meningococcus		
	Week ended		Median 1936–40	Week ended		Median 1936–40	Week ended		Median 1936–40	Week ended		Median 1936–40
	Dec. 20, 1941	Dec. 21, 1940		Dec. 20, 1941	Dec. 21, 1940		Dec. 20, 1941	Dec. 21, 1940		Dec. 20, 1941	Dec. 21, 1940	
NEW ENG.												
Maine	1	0	4	-------	3	1	174	37	37	1	1	1
New Hampshire	0	0	0	-------	2	-------	6	4	4	0	0	0
Vermont	0	0	0	-------	-------	-------	3	37	25	0	0	0
Massachusetts	4	1	5	-------	-------	-------	167	294	196	2	3	1
Rhode Island	1	0	0	1	1	-------	21	0	3	0	0	0
Connecticut	0	0	2	1	2	3	61	6	67	0	0	0
MID. ATL.												
New York [3]	22	20	23	[1] 6	[1] 41	[1] 15	294	1,194	395	3	6	5
New Jersey	7	8	8	13	4	6	51	336	158	1	0	0
Pennsylvania	9	17	44	-------	-------	-------	678	1,121	67	5	1	6
E. NO. CEN.												
Ohio	16	5	17	17	12	8	108	42	22	1	2	2
Indiana	2	8	19	20	979	31	11	33	12	0	0	0
Illinois	45	17	37	11	23	23	64	669	27	0	0	0
Michigan [3]	8	7	9	2	2	1	59	780	253	0	1	1
Wisconsin	0	0	1	22	42	42	142	330	103	1	0	0
W. NO. CEN.												
Minnesota	4	1	2	2	1	1	72	29	29	1	0	0
Iowa	0	3	5	1	8	5	69	133	69	0	0	0
Missouri	5	10	10	2	6	59	13	15	7	1	3	1
North Dakota	0	3	1	4	52	6	115	12	2	0	1	0
South Dakota	4	4	4	-------	-------	-------	7	1	1	0	0	0
Nebraska	2	0	2	2	-------	-------	14	8	3	0	0	0
Kansas	9	3	5	15	269	4	109	70	59	1	1	2
SO. ATL.												
Delaware	0	2	0	-------	-------	-------	1	25	5	0	0	0
Maryland [3]	13	0	10	3	4	10	144	1	5	0	0	0
Dist. of Col	0	4	5	-------	3	3	5	3	3	1	1	0
Virginia	14	10	30	152	203	33	86	41	46	0	2	2
West Virginia	6	12	11	18	38	38	135	6	12	0	1	2
North Carolina [3]	38	28	39	11	10	10	257	31	145	0	2	1
South Carolina [3]	6	4	4	421	315	315	24	21	7	0	0	1
Georgia [3]	18	7	15	50	178	178	75	18	9	0	0	0
Florida [3]	10	3	8	9	28	9	57	2	3	1	1	2
E. SO. CEN.												
Kentucky	5	3	9	4	184	31	12	195	60	0	1	3
Tennessee	11	11	11	28	52	52	67	29	29	3	0	2
Alabama [3]	23	11	18	66	222	170	20	61	19	0	2	1
Mississippi [3]	10	5	5	-------	-------	-------	-------	-------	-------	3	1	1
W. SO. CEN.												
Arkansas	11	5	5	97	2,191	79	68	28	9	0	0	0
Louisiana [3]	10	3	9	3	8,000	12	11	1	1	1	1	0
Oklahoma	6	15	15	97	1,369	119	11	0	9	0	0	1
Texas [3]	64	36	50	1,320	1,236	561	270	35	72	1	1	2
MOUNTAIN												
Montana	1	0	0	9	106	65	80	1	4	0	0	0
Idaho	2	0	0	-------	51	4	2	3	13	0	0	0
Wyoming	1	0	1	4	1,085	-------	14	1	1	0	0	0
Colorado	18	4	11	36	47	7	420	79	24	0	0	0
New Mexico	0	1	3	-------	27	2	10	66	44	0	0	0
Arizona	0	2	3	126	1,006	93	33	38	3	0	0	0
Utah [3]	0	0	0	2	5,133	17	19	3	38	0	0	1
Nevada	0	-------	-------	-------	1,000	-------	0	-------	-------	0	-------	-------
PACIFIC												
Washington	3	0	2	3	3,796	-------	4	182	146	0	2	1
Oregon	0	3	1	13	2,645	71	45	5	10	0	0	0
California [3]	15	5	26	102	12,081	58	500	53	53	1	0	1
Total	424	281	525	2,693	42,457	2,225	4,608	6,079	4,544	28	34	41
51 weeks	16,571	15,413	27,196	595,386	264,194	182,255	864,454	269,654	291,343	1,986	1,636	2,781

See footnotes at end of table.

Telegraphic morbidity reports from State health officers for the week ended December 20, 1941, and comparison with corresponding week of 1940 and 5-year median—Continued

Division and State	Poliomyelitis			Scarlet fever			Smallpox			Typhoid and paratyphoid fever		
	Week ended		Median 1936–40	Week ended		Median 1936–40	Week ended		Median 1936–40	Week ended		Median 1936–40
	Dec. 20, 1941	Dec. 21, 1940		Dec. 20, 1941	Dec. 21, 1940		Dec. 20, 1941	Dec. 21, 1940		Dec. 20, 1941	Dec. 21, 1940	
NEW. ENG.												
Maine	1	0	0	32	19	16	0	0	0	3	1	1
New Hampshire	2	0	0	16	6	6	0	0	0	0	0	0
Vermont	1	0	0	1	11	7	0	0	0	0	0	0
Massachusetts	1	0	0	259	145	145	0	0	0	3	0	1
Rhode Island	0	0	0	5	2	7	0	0	0	1	0	0
Connecticut	0	0	0	23	33	57	0	0	0	0	2	1
MID. ATL.												
New York [3]	7	1	1	297	284	350	0	0	0	6	19	8
New Jersey	1	0	0	92	137	103	0	0	0	0	0	1
Pennsylvania	1	1	1	245	218	343	0	0	0	6	7	9
E. NO. CEN.												
Ohio	1	2	1	268	167	258	0	1	2	2	3	3
Indiana	0	2	0	45	84	126	0	1	5	1	1	2
Illinois	6	3	1	236	334	355	1	6	3	2	4	4
Michigan [3]	0	5	1	155	182	344	1	5	2	3	1	2
Wisconsin	1	10	1	153	127	141	0	6	6	1	0	1
W. NO. CEN.												
Minnesota	1	2	1	76	78	93	0	17	17	0	1	1
Iowa	0	2	0	56	70	99	0	2	5	1	1	1
Missouri	0	0	0	35	79	101	4	2	2	3	6	5
North Dakota	0	0	0	13	12	22	0	1	1	0	0	0
South Dakota	0	1	1	25	17	17	2	2	4	0	0	0
Nebraska	0	2	1	25	27	27	0	1	1	0	0	0
Kansas	0	0	0	85	82	115	0	0	0	0	0	0
SO. ATL.												
Delaware	0	1	0	19	18	18	0	0	0	0	0	0
Maryland [3]	2	1	0	43	39	46	0	0	0	3	0	2
Dist. of Col.	0	0	0	22	7	8	0	0	0	1	1	1
Virginia	1	3	1	38	17	31	0	0	0	5	3	3
West Virginia	1	3	1	67	41	71	0	0	0	3	2	2
North Carolina [3]	0	0	0	72	87	65	0	0	0	0	2	1
South Carolina [3]	0	0	0	5	10	10	0	0	0	2	0	1
Georgia [3]	1	0	0	23	16	21	0	0	0	1	0	6
Florida [3]	0	0	0	10	1	8	0	0	0	2	0	0
E. SO. CEN.												
Kentucky	0	0	0	85	59	60	1	0	0	3	2	2
Tennessee	2	0	0	49	58	45	2	0	0	2	2	2
Alabama	11	1	1	35	25	23	0	0	0	2	1	3
Mississippi [3]	0	0	0	24	9	8	1	0	0	1	0	1
W. SO. CEN.												
Arkansas	3	0	0	16	5	12	0	0	0	3	3	3
Louisiana [3]	1	3	1	8	20	16	0	0	0	1	16	6
Oklahoma	0	0	2	17	24	24	0	2	2	1	0	2
Texas [3]	3	1	1	48	32	84	5	0	4	7	4	12
MOUNTAIN												
Montana	1	0	0	38	30	30	0	0	1	1	0	0
Idaho	0	0	0	7	9	18	0	0	0	0	1	1
Wyoming	0	0	0	1	11	11	0	0	1	0	0	0
Colorado	0	0	0	29	17	24	0	1	7	0	0	1
New Mexico	0	0	0	6	7	22	0	0	0	0	5	3
Arizona	0	0	0	5	1	5	0	0	0	1	1	1
Utah [3]	0	1	0	9	6	15	0	0	0	0	0	0
Nevada	0			0			0			0		
PACIFIC												
Washington	1	1	1	44	38	48	2	0	0	3	0	0
Oregon	2	1	0	10	7	32	0	0	6	2	0	1
California [3]	3	1	1	107	68	142	0	0	4	8	5	5
Total	55	48	45	2,979	2,776	3,599	19	47	141	89	100	103
51 weeks	9,017	9,733	7,261	124,854	152,425	183,035	1,351	2,401	9,456	8,433	9,506	14,126

See footnotes at end of table.

Telegraphic morbidity reports from State health officers for the week ended December 20, 1941, and comparison with corresponding week of 1940—Continued

Division and State	Whooping cough	
	Week ended	
	Dec. 20, 1941	Dec. 21, 1940
NEW ENG.		
Maine	26	19
New Hampshire	9	7
Vermont	23	18
Massachusetts	206	274
Rhode Island	59	4
Connecticut	43	81
MID. ATL.		
New York [1]	504	410
New Jersey	176	162
Pennsylvania	228	571
E. NO. CEN.		
Ohio	205	192
Indiana	13	10
Illinois	221	171
Michigan [2]	209	235
Wisconsin	282	128
W. NO. CEN.		
Minnesota	47	70
Iowa	9	22
Missouri	12	51
North Dakota	3	11
South Dakota	2	12
Nebraska	0	9
Kansas	39	64
SO. ATL.		
Delaware	0	39
Maryland [2]	20	66
Dist. of Col	16	13
Virginia	30	71
West Virginia	14	34
North Carolina [2]	85	239
South Carolina [2]	46	29
Georgia [2]	10	13
Florida [2]	12	3
E. SO. CEN.		
Kentucky	52	51
Tennessee	19	58
Alabama [2]	6	47
Mississippi [2]	----------	----------
W. SO. CEN.		
Arkansas	8	34
Louisiana [2]	5	5
Oklahoma	3	13
Texas [2]	121	142
MOUNTAIN		
Montana	25	3
Idaho	30	18
Wyoming	3	0
Colorado	35	40
New Mexico	11	15
Arizona	23	1
Utah [2]	24	11
Nevada	0	----------
PACIFIC		
Washington	104	36
Oregon	21	12
California [2]	137	149
Total	3,176	3,713
51 weeks	205,930	167,944

[1] New York City only.
[2] Period ended earlier than Saturday.
[3] Typhus fever, week ended Dec. 20, 1941, 62 cases, as follows: New York, 1; North Carolina, 5; South Carolina, 1; Georgia, 22; Florida, 3; Alabama, 14; Mississippi, 2; Louisiana, 4; Texas, 7; California, 3.

WEEKLY REPORTS FROM CITIES

City reports for week ended December 6, 1941

This table lists the reports from 126 cities of more than 10,000 population distributed throughout the United States, and represents a cross section of the current urban incidence of the diseases included in the table.

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Maine:											
Portland	0	1	1	2	1	10	0	0	0	6	28
New Hampshire:											
Concord	0	------	0	0	0	1	0	2	0	0	18
Manchester	0	------	1	2	0	18	0	0	0	1	13
Nashua	1	------	0	1	0	2	0	0	0	9	11
Vermont:											
Barre	0	------	0	0	0	0	0	0	0	0	--------
Burlington	0	------	0	0	0	0	0	0	0	0	8
Rutland	0	------	0	0	0	0	0	0	0	0	5
Massachusetts:											
Boston	2	------	0	23	9	51	0	7	3	40	194
Fall River	2	------	0	0	0	21	0	2	0	2	44
Springfield	0	------	0	8	0	19	0	0	0	26	25
Worcester	0	------	0	3	3	21	0	2	0	18	45
Rhode Island:											
Pawtucket	1	------	0	12	0	2	0	0	0	2	11
Providence	3	------	0	2	0	8	0	0	0	26	59
Connecticut:											
Bridgeport	0	------	0	1	0	7	0	0	1	3	40
Hartford	0	------	0	2	5	1	0	0	0	2	47
New Haven	0	------	0	35	1	3	0	0	0	1	33
New York:											
Buffalo	0	------	0	0	9	14	0	7	0	16	189
New York	15	8	0	20	69	94	0	66	2	372	1,455
Rochester	0	------	0	3	2	7	0	1	0	17	71
Syracuse	0	------	0	0	2	2	0	0	0	41	56
New Jersey:											
Camden	0	------	0	0	6	2	0	0	0	12	38
Newark	0	------	0	7	4	21	0	2	0	39	96
Trenton	1	------	0	0	2	3	0	4	0	6	32
Pennsylvania:											
Philadelphia	2	4	2	3	24	69	0	17	0	46	480
Pittsburgh	0	2	3	1	12	17	0	6	1	13	184
Reading	0	------	0	1	2	1	0	1	0	0	36
Ohio:											
Cincinnati	5	------	0	0	3	17	0	7	0	17	143
Cleveland	4	5	0	2	7	40	0	20	0	38	211
Columbus	0	------	0	3	3	2	0	2	3	2	71
Toledo	0	------	0	0	2	2	0	1	0	22	71
Indiana:											
Anderson	2	------	0	0	1	0	0	0	0	0	4
Fort Wayne	0	------	0	0	2	0	0	1	0	0	29
Indianapolis	0	------	1	0	3	18	0	7	0	7	102
Muncie	0	------	0	0	0	0	0	1	0	4	12
South Bend	0	------	0	0	0	1	0	0	0	0	22
Terre Haute	0	------	0	0	5	0	0	0	0	0	21
Illinois:											
Chicago	27	4	2	9	32	76	0	41	0	123	682
Elgin	0	------	0	0	0	0	0	0	0	1	12
Moline	0	------	0	1	0	0	0	0	0	7	8
Springfield	1	------	0	0	2	2	0	0	0	0	23
Michigan:											
Detroit	3	------	0	21	12	70	0	13	1	84	274
Flint	0	------	0	0	3	1	0	0	1	4	29
Grand Rapids	0	------	0	2	1	7	0	0	0	1	34
Wisconsin:											
Kenosha	0	------	0	0	0	3	0	0	0	4	6
Madison	0	------	0	4	1	1	0	0	0	9	26
Milwaukee	0	------	1	6	3	26	0	3	0	0	102
Racine	0	------	0	1	0	9	1	0	1	19	13
Superior	0	------	0	0	0	0	0	0	0	4	6
Minnesota:											
Duluth	0	------	0	1	0	2	0	0	0	8	28
Minneapolis	0	------	0	0	3	8	1	2	0	16	88
St. Paul	0	------	0	3	1	2	0	2	0	31	71
Iowa:											
Cedar Rapids	0	------	--------	0	--------	3	0	--------	0	0	--------
Davenport	0	------	--------	0	--------	5	0	--------	0	0	--------
Des Moines	2	------	--------	2	--------	3	0	--------	0	0	33
Sioux City	0	------	--------	2	--------	0	0	--------	0	0	--------
Waterloo	0	------	--------	1	--------	2	0	--------	0	2	--------

City reports for week ended December 6, 1941—Continued

State and city	Diphtheria cases	Influenza cases	Influenza deaths	Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
Missouri:											
Kansas City	0	------	1	1	6	5	0	2	0	1	94
St. Joseph	0	------	0	5	4	2	0	1	0	0	32
St. Louis	0	6	0	1	12	13	0	5	0	2	199
North Dakota:											
Fargo	0	------	0	0	1	0	0	0	0	0	15
Grand Forks	0	------	-------	0	-------	0	0	-------	0	0	-------
Minot	0	------	-------	21	-------	0	0	-------	0	0	4
South Dakota:											
Aberdeen	0	------	-------	0	-------	5	0	-------	0	0	-------
Sioux Falls	0	------	-------	0	-------	1	0	-------	0	0	6
Nebraska:											
Lincoln	0	------	-------	0	-------	2	0	-------	0	0	-------
Omaha	0	------	0	0	4	5	0	1	0	0	58
Kansas:											
Lawrence	0	3	0	0	1	0	0	0	0	0	6
Topeka	0	------	0	1	1	7	0	0	0	11	23
Wichita	0	3	0	1	2	2	0	1	0	4	30
Delaware:											
Wilmington	0	------	0	0	2	1	0	0	0	0	31
Maryland:											
Baltimore	2	2	1	83	11	17	0	6	0	24	233
Cumberland	0	------	0	0	0	1	0	0	2	0	3
Frederick	0	------	0	0	0	0	0	0	0	0	1
Dist. of Col.:											
Washington	0	2	1	4	9	15	0	8	1	20	163
Virginia:											
Lynchburg	0	------	0	0	1	2	0	0	0	3	12
Norfolk	1	------	0	1	0	3	0	0	0	1	23
Richmond	3	------	2	0	1	2	0	1	0	0	49
Roanoke	0	------	0	1	1	1	0	0	0	0	14
West Virginia:											
Charleston	0	------	0	0	1	0	0	0	0	6	27
Huntington	2	------	-------	0	-------	1	0	-------	0	0	-------
Wheeling	0	------	0	6	1	1	0	0	0	0	23
North Carolina:											
Gastonia	0	------	-------	0	-------	0	0	-------	0	0	-------
Raleigh	0	------	0	0	0	0	0	0	0	3	8
Wilmington	0	------	0	8	0	1	0	3	0	0	13
Winston-Salem	2	------	0	71	2	0	0	0	0	0	12
South Carolina:											
Charleston	2	65	1	0	1	2	0	0	0	3	30
Florence	0	------	0	0	0	0	0	0	0	0	12
Greenville	1	------	0	2	0	1	0	0	0	1	4
Georgia:											
Atlanta	0	7	3	0	1	9	0	7	0	1	96
Brunswick	0	------	0	0	2	0	0	0	0	0	6
Savannah	0	------	0	13	2	3	0	0	0	0	34
Florida:											
Miami	0	3	0	0	0	0	0	2	0	3	48
St. Petersburg	0	------	0	0	2	0	0	0	0	3	28
Tampa	0	------	0	0	1	0	0	1	0	0	20
Kentucky:											
Ashland	1	------	0	1	0	1	0	1	0	12	5
Covington	1	------	0	2	1	4	0	1	0	0	12
Lexington	0	------	0	0	2	0	0	0	0	4	14
Louisville	1	1	0	1	2	24	0	3	0	31	71
Tennessee:											
Knoxville	0	2	0	4	0	1	0	1	0	1	17
Memphis	2	4	1	0	0	4	0	5	0	15	117
Nashville	1	------	0	1	1	2	0	0	0	0	44
Alabama:											
Birmingham	1	------	0	0	8	7	0	2	1	1	89
Mobile	1	1	0	1	3	0	0	2	0	0	26
Montgomery	0	------	-------	0	-------	1	0	-------	0	0	-------
Arkansas:											
Fort Smith	0	------	-------	2	-------	0	0	-------	0	1	-------
Little Rock	0	15	0	0	3	0	0	0	0	2	37
Louisiana:											
Lake Charles	0	------	0	0	0	0	0	0	0	0	5
New Orleans	0	6	2	1	11	7	0	6	1	2	103
Shreveport	0	------	0	0	5	0	0	0	0	0	42
Oklahoma:											
Oklahoma City	2	------	0	0	4	0	0	1	0	0	43
Tulsa	3	------	0	94	0	6	0	1	0	0	6
Texas:											
Dallas	8	1	1	50	0	13	0	0	0	6	53
Fort Worth	0	------	1	0	1	2	0	0	0	6	29
Galveston	0	------	0	0	0	0	0	1	0	0	15
Houston	2	------	0	1	13	4	0	6	0	1	91
San Antonio	1	15	3	0	5	2	0	4	0	0	75

City reports for week ended December 6, 1941—Continued

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Montana:											
Billings	0	------	0	0	0	0	0	0	0	0	10
Great Falls	0	------	0	39	0	0	0	0	0	16	12
Helena	0	------	0	0	0	5	0	0	0	3	4
Missoula	0	------	0	2	0	0	0	0	0	0	3
Idaho:											
Boise	0	------	0	2	2	1	0	1	0	0	13
Colorado:											
Colorado Springs	0	------	0	0	0	3	0	0	0	6	4
Denver	11	28	0	22	7	6	0	3	0	6	74
Pueblo	0	------	0	174	3	1	0	1	0	0	9
New Mexico:											
Albuquerque	0	------	0	0	0	1	0	1	1	0	9
Arizona:											
Phoenix	1	38	-------	0	-------	1	0	-------	0	7	-------
Utah:											
Salt Lake City	0	------	0	2	3	3	0	1	0	3	37
Washington:											
Seattle	0	------	0	1	3	2	0	2	0	55	81
Spokane	0	2	0	0	2	3	0	0	0	0	39
Tacoma	0	------	0	0	1	2	0	0	0	1	28
Oregon:											
Portland	1	2	0	0	3	4	0	1	0	3	86
Salem	0	------	-------	0	-------	0	0	-------	0	0	-------
California:											
Los Angeles	4	19	2	15	2	31	0	17	2	21	331
Sacramento	0	------	0	9	4	2	0	1	0	4	29
San Francisco	0	3	0	1	5	6	0	4	0	3	185

State and city	Meningitis, meningococcus		Poliomyelitis cases	State and city	Meningitis, meningococcus		Poliomyelitis cases
	Cases	Deaths			Cases	Deaths	
Massachusetts:				Maryland:			
Worcester	1	0	0	Baltimore	3	1	0
New York:				South Carolina:			
Buffalo	0	1	0	Florence	0	1	0
New York	2	1	1	Kentucky:			
Rochester	0	0	3	Louisville	1	0	0
New Jersey:				Tennessee:			
Trenton	0	0	1	Knoxville	0	0	1
Pennsylvania:				Alabama:			
Philadelphia	0	0	1	Birmingham	0	0	1
Pittsburgh	0	1	0	Mobile	0	0	1
Illinois:				Arkansas:			
Chicago	0	0	2	Little Rock	0	0	1
Michigan:				Louisiana:			
Detroit	1	1	0	Shreveport	0	1	0
Iowa:				Texas:			
Waterloo	1	0	0	Dallas	0	0	1
North Dakota:							
Fargo	0	0	1				

Encephalitis, epidemic or lethargic.—Cases: Rochester, 1.
Pellagra.—Cases: Boston, 2; Atlanta, 2; Savannah, 3.
Typhus fever.—Cases: New York, 1; Norfolk, 1; Charleston, S. C., 1; Atlanta, 1; Savannah, 1; Miami, 1; Tampa, 2; Nashville, 6; Mobile, 1; Houston, 1.

Rates (annual basis) per 100,000 population for a group of 90 selected cities (population, 1940, 33,929,112)

Period	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Smallpox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases
		Cases	Deaths							
Week ended Dec. 6, 1941	16.14	31.20	4.30	103.73	58.09	132.17	0.31	47.18	3.38	194.71
Average for week, 1936–40	21.90	105.94	6.83	176.14	84.34	156.26	1.86	50.79	3.88	176.61

FOREIGN REPORTS

CANADA

Provinces—Communicable diseases—Week ended November 22, 1941.—During the week ended November 22, 1941, cases of certain communicable diseases were reported by the Department of Pensions and National Health of Canada as follows:

Disease	Prince Edward Island	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Total
Cerebrospinal meningitis		1	1	6	6			1	1	16
Chickenpox		19		271	513	62	95	23	131	1,114
Diphtheria	4	18	1	38		6	3			70
Dysentery				2						2
Influenza		21							23	44
Measles		3		267	135	12	15	1	7	440
Mumps				396	220	63	45	18	92	834
Pneumonia	2	4			11				4	21
Poliomyelitis		2	4		4		1	2		13
Scarlet fever	1	17	11	130	284	21	15	21	8	508
Tuberculosis		4	3	89	43		20			159
Typhoid and paratyphoid fever	1	1		20	3				1	26
Whooping cough		56	2	163	158	2	1		30	412

DENMARK

Notifiable diseases—July–September 1941.—During the months of July, August, and September 1941, cases of certain notifiable diseases were reported in Denmark as follows:

Disease	July	August	September
Cerebrospinal meningitis	16	5	10
Chickenpox	1,194	552	498
Diphtheria	63	55	66
Dysentery	202	416	294
Epidemic encephalitis	2	7	5
Erysipelas	202	227	271
Gastroenteritis	13,519	32,440	11,176
German measles	1,827	503	287
Gonorrhea	963	1,088	1,001
Influenza	2,079	2,556	3,842
Measles	3,799	1,628	1,809
Mumps	488	474	864
Paratyphoid fever	11	12	9
Poliomyelitis	17	144	171
Puerperal fever	16	17	17
Scarlet fever	416	511	996
Syphilis	40	46	58
Tetanus, neonatorum	2	4	2
Typhoid fever	5	10	14
Undulant fever	30	31	26
Weil's disease	1	2	1
Whooping cough	4,039	5,047	4,719

NEW ZEALAND

Vital statistics—Year 1939.—Following are vital statistics for New Zealand for the year 1939:

	Number	Rate per 10,000 inhabitants		Number	Rate per 10,000 inhabitants
Live births	28,883	[1] 18.73	Deaths from:—Continued.		
Deaths	14,158	[1] 9.20	Heart disease	4,279	27.80
Stillbirths	900	[2] 30.27	Hernia and intestinal obstruction	108	.70
Infant mortality	898	[3] 31.14	Influenza	170	1.10
Deaths from:			Measles	8	.05
Apoplexy	888	5.77	Pneumonia	311	2.02
Appendicitis	106	.69	Scarlet fever	2	.01
Bright's disease	534	3.47	Senility	333	2.16
Bronchitis	210	1.36	Tuberculosis	613	3.98
Cancer	1,815	11.79	Typhoid and paratyphoid fever	4	.02
Diabetes	344	2.23	Violence	381	5.72
Diarrhea and enteritis	70	.45	Whooping cough	2	.01
Diphtheria	24	.16			
Diseases and accidents of childbirth	105	.68			
Diseases of the arteries	532	3.46			

[1] Per 1,000 population. [2] Per 1,000 total births. [3] Per 1,000 live births.

SWEDEN

Notifiable diseases—September 1941.—During the month of September 1941, cases of certain notifiable diseases were reported in Sweden as follows:

Disease	Cases	Disease	Cases
Cerebrospinal meningitis	6	Poliomyelitis	166
Diphtheria	14	Scarlet fever	873
Dysentery	102	Syphilis	25
Epidemic encephalitis	4	Typhoid fever	12
Gonorrhea	1,126	Undulant fever	5
Paratyphoid fever	84		

WORLD DISTRIBUTION OF CHOLERA, PLAGUE, SMALLPOX, TYPHUS FEVER, AND YELLOW FEVER

From medical officers of the Public Health Service, American consuls, International Office of Public Health, Pan American Sanitary Bureau, health section of the League of Nations, and other sources. The reports contained in the following tables must not be considered as complete or final as regards either the list of countries included or the figures for the particular countries for which reports are given.

CHOLERA

[C indicates cases]

NOTE.—Since many of the figures in the following tables are from weekly reports, the accumulated totals are for approximate dates.

Place		January–September 1941	October 1941	November 1941—week ended—				
				1	8	15	22	29
ASIA								
Afghanistan: Southern Province.[1]								
Ceylon	C	2	1	------	------	------	------	------
China:								
Canton	C	464	------	------	------	------	------	------
Hong Kong	C	1,635	16	------	------	------	------	------
Macao	C	1,182	229	34	12	14	2	------
Shanghai	C	731	81	11	10	1	------	------
India	C	73,715	13,871	------	------	------	------	------
Bombay	C	115	------	------	------	------	------	------
Calcutta	C	1,908	64	------	------	------	------	------
Rangoon	C	116	------	------	------	------	------	------
India (French)	C	34	------	------	------	------	------	------
Japan: Taiwan	C	2	------	------	------	------	------	------

[1] During the week ended Dec. 6, 1941, cholera was reported present in Southern Province, Afghanistan.

PLAGUE

[C indicates cases]

Place	January–September 1941	October 1941	November 1941—week ended— 1	8	15	22	29
AFRICA							
Belgian Congo C	[1] 28						
British East Africa:							
Kenya C	447	142					
Uganda C	122	31					
Egypt: Port Said C	10						
Madagascar C	207	22					[2] 19
Morocco C	2,065	52	6	12	17	10	
Casablanca [3] C	1		3				
Tunisia: Tunis C	2						
Union of South Africa C	88	3					
ASIA							
China:							
Fukien Province.[4]							
Foochow C	3						
Dutch East Indies:							
Java and Madura C	435						
West Java C	322						
India C	3,500	348					
Calcutta C	3						
Rangoon C	9						
Indochina (French) C	22	2		1			
Palestine: Haifa C	10			1			
Plague-infected rats	25						
Thailand: Lampang Province C	2						
EUROPE							
Portugal: Azores Islands C	2						
NORTH AMERICA							
Canada—Alberta—Plague-infected ground squirrel	1						
SOUTH AMERICA							
Argentina:							
Cordoba Province C	[5] 21						
Santa Fe Province—Plague-infected rats	67						
Brazil:							
Alagoas State [2] C	33	3					
Bahia State C	8	2					
Pernambuco State C	64	6					
Rio de Janeiro State C	2						
Chile: Valparaiso C		1					
Ecuador C	33						
Peru:							
Ancash Department C	1						
Lambayeque Department C	3						
Libertad Department C	7						
Lima Department C	10	5					
Moquegua Department—Ilo C	7						
Piura Department C	2						
OCEANIA							
Hawaii Territory:[6] Plague-infected rats	52	2		1		2	
New Caledonia C	9					2	

[1] Includes 21 cases of pneumonic plague.
[2] For the month of November.
[3] A report dated June 23, 1941, stated that an outbreak of plague had occurred in Casablanca, Morocco, where several deaths had been reported.
[4] A report dated Nov. 22, 1941, stated that bubonic plague had appeared in epidemic form in Shaowu and Yangkow, Fukien Province.
[5] Includes 3 cases of pneumonic plague.
[6] During April and May, 4 lots of plague-infected fleas were also reported in Hawaii Territory.

SMALLPOX

[C indicates cases]

Place		January–September 1941	October 1941	November 1941—week ended—				
				1	8	15	22	29
AFRICA								
Algeria	C	304	154		63			
Angola	C	[1] 29						
Belgian Congo	C	634						
British East Africa	C	30						
Dahomey	C	466	1					
French Guinea	C	45						
Gold Coast	C	1						
Ivory Coast	C	39						
Morocco	C	296						
Nigeria	C	528	28					
Niger Territory	C	267						
Portuguese East Africa	C	9						
Rhodesia: Southern	C	86						
Senegal	C	59	4					
Sierra Leone	C	15						
Sudan (Anglo-Egyptian)	C	7						
Sudan (French)	C	19						
Union of South Africa	C	521	11					
ASIA								
Ceylon	C	114						
China	C	252	4		2	1		
Chosen	C	696						
Dutch East Indies—Bali Island	C	3						
India	C	22, 669	1, 017					
India (French)	C	9						
India (Portuguese)	C	70						
Indochina (French)	C	1, 034	89		17		28	
Iran	C	8						
Iraq	C	1, 230	22	1				
Japan	C	200						
Straits Settlements	C	1						
Syria	C	1						
Thailand	C	260	23					
EUROPE								
France	C	1						
Portugal	C	37	2	1		1		
Spain	C	301	50					
Switzerland	C				1			
NORTH AMERICA								
Canada	C	24	1					
Dominican Republic	C	2						
Guatemala	C	5						
Mexico	C	53						
Panama Canal Zone (alastrim)	C	[2] 1						
SOUTH AMERICA								
Bolivia	C	[3] 18						
Brazil	C	[4] 1						
Colombia	C	716						
Paraguay	C	[3] 8						
Peru	C	778						
Uruguay	C	7						
Venezuela (alastrim)	C	207	22					

[1] For June.
[2] For September.
[3] For January, February, and March.
[4] For August.

TYPHUS FEVER

[C indicates cases]

Place		January–September 1941	October 1941	November 1941—week ended—				
				1	8	15	22	29
AFRICA								
Algeria	C	9,757	326	------	190	------	------	------
British East Africa: Kenya	C	5	1	------	------	------	------	------
Egypt	C	[1] 8,632	------	------	------	------	------	------
Morocco	C	884	25	15	36	41	48	------
Sierra Leone	C	5	------	------	------	------	------	------
Tunisia	C	4,958	156	108	125	209	------	------
Union of South Africa	C	333	------	------	------	------	------	------
ASIA								
China	C	217	20	------	------	------	------	------
Chosen	C	425	------	------	------	------	------	------
Dutch East Indies: Sumatra	C	136	------	------	------	------	------	------
India	C	[2] 3	1	------	------	------	------	------
Iran	C	105	------	------	------	------	------	------
Iraq	C	47	3	1	1	------	1	------
Japan	C	864	------	------	------	------	------	------
Malaya: Unfederated States	C	1	------	------	------	------	------	------
Palestine	C	108	------	4	15	------	------	------
Straits Settlements	C	7	------	------	------	------	------	------
Trans-Jordan	C	9	------	------	------	------	------	------
EUROPE								
Bulgaria	C	224	3	------	------	------	------	------
France (unoccupied zone)	C	2	------	------	------	------	------	------
Germany	C	1,706	65	8	23	------	------	------
Gibraltar	C	2	------	------	------	------	------	------
Greece	C	7	------	------	------	------	------	------
Hungary	C	408	25	8	------	------	------	------
Irish Free State	C	26	------	------	------	------	------	------
Poland	C	937	------	------	------	------	------	------
Portugal	C	5	------	------	------	------	------	------
Rumania	C	761	31	------	23	65	63	176
Spain	C	9,078	97	31	------	------	------	------
Switzerland	C	5	------	------	------	------	------	------
Turkey	C	645	------	------	------	------	------	------
Yugoslavia	C	78	------	------	------	------	------	------
NORTH AMERICA								
Guatemala	C	157	11	------	------	------	------	------
Mexico	C	151	------	------	------	------	------	------
Panama Canal Zone	C	3	------	------	------	------	------	------
Puerto Rico	C	4	4	------	------	1	------	------
SOUTH AMERICA								
Bolivia	C	[3] 75	------	------	------	------	------	------
Brazil	C	1	------	------	------	------	------	------
Chile	C	217	------	------	------	------	------	------
Colombia	C	1	------	------	------	------	------	------
Ecuador	C	119	------	------	------	------	------	------
Peru	C	1,079	------	------	------	------	------	------
Venezuela	C	42	3	------	------	------	------	------
OCEANIA								
Australia	C	12	------	------	------	------	------	------
Hawaii Territory	C	34	13	2	------	3	------	------

[1] Jan. 1 to Nov. 1.
[2] For September.
[3] For January, February, and March.

YELLOW FEVER

[C indicates cases; D, deaths]

Place		January–September 1941	October 1941	November 1941—week ended—				
				1	8	15	22	29
AFRICA								
Belgian Congo:[1]								
Kimvulu	C	1						
Libenge	C	1						
Stanleyville	D			[2]1				
British East Africa: Uganda	C	1						
French Equatorial Africa:								
Gabon	C	2						
Mayumba	C	4						
French Guinea	C			1	1	[2]1		
French West Africa	C				[2]5			
Gold Coast	C	2	1		[2]1			
Accra	C	1						
Ivory Coast[4]	C	[2]6	1				[2]1	
Nigeria	C	[2]1						
Spanish Guinea	D	4						
Sudan (French)[6]	C			[2]5	[7]4		1	
SOUTH AMERICA[8]								
Brazil:								
Amazonas State	D	3						
Bahia State	D	2						
Para State	D	7	1					
Colombia:								
Antioquia Department	D	2						
Boyaca Department	D	8						
Intendencia of Meta	D	8		1	1			
Santander Department	D	14	3	1				
Tolima Department	D	1						
Peru: Junin Department	C	5						
Venezuela: Bolivar State	C	1						

[1] During the week ended Dec. 13, 1 suspected case of yellow fever was reported in Aba, Belgian Congo.
[2] Suspected.
[3] For the period Nov. 1–10, 1941.
[4] During the week ended Dec. 6, 1 suspected case of yellow fever was reported in Abengourou, Ivory Coast.
[5] Includes 2 suspected cases.
[6] During the week ended Dec. 6, 1 death from suspected yellow fever was reported in Sama, French Sudan.
[7] Includes 1 suspected case.
[8] All yellow fever reported in South America is of the jungle type unless otherwise specified.

ANTHRACO-SILICOSIS AMONG SOFT COAL MINERS[1]

A Review

Public Health Bulletin No. 270, "Soft Coal Miners—Health and Working Environment," which was recently issued reports the presence of anthraco-silicosis among a group of bituminous coal mine workers in Utah. A previous Bulletin, No. 221, described anthraco-silicosis among hard coal miners. The present study is part of an investigation of the health and working environment of industrial workers in Utah, made with the cooperation of agencies such as the State Industrial Commission, the State Board of Health, industrial organizations, and labor groups.

Occupational and medical histories were taken, and physical and roentgenological examinations and standard laboratory tests of blood and urine were made on 545 bituminous coal mine workers. Engineering studies included examinations as to the nature and concentration of various types of dust, especially with regard to total silica and free silica, to which workers were exposed. Also studies of ventilation, humidity, and exposure to various gases were carried out.

Studies of the working environment indicated that the dustiest operations were at the face and were associated with the underground occupations of hand loading, undercutting, rock dusting, and drilling. The weighted average dust exposure of workers in these occupations, on the basis of millions of dust particles per cubic foot of air, was 38, 34, 34, and 26, respectively. When all occupations were considered, irrespective of location of work, it was found that only 24 percent of the workers were exposed to more than 30 million particles per cubic foot of air. The majority of the workers (59 percent) were exposed to concentrations varying from 5 to 29 million particles, while the remaining 17 percent had a dust exposure of less than 5 million particles. Ventilation studies showed that although each mine was supplied with air much in excess of the 150 cubic feet per minute per man required by State law, more than half of the working faces had air velocities of less than 40 feet per minute. In some work places the air movement was practically zero. Dry-bulb temperatures in the mines were found to be fairly constant, averaging 60° F., while the relative humidity averaged 85 percent, with considerable variation. The results of gas analyses of mine air indicated that carbon dioxide, oxygen, and nitrogen did not vary greatly from the usual concentrations found in the general outdoor atmosphere. Carbon monoxide

[1] Soft Coal Miners—Health and Working Environment. By R. H. Flinn, H. E. Seifert, H. P. Brinton, J. L. Jones and R. W. Franks. With a chapter on the physiological response of peritoneal tissue by J. W. Miller. Public Health Bulletin No. 270. Government Printing Office, 1941. For sale by the Superintendent of Documents, Washington, D. C. Price 25 cents.

occurred only in samples taken after blasting and was quickly dissipated. Face workers were found to be inhaling dusts containing small amounts (less than 12 percent) of free silica in the form of quartz. Measurements of dust particles indicated that practically all of the dust suspended in the atmosphere of these mines was of a size capable of entering the lung tissue.

The medical study revealed that anthraco-silicosis, a modified form of silicosis due to breathing siliceous dust intermixed with large amounts of carbon dust, was the principal occupational disease found among 507 workers whose only experience in dusty trades had been in bituminous coal mines. The diagnosis of anthraco-silicosis was based upon characteristic X-ray findings, symptoms and physical findings, and a history of several years' employment in bituminous coal mines. It is generally believed that silica must be present in the atmospheric dust which reaches the breathing zone in order to produce disabling pulmonary fibrosis. The free silica exposure of the men in this study is thought to have resulted from rock work, the handling of coal containing bone, rock dusting, and from the dispersion of fine sand in the haulageways. Sixteen (3.2 percent) bituminous coal mine workers were found to have anthraco-silicosis, one with moderate disability and 15 with but slight disability. Anthraco-silicosis was found only in workers who had been employed principally underground, no case being found among tipple or other surface workers. Thirteen cases occurred among men working at the face and three cases occurred among transportation workers. The incidence of anthraco-silicosis increased with increasing weighted average dust concentrations and increasing durations of employment. No case of anthraco-silicosis was found among workers with less than 10 years of employment in bituminous coal mines, and only 2 cases were found among workers with average weighted dust exposures of less than 20 million particles per cubic foot of air. In dust concentration groups above this level, duration of employment was of importance since the incidence of anthraco-silicosis rose from 3.9 percent for those employed from 10 to 19 years to 11.1 percent for those employed from 20 to 29 years, to 20 percent for the 12 persons employed 30 or more years.

Pulmonary tuberculosis seemed to be of minor importance in the group of 507 bituminous coal mine workers since only 3 cases were found showing clinical evidence of activity, all minimal, and 10 workers showed X-ray evidence of apparently healed, minimal tuberculosis. Only 1 lesion, minimal and healed, was found among the 16 persons with anthraco-silicosis.

Recommendations included the use of wet methods in coal mining and processing operations and the adequate ventilation of all work

places. Preemployment physical examinations and annual medical examinations were suggested which included an X-ray film of the chest. It was recommended that no worker be removed from his usual employment because of a diagnosis of simple anthraco-silicosis, but rather the atmospheric dust should be brought within safe limits. However, workers showing evidence of active tuberculosis should be removed from a dusty industry and placed under medical care.

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