
A WATER-BORNE TYPHOID FEVER EPIDEMIC.*

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The city of Healdsburg in Sonoma County, California, was almost entirely free from typhoid fever for a number of years prior to the summer of 1914. Between July 15 and September 22 of that year the city was visited by an epidemic of typhoid fever consisting of ninety reported cases and seven deaths.

Eighty of the persons affected resided in Healdsburg, and eight on near-by farms. One lived in Oakland, and one in Petaluma. All received their infection in Healdsburg. How many travelers

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contracted the disease and became sick in distant cities is a matter of conjecture.

As there were seven deaths among the ninety cases recognized as a part of this epidemic, the mortality was 7.8%. One of the deaths occurred on a farm near Healdsburg. The Oakland patient died in a San Francisco hospital. The five other deaths occurred among the eighty residing in Healdsburg.

Healdsburg has an estimated population of 2100 persons. Excluding from consideration the incomplete reports of cases outside the city, we have the following statistics for the eighty cases (including five deaths) among residents of the city.

The cases were 3.8% of the population, or in the ratio of 3810 per 100,000 people. The deaths were 0.24% of the population, or 238 per 100,000 people. The case mortality was 6.3%.

The distribution of cases among patients of various ages departs but little from the usual arrangement as determined by the United States Public Health Service in a recent study of the available statistics.¹ The cases of the Healdsburg epidemic have been arranged according to the ages of the patients in Table I.

Table I—Ages of the Typhoid Fever Patients by Decades.

| Ages in Years. | Numbers of Patients. |
|----------------|----------------------|
| 3 to 10 | 17 |
| 11 to 20 | 19 |
| 21 to 30 | 22 |
| 31 to 40 | 18 |
| 41 to 50 | 8 |
| 51 to 60 | 5 |
| 61 to 66 | 1 |
| Total | 90 |

In 64 of the 90 cases of typhoid fever the diagnosis was confirmed by a positive microscopic agglutination test. In 17 cases the agglutination test was negative, but most of the samples of blood failing to give a positive reaction were taken early in the disease. In only three cases were negative results obtained from blood drawn over nine days after the onset. All but two of the Widal tests were made in the State Hygienic Laboratory. In nine cases samples of blood were not submitted for examination. Sixteen additional cases were reported but were shown by investigation or later developments to be probably not typhoid fever.

The severity of the cases, as in most typhoid fever epidemics, varied within wide limits. One patient in whom the diagnosis was determined by a positive Widal reaction was in bed only four days. As a prolonged and intensive investigation of this epidemic was not possible, a number of the lighter cases probably escaped attention. There were many severe cases, and among the complications reported were relapses, bronchitis, pneumonia, convulsions, hemorrhages from the bowels, and perforation of the intestines.

THE INVESTIGATION.

In response to a request from Dr. J. W. Seawell, Health Officer of Healdsburg, the California State Board of Health instructed me on August 1 to go to Healdsburg and co-operate with the authorities there in finding out the source of the outbreak of typhoid fever. From August 2 to 6 I

made a field study of the epidemic, gathering data from physicians and patients, studying the water supply, investigating suspected sources of pollution of the Russian River as far north as Cloverdale, and advising the city authorities regarding emergency measures of control. In this work I was greatly assisted by the vigorous co-operation of Dr. J. W. Seawell, Health Officer; Mr. C. R. Nelson, Superintendent of the Municipal Water and Electric Light Plants; Mayor A. F. Stevens; and the physicians of Healdsburg.

The source of infection was found to be the city water supply. The city water had been used by all whose cases were investigated, including those persons who resided in the country. The milk supply, on the other hand, came from many sources, including several dairies. Some of the patients were supplied from neighborhood cows. Others used canned milk, and one used only goat's milk. There were no vegetable or food supplies nor eating places common to the majority of the patients. The case against the city water was further strengthened by the fact that a sample of the water had been sent by a city official to the State Hygienic Laboratory on May 5, 1914, and colon bacilli had been isolated from amounts of the water as small as one cubic centimeter. A moderate pollution with intestinal bacteria was, therefore, demonstrable at least two months before the epidemic began. If the State Board of Health had had in its employ a sanitary engineer to make the field investigation necessary to determine the full significance of the laboratory findings, he could then have demonstrated to the local officials the need for immediate treatment of the water supply, and the epidemic might have been prevented and seven lives saved.

The course of the epidemic is shown in the accompanying chart. The number of cases beginning on each day is shown by the height of the shaded area. Light shading indicates that the patient recovered, and dark shading denotes a fatal termination. The characteristics of a water-borne typhoid fever epidemic, as contrasted with a milk-borne or food-borne epidemic, are shown by the gradual beginning and prolonged course. To emphasize this contrast, this water-borne epidemic is compared in the chart with the recent food-borne typhoid fever outbreak in Hanford, California.² The former began gradually and was prolonged, because the infectious material was supplied through a long period of time, while the Hanford epidemic began suddenly and was brief, since it was due to infection from a single dish of food. In the former, a very small proportion, probably about five per cent., of the people who repeatedly drank the moderately polluted water came down with typhoid fever, while in the latter 57 per cent. of those who ate the highly infected food developed the disease. In epidemics due to a sudden, severe, and brief infection of a drinking water supply the outbreak may be explosive, like a typical food-borne epidemic, but the Healdsburg outbreak represents the more usual type of water-borne epidemic.

Some of the late cases in the Healdsburg epidemic were probably infected from the earlier cases

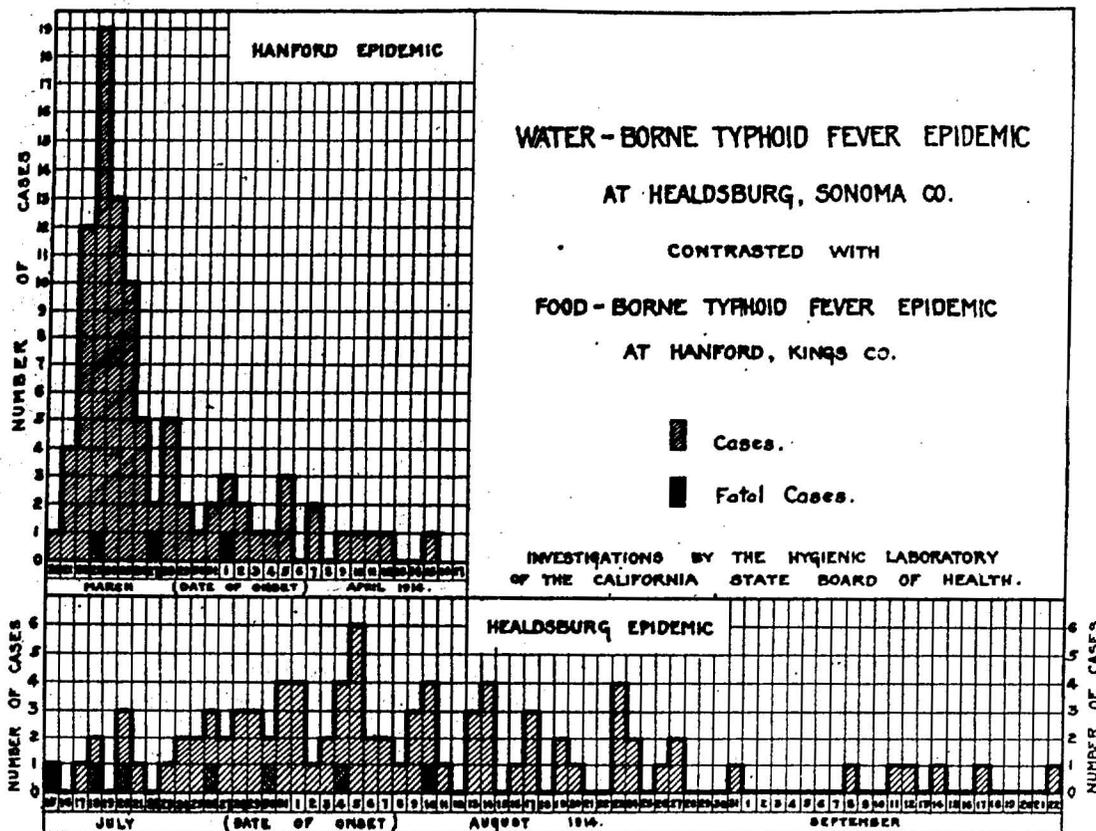
instead of directly from the city water. This would account for most of the cases in the small group at the end of the epidemic.

About the middle of July, when the epidemic was beginning, there were many cases of diarrhea among the people of Healdsburg, according to the reports of several of the physicians. It is not uncommon for cases of diarrhea to accompany or precede a water-borne epidemic of typhoid fever. In the water-borne typhoid epidemic at Rockford, Illinois, a city of 50,000 people, about 10,000 cases of enteritis occurred between January 16 and 20, 1912, and this outbreak was followed by 199 cases of typhoid fever having their onsets between January 23 and February 29.³ Many Rockford people had both diseases.

The parts of town which received the least water through the supposedly infected pipes had their full share of cases. Moreover, at the time of the field investigation the daily number of new cases was increasing, although over three weeks had elapsed since the last pipe was laid. The epidemic was evidently not due to sewage accidentally admitted to the new pipes.

THE WATER SUPPLY.

The Healdsburg water supply is pumped from five wells situated a short distance above the city in the bed of the Russian River. The wells are in that portion of the wide river bed which is submerged only during high water. Three of the wells, 1, 2, and 3, were bored to depths of 54, 34



It was suspected by some of the physicians that the diarrhea and the earlier cases of typhoid fever in the Healdsburg epidemic were due to the accidental inclusion of sewage in some new water mains. Some 1500 feet of new cast-iron pipe were laid in certain streets of Healdsburg, mostly in the business district, between June 23 and July 10. At one point a disconnected house-drain was said to have been seen discharging into a ditch which had been dug to receive the pipes. The contractor who laid the pipes denied the possibility of the inclusion of sewage. No cases of typhoid fever antedating the epidemic had come to the attention of the physicians of Healdsburg, and the laborers who dug the ditches and laid the pipes were all local men who were apparently well.

and 36 feet respectively. They were 20 inches in diameter and had been sealed at the top with cement to prevent the entrance of river water during freshets. Well No. 4, the one nearest the river, is an old dug well with a brick curb, and is ten feet in diameter and between 25 and 30 feet deep. A wooden cover bolted in place was intended to prevent the entrance of river water. This well is 42 yards (measured by pacing) from the edge of the water in the river at the summer level. Well No. 5 is a large dug well situated near well No. 4 and almost as near to the river. This well is 12 feet in diameter and 40 feet deep, and is protected by a wooden cover. All five of the wells were sunk into the gravel and sand of

the river bed without encountering any impervious strata.

The pipes from the five wells are all connected and it is impossible to tell how much water comes from each. From the pumping station the water goes to two reservoirs on a hill 122 feet higher than Healdsburg. Their combined capacity is said to be 500,000 gallons. The wells are reported to furnish between 500,000 and 600,000 gallons a day.

On August 3rd and 4th samples were taken at the surface of the water in each of the two dug wells, at the surface of the water in each reservoir, from the pipe carrying the mixed water of the five wells from the pumping station, from a faucet in the center of the city, and also from the Russian River opposite the wells. These samples were packed in ice and sent to the State Hygienic Laboratory for bacteriological examination.

At the laboratory it was found that the total number of bacteria in the samples from the two dug wells and from the pipe carrying the mixed water from the five wells was approximately half the number found in the samples from the river opposite the wells. The bacterial count of the water in the reservoirs exceeded that of the river water, and the bacteria in the water collected in the city were five times as numerous as those in the river.

These variations were due largely to water bacteria and were not so important to the investigation as were estimates of the numbers of intestinal bacteria, represented by the colon bacillus. In the river water colon bacilli were isolated from amounts of the water as small as one cubic centimeter, but not from 0.1 c.c. In well No. 4 they were found in 3.0 c.c. and not in 1.0 c.c. In well No. 5 they were not found in 3.0 c.c., although bacteria producing gas in glucose medium were demonstrated in 1.0 c.c. of the water. In the sample from the mixed water of all the wells colon bacilli were found in 3.0 c.c. but not in 1.0 c.c., and in each reservoir they were found in 5.0 c.c. but not in 3.0 c.c. In the sample from a faucet in the city, taken August 4th, colon bacilli were isolated from 1.0 c.c. and not from 0.1 c.c., a result the same as that for the sample in the Russian River and for the sample previously taken from the distributing system on May 5, 1914. The samples taken where the water was kept agitated, as in the river and in the pipes above the pumping station and in Healdsburg, as a rule showed a number of colon bacilli which was greater than where the water was quiet and undergoing sedimentation, as at the surfaces of the reservoirs and of the dug wells when the pumps were not running. When the pumps are in operation, a large part of the water enters the distributing system without passing through the reservoirs, and there is, therefore, little purification by sedimentation between the wells and the consumer.

In brief, the laboratory examinations showed that the water in the river was polluted with sewage and was not appreciably purified by passing through at least 42 yards of gravel and the city water system. The pollution in the river was about equal to that in the distributing system of the city. In

each instance colon bacilli were demonstrated in 1.0 c.c. of the water but not in 0.1 c.c. The same grade of pollution had been demonstrated in the water previous to the appearance of typhoid fever, i. e., on May 5, 1914.

In order to complete the demonstration that the city water came from the Russian River, samples were taken from a faucet in the city and from the river and sent for chemical analysis to Professor M. E. Jaffa, Director of the State Food and Drug Laboratory. The reports of the analyses were almost identical, and Professor Jaffa stated in the letter with his report, "It would appear from the enclosed data that these waters are practically from the same source."

THE POLLUTION OF THE RIVER.

Many towns and the city of Ukiah are situated on the Russian River above Healdsburg, and some sewage pollution, coming from many sources, would be expected. The principal communities as far up the river as Cloverdale were visited and their sewage systems investigated, without discovering evidence bearing directly on the epidemic. The banks of the river in the vicinity of Healdsburg were carefully studied. About a mile above the city wells a sewer from a summer resort was found discharging fecal matter into a part of the river freely used for boating and swimming. The outlet was concealed by a dense growth of willows and was discovered only by entering the thicket in a boat. There had been no case of typhoid fever at the building from which the sewage came, but a typhoid convalescent or a chronic typhoid carrier may have been among the summer guests or servants. Some connection between the epidemic and the summer guests is probable, because the height of the season for the summer resorts was early in July, just before the epidemic began. The resort whose untreated sewage was found flowing into the river had only six guests at the time of the investigation, but had had over a hundred early in July.

A grave responsibility rests with the physician who sends a convalescent from typhoid fever to a summer resort without first ascertaining whether the sewage from the resort is properly disposed of, or at least warning the local health officer so that he can investigate.

At the time of greatest population in the camps and taverns along the river it is probable that the sewage pollution was greater than at the time of the investigation. A number of cottages have cesspools in the bed of the river where the water can quickly drain through the loose sand and gravel and pollute the stream.

So long as the Russian River is used extensively for boating and swimming, the pollution of the river by the entrance of raw sewage, the untreated effluent from septic tanks, and the seepage from cesspools situated in the river bed should be prohibited. Otherwise typhoid fever and other water-borne diseases must be expected.

SEWAGE DISPOSAL.

The sewage of a city in which typhoid fever is prevalent is a source of danger. The Healdsburg sewage passes through a septic tank and is then

conveyed to Dry Creek, which empties into the Russian River several miles below Healdsburg. Inspection of the creek showed a condition typical of many of our California water-courses in summer. There was a wide gravelly creek-bed through which flowed a small stream, sometimes rippling over the stones, often concealed under the gravel for twenty yards or more, and occasionally standing in shallow pools. A sample of water was taken from a pool 197 yards below the sewer outlet. The water had flowed through three pools for a total of 150 yards and through two stretches of gravel for 47 yards. Colon bacilli were isolated from 0.001 c.c. of the water, which was not tested in smaller amounts. Such a test demonstrates only the facts, well known to sanitary engineers, that the septic tank cannot be depended upon to remove colon bacilli from sewage, and that the same can be said regarding rapid percolation through loose gravel. Investigations of septic tanks under favorable conditions have shown that the content of intestinal bacteria, as indicated by the number of colon bacilli, is not greatly reduced when the sewage passes through a septic tank.⁴ Likewise, typhoid bacilli and many other pathogenic organisms can survive the septic tank, as the conditions are not sufficiently unfavorable to bring about their destruction. The function of the septic tank, whether it be of the Cameron type, of the Imhoff type, or of any other variety, is to reduce the amount of suspended solids by sedimentation and putrefaction of the sediment under anaerobic conditions. The effluent from the tank is about as dangerous as the same sewage without treatment, but owing to the decrease in putrescible solids, it becomes less of a nuisance. The effluent should undergo further treatment if it is to enter a stream which is used, unpurified, for drinking purposes.

The flowing of polluted streams through the gravel of their beds, under the summer conditions exemplified in Dry Creek, does not purify the water, and the drinking of water from the pools or "springs," as they are sometimes called, is dangerous. It is obvious that water running rapidly through gravel, either from a river to shallow wells or in the bed of a stream, does not allow a sufficient time factor to insure adequate filtration. Both the rapidity of flow and the coarseness of the material are such that sufficient purification by filtration is not effected.

The epidemic of 350 cases of typhoid fever at Centralia, Washington, in December, 1913, and January, 1914, was caused, like the Healdsburg epidemic, by taking water from wells sunk into the gravel at the edge of a polluted river.⁵ The water had to pass through at least twenty feet of gravel. The percentage of the population involved (3.5%) and the case mortality (6.5%) were almost the same as the corresponding figures for the Healdsburg epidemic.

CONTROL OF THE EPIDEMIC.

Prior to the investigation, Dr. Seawell, City Health Officer of Healdsburg, suspected the city water supply as the source of the infection and instructed the people, through a local newspaper,

to boil all drinking water, to protect food from flies, and to avoid the eating of raw vegetables. The public was slow to heed this advice, and one of the principal hotels continued to serve raw city water until specially warned.

When the source of infection had been determined, recommendation was made to the city authorities that the city water be treated with hypochlorite as an emergency measure. An extemporized plant for introducing hypochlorite at the pumping station was set up under the direction of Professor H. S. Griswold of the University of California and was operated by local men, beginning on August 7th. Six days after the treatment began, examination showed that colon bacilli could still be demonstrated in 1.0 c.c. of the water, although the total bacterial count had fallen from 600 to 20 per c.c. The amount of hypochlorite was then increased. Twenty days after the treatment began the local authorities sent another sample, which showed that the water was entirely safe. The bacterial count was 1 per c.c. and colon bacilli were absent in 10 c.c.

The new cases continued to be reported in considerable number for twenty days after the first application of the hypochlorite treatment, but after that there were only scattered cases, probably secondary to earlier cases.

In order to reduce the number of new infections from the city water and from the earlier cases, the physicians administered typhoid vaccine to many persons. The State Hygienic Laboratory issued to Healdsburg physicians, between July 28 and September 4, vaccine for immunizing 642 people, and most of it was undoubtedly administered. The vaccine used was the sensitized typhoid vaccine manufactured in accordance with the method of Gay and Claypole and issued free to physicians of California. The vaccine was given in three doses at intervals of two or three days, thus permitting the complete treatment to be administered in five days instead of in twenty-one days, as is required by the usual methods. Two persons developed typhoid fever between the first and last dose. Only one suspected case of typhoid fever was reported among those for whom vaccination was completed. A man who received his three doses of vaccine on August 5, 7 and 12, became sick on December 13, nearly three months after the last case of the epidemic, complaining of headache and backache and swelling of the eyelids. He had a moderate fever which had fallen to normal on December 29. A diagnosis of abortive typhoid fever was made by the attending physician. A positive Widal reaction was obtained, but it may have been entirely due to the vaccination. Unfortunately the case came under the observation of his physician too late for a blood culture to be of value. Among the unvaccinated there were 41 cases subsequent to August 6, a date sufficiently late to permit the earliest patients to have received three doses of vaccine.

SUMMARY AND CONCLUSIONS.

1. The Healdsburg epidemic of 90 cases, including seven deaths, was caused by polluted water which passed from the Russian River through at

least 42 yards of gravel to the wells of the city water system.

2. Rapid straining through coarse gravel and sand, either naturally through the beds of our dry creeks, or from a contaminated stream to wells, cannot be depended upon adequately to purify polluted water.

3. Septic tanks do not free sewage from typhoid bacilli and other pathogenic organisms, and their untreated effluents may seriously contaminate a stream.

4. As long as the Russian River is used extensively for boating and swimming, it should be protected from the entrance of raw sewage, the untreated effluent of septic tanks, and the seepage from cesspools situated in the river bed.

5. Inasmuch as every typhoid fever epidemic increases the amount of the disease in distant parts of the state and in future generations, and since the question of the water supply and sewage disposal of each community necessarily involves more than the one community, it is the duty of the state to examine all public water supplies and sewage disposal systems at frequent intervals and to prevent the use for drinking purposes of dangerously polluted water. Sanitary engineers in the state's employ are needed for carrying on this work. They are needed, also, to look after engineering aspects of the investigation of water-borne epidemics like the one in Healdsburg, and to aid in emergency measures for their control.

¹ Public Health Reports, U. S. Public Health Service, Feb. 19, 1915, XXX, No. 8, 534-536.

² Sawyer, W. A.: Ninety-three Persons Infected by a Typhoid Carrier at a Public Dinner. *Jour. Am. Med. Assoc.*, Oct. 31, 1914, LXIII, 1537-1542.

³ Jordan, Edwin O., and Irons, Ernest E.: The Rockford (Ill.) Typhoid Epidemic. *Jour. of Infectious Diseases*, July, 1912, Vol. XI, No. 1, 21-43.

⁴ Kinnicutt, L. P., Winslow, C. E. A., and Pratt, R. W.: *Sewage Disposal*, first edition, 1910, pp. 378-379.

Fuller, George W.: *Sewage Disposal*, 1912, pp. 472-474.

⁵ Kelley, E. R., and Macomber, S.: Typhoid Fever Epidemic—Centralia, Washington. *American Journal of Public Health*, November, 1914, Vol. IV, No. 11, pp. 1035-1045.