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## TWO LINCOLN (NEBRASKA) TYPHOID FEVER EPIDEMICS OF 1911 AND 1912.\*

HERBERT H. WAITE.

*(From the Bacteriological Laboratory, University of Nebraska, Lincoln, Nebraska.)*

On August 29, 1912, I was requested by the Board of Health of the city of Lincoln to make an investigation to determine if possible the origin and cause of an outbreak of a disease reported as typhoid fever which was then prevailing. This outbreak was said to be most prevalent in one particular portion of the city and consequently attention was turned to that portion. Of the cases reported an investigation was made of over 60 individuals and after considering all the probable causes for the majority of those affected the conclusion was reached that all could be logically excluded except water.

### DESCRIPTION OF CITY WELLS.

The city of Lincoln has a population of about 45,000. The city water supply is owned and controlled by the city. At the time of both typhoid epidemics the city was supplied by the combined output of the three wells described below. The average daily supply from these three wells was about 3,275,000 gallons. Of this amount the A Street well delivered about 2,500,000 gallons, the Rice well 600,000 gallons, the F Street well 175,000 gallons. To produce this output required continuous pumping for 24 hours daily at the A Street well, from six to eight hours daily at the F Street well, and 20 hours daily at the Rice well. At the present time, August 22, 1912, the combined capacity of all the city wells, provided they were all used 24 hours per day, would be 7,000,000 gallons. The increase in the amount of water which could be obtained has been secured through the construction of five new driven wells. These new wells have water-tight casings from the water-bearing strata to the surface. Their combined capacity is 4,500,000 gallons per day. The remaining 2,500,000 gallons represent the combined

\* Received for publication September 5, 1912.

capacity of the A and F Street wells, the Rice well having been permanently abandoned.

#### THE MOCKETT OR A STREET WELL.

[In describing the city wells I shall quote directly from the report of Mr. James C. Harding, one of the associates of Mr. George W. Fuller, consulting hydraulic engineer and sanitary expert.]

"The A Street well, pumping-station, and reservoirs are located on A Street between the C.R.I. & P. Railroad and Normal Boulevard. The main well is circular, about 47 feet in diameter at the top and for a distance of about 28 feet below the surface of the ground. There it narrows to about 37 feet for a distance of 27 feet. The bottom section, 33 feet 7 inches in diameter, is about 22 feet deep, making a total depth to the sandstone of about 77 feet. The well casing is of brick masonry 16 inches thick in the two upper sections and 12 inches thick in the lower. Up to a few years ago the well was uncovered, but has been recently roofed over with a corrugated steel roof. In the bottom of this well are six borings made to a depth of from 50 to 100 feet in the sandstone, and it is through these borings that practically all the water is obtained.

"Besides the main well there are six eight-inch driven wells operated by air lifts which discharge water directly into the storage reservoirs.

"*Water levels.*—The normal water level in the main well when it was first built was about 30 feet below the surface of the ground when the pumps were not operating. At the end of a day's pumping when the water was being taken from the well at an average rate of 2,000,000 gallons per day the water level was about 60 feet below the surface of the ground. At the present time with the Rice well out of commission and with the pumps taking water as fast as it flows into the well, the sandstone at the bottom is exposed during the pumping and the water level stands only about 75 feet below the surface of the ground. From records obtained by the city engineer it is evident that the water level around this well has been lowered during the last 10 years about 11 feet.

"*Pumping equipment.*—During normal operation the water from the main well and from the air lifts is discharged into the storage reservoirs and from there pumped to the mains by high-lift pumping engines. The pump has a rated capacity of three million gallons a day. This is the pump which is ordinarily used and which furnishes the main supply for the city.

"*Storage reservoirs.*—On the south side of A Street and east of the pumping-station are located the two covered masonry storage reservoirs. The first of these is about 60 by 190 feet on the inside and has a capacity of about 1.3 million gallons. The second reservoir, built more recently, is about 45 by 190 feet inside and has a capacity of about one million gallons.

"*Geology.*—The record of the different strata encountered in drilling a test well, located about 700 feet west of the A Street pumping-station, as given by the city engineer, shows surface soil to a depth of 2 feet, clay to 20 feet, and sand to 50 feet. The sandstone below this varies in coarseness to 175 feet, and below this depth very fine sandstone to 198 feet. A stiff clay was encountered at 203 feet. The water level was 48 feet below the surface of the ground.

"*Sewers and surroundings.*—There is a 10-inch vitrified sewer running from the alley between A Street and Washington Street and in Washington Street and across

private land from Washington Street to A Street. At one point this sewer is within 20 feet of the southeast corner of the smaller storage reservoir. At the nearest point it is about 200 feet from the main well. The 16-inch discharge line from the air lifts and driven wells crosses this sewer near the reservoirs about 4.5 feet below the invert of the sewer.

"Northeasterly of the main well is the old channel of Antelope Creek. This channel has been filled in at both ends, leaving a hole along the old stream bed at a distance of from 150 to 300 feet from the well. Probably some surface wash from the street collects in this hole and possibly percolates through the ground into it.

"*Quality of the water.*—So far as we know, there have been no chemical analyses made of the water of this well.<sup>1</sup> Dr. Waite has, however, made some bacterial analyses and on some occasions has found results which he believes show that some polluting matter is entering the well on the east side. From the surroundings of the well and from our own investigations we did not see anything to cause us to condemn this well for water supply purposes. There is a small amount of ground water leaking into the well at various places which, according to Dr. Waite, have in some instances shown indication of being contaminated by some foreign matter. Such conditions, however, might easily have arisen from the fact that this seepage is probably surface water and contains matters not filtered out by its passage through the ground.

#### F STREET WELL SUPPLY.

"*Well.*—The F Street well is an open well somewhat similar to that just described, but differing in that it does not extend to the sandstone but rests on a bed of clay overlying the gravel strata. This well is 39 feet in diameter at the top and for a depth of 26 feet below the surface of the ground. Inside of this upper section there is a second well 29 feet in diameter and about 20 feet deep. The walls of this well are of brick masonry, the outside section about two feet thick and the inside about 15 inches. The well is covered by a corrugated steel roof. At the time the well was constructed a hole was dug some 12 feet below the inner well section to gravel, but it was found upon testing the water that it was very salty, and an effort was made more or less successfully to close up this opening and cut out the salt water. As shown by the analysis of the water, however, it is apparent that considerable of this salt water still gets into the well.

"*Pumping equipment.*—This well is equipped with an electrically operated pump. This pump has a capacity of about 1,500,000 gallons per day, but is used only about five hours out of the 24, as there is not sufficient water to operate it for a greater length of time.

"*Geology.*—In sinking this well, soil was encountered to a depth of about 25 feet below the surface. Below this was a gravel layer about two and one-half feet in thickness resting on a bed of yellow clay about eight feet in depth. The bottom of the shoe of the outer section of the well stops at approximately the top of this clay stratum. Below this clay is a gravel layer about two feet in thickness, and below this is blue clay about 13 feet in depth and a third gravel layer of about 10 feet in depth. It is from this gravel that most of the water is obtained. Below this is a four-foot layer of clay and a gravel layer of about the same thickness in which the salt water mentioned above is encountered.

<sup>1</sup> Several chemical analyses of the water from this well had been made previous to this physical examination and could have been easily obtained.

*"Sewers and surroundings.*—On Sixth Street there is a 15-inch sewer which takes the sewage from a large part of the business part of the city and which at times is greatly overloaded, so much so, in fact, that the water is backed up to the surface of the roadway on Sixth Street at times of heavy rainfall. This sewer is about 60 feet from the side of the well. There is also a four-inch tile drain connecting with this 15-inch sewer which passes within eight feet of the well and is connected to the water-closet in the F Street park. This drain was cut off at the curb line in the latter part of January by the city engineer and carefully plugged.

*"Quality of the water.*—While, as stated above, most of the water from this well comes from the lower gravel layers, and, excepting for the large salt content, is apparently of good quality, yet there is every indication that a small quantity of water gets into the well through the upper gravel layer. Whether or not the flow from this place increases greatly during times of high water we do not know, but in all probability it does. We believe that it is reasonable to suppose that the leakage from the sewer on Sixth Street, should it occur, could readily find its way into this well below the outside wall. We have a chemical analysis of the water from this well, made by Mr. C. J. Frankfurter in October, 1911, for Dr. H. H. Waite and taken from his report, as follows:<sup>2</sup>

	Parts per Million	Grains per Gallon
Total solids.....	1,294.6	85.73
Organic and volatile matter.....	111.4	6.52
Albuminoid ammonia.....	.252	.015
Free ammonia.....	.352	.020
Total ammonia.....	.604	.035
Oxygen-consuming power.....	.72	.042
Nitrate nitrogen.....	.65	.038
Nitrite nitrogen.....	None	None
Chlorine.....	545.85	31.93
Sodium chloride (calculated from chlorine content).....	900.00	52.65

<sup>2</sup> "A chemical analysis of water from the F Street well was made on October 10, 1911, by Mr. C. J. Frankfurter. The results of this analysis were as follows:

	Parts per Million	Grains per Gallon
Total solids.....	1,507.5	88.18
Organic and volatile matter.....	142.4	8.33
Albuminoid ammonia.....	.01	.0006
Free ammonia.....	.03	.0017
Total ammonia.....	.04	.0023
Oxygen-consuming power.....	.097	.0056
Nitrate nitrogen.....	2.6	.15
Nitrite nitrogen.....	Trace	Trace
Chlorine.....	606.5	35.48
Sodium chloride (calculated from chlorine content).....	1,000.0	58.5
No charring.....	.....	.....

#### RICE WELL SUPPLY.

*"Well.*—The Rice well, built 23 years ago, is located near N Street between 23d and 24th Streets. The well proper is 24 feet in diameter and about 60 feet deep below

<sup>2</sup> The chemical analysis given above was made from water collected from the Rice well and not from the F Street well. There is no reason why this analysis should have been credited to the F Street well, the record being explicit concerning the Rice well from which the water was obtained.

the surface of the roadway. At the present time the walls of this well are cracked in a number of places, not enough to endanger the structure, but sufficiently to admit of the entrance of water. Besides this there are many places where there is evidence that the ground water has found its way into the well at various times.

*"Water level.*—The elevation of the roadway in front of the well is about 70. The normal water level when not pumping is 32 feet below this, or elevation 38, while the bottom of the well is at elevation 8. During times of heavy pumping the water level is drawn down to about elevation 20. At the time of the recent investigation the ground water immediately surrounding the well was at about elevation 53, while at a point about 50 feet westerly of the well ground water was not encountered at elevation 40.

*"Pumping machinery.*—The water from this well is pumped by two electrically operated pumps in the pump pit located about 50 feet southeast of the well. This pump pit is 25 feet in diameter and about 35 feet deep. Each of these pumps has a capacity of 700,000 gallons per day and they are so arranged that either one can be used for ordinary day service and both in series when it is desired to raise the pressure for fire service.

*"Sewers and surroundings.*—There is an eight-inch house sewer which runs from N Street through the alley west of 24th Street and across private property back of the pump pit to a manhole south of N Street. From there it runs directly past the wall inclosing the entrance to the boiler house and across N Street to the manhole in the alley between N and O Streets. Besides this sewer a number of outhouses are in close proximity to the well and there are also other features, such as filling-in of the surrounding ground with street cleanings and other rubbish and the depression caused by changing the course of the Antelope Creek, which make the surroundings unsightly and unsanitary. There are also numerous pipes used for drains, blow-offs, and other purposes at the time the plant was steam-operated, leading out from the well and for the most part forgotten at present, which would form easy routes by which the ground water might enter the well.

*"Quality of the water.*—We have no chemical analysis of this water, but from bacterial analyses made from time to time by Dr. Waite and others it is apparent that this water is not ordinarily contaminated by seepage of water into the well. From the fact that ground water about the well, however, is drawn down to a considerable depth and that there is no outlet for the considerable amount of surface wash coming into the hollow back of the station and into the old water course of the Antelope Creek, we should expect that during times of heavy rain a considerable amount of foreign matter could be and undoubtedly is carried into the well."

#### INVESTIGATION OF FIRST EPIDEMIC.

During the first three weeks of this investigation samples of water were collected and examined from all three of the city wells without finding any evidence of contamination or infection. The localization of the outbreak and the surroundings of the Rice well were constantly kept in mind, since a contamination of this well would have furnished the most probable source of infection.

Repeated examinations, however, failed to give any evidence whatever of contamination. This was true not only when the water was collected at the pump but also when it was collected from the well itself. At this time there was very little seepage and at no place was the amount sufficient for collection from the wall itself. In order to get a sample it was necessary to scrape the wall. This was done in several places where the wall was covered with a brown, moist layer which appeared to be composed chiefly of iron rust. In these scrapings there was absolutely nothing to indicate pollution.

Having found nothing in the water from the wells, an examination was made of the water from the faucets in different parts of the city but especially in that part where the majority of the cases existed. Here evidence of contamination in the mains was soon found. During the last two weeks in September samples of water were obtained from 14 of the city schools. No colon bacilli were found in the samples from 11 of the schools. Colon bacilli were present in one cubic centimeter amounts in every one of 10 samples taken from two schools and in one cubic centimeter amounts in five of 10 samples taken from one school. The three schools where colon bacilli were found were all in the section where the epidemic was most prevalent. Since colon bacilli were not found in water from the schools outside the area where the disease prevailed nor from other places outside this area, at this time, numerous samples were collected at various places covering the entire section involved. Colon bacilli were found in one cubic centimeter amounts in more than 50 per cent of the samples collected. Since there was evidence of contamination of the water in the mains in the area presumably supplied by the Rice well, an attempt was made to find out where this contamination came from. At this time there were two possible explanations for the source of contamination: one that the mains were being or had been contaminated directly, the other that they had been contaminated by the Rice well some time before the investigation was begun. It has been shown conclusively in several instances that direct contamination of mains may occur under certain conditions. No positive evidence of conditions favorable to such contamination was obtained during this

investigation. In the light of what was found at the time the second epidemic was investigated the evidence is convincing that the most probable explanation of the contamination of the city mains in northeast Lincoln during the time when such contamination was found to exist was through the Rice well.

That evidence of contamination of the Rice well at this time was not found is easy of explanation. The investigation was not begun until August 30. A very large proportion of those having the disease were attacked about the middle of August. The contamination which caused this infection began at least from one to three or more weeks before this time. There was practically no precipitation in July except on July 9 and 23. At this time the condition of the soil was such that seepage of surface water might have occurred very easily. The total precipitation for August 2, 3, and 4 was 1.16 inches. A contamination of the water at this time, if it occurred—and it is quite probable that it did—would have taken place at just about the right time to explain the large number of those attacked about August 20, since it would correspond quite closely with the usual typhoid incubation period. Since the investigation was not begun until the last of August, there was abundant time for all evidence of contamination to have disappeared from the well, and it would not have been at all unusual for it to have disappeared from the mains.

Following the request of the Governor, Dr. L. L. Lumsden, passed assistant surgeon of the United States Public Health and Marine Hospital Service, was detailed by the Surgeon General to proceed to Lincoln, Neb., to make an investigation of an outbreak of typhoid fever in the city and to determine the sources of infection and the measures necessary for the control of the disease.

Dr. Lumsden began his investigation on November 4 and terminated it on November 11, 1911. During this investigation the colon bacillus was encountered for the first time in water taken from the A Street well on November 10 in 10 c.c. amounts of water. It was found a number of times after this during Dr. Lumsden's<sup>1</sup> investigation and since then I have obtained it repeatedly in samples from this well up to the first of August, 1912.

<sup>1</sup> *Public Health Report*, 1912, 27, No. 21.

From November 18, 1911, to December 5, 1912, 57 samples of water were secured from the A Street well and its surroundings. Three of these were taken from pools in the more or less immediate vicinity of the well. A sample was taken from standing water which collected chiefly from the overflow of a watering trough situated at a distance of from 125-50 feet east of the well. This water disappeared although it had no visible outlet. Colon bacilli were present in this water in large numbers. A second sample was taken from the Antelope at a point where some of the waste water from the pumping-station empties into the creek. This sample was taken at a distance of about 100 yards east of the well. There were many colon bacilli present in this sample. A third sample was taken from a pool near the driveway northeast of the well. In this sample, colon bacilli were also present in lesser numbers than in the other two samples. Colon bacilli have never been found in the seepage of the A Street well except in that which comes from the wall on the east. The seepage here is very slight compared with that which comes from the wall on the west and south. Seepage occurs only on the walls of the middle and bottom section of the well. In the many samples of seepage collected from both sections of the well, colon bacilli have been found in only one sample from the middle section. At this time they were present in one cubic centimeter of the seepage. A large percentage of the samples collected from the bottom section show colon contamination. Since colon bacilli are rarely encountered in seepage from the middle section of the well and are of frequent occurrence in samples from the bottom section, it seems logical to suspect that the contamination does not come from surface washings directly, since seepage begins at a distance of about 30 feet below the surface and colon bacilli are not found until a depth of 60 feet or more is reached. A series of experiments had been planned to determine if possible the source of this contamination. Very soon after they were begun they had to be abandoned, since the time necessary to carry out these plans was required in the investigation of the epidemics which began about the middle of December. The results of the examinations of the water from the three pools in

the vicinity of the A Street well and from the seepage in the A Street well are as follows:

RESULTS OF EXAMINATIONS OF WATER FROM POOLS AND FROM SEEPAGE FROM THE A STREET WELL.

SOURCE	DATE OF EXAMINATION	NUMBER OF BACTERIA PER CUBIC CENTIMETER ON AGAR, AFTER 48 HOURS' INCUBATION AT 37.5° C.	GAS IN LACTOSE BROTH FROM		B. coli IN	
			1 C.C.	10 C.C.	1 C.C.	10 C.C.
1911						
Pool nearest A well. . . . .	Nov. 18	1,500	+	+	+	+
Pool northeast of A well. . . . .	" "	155	+	+	+	+
Antelope Creek, east. . . . .	" "	240	+	+	+	+
Seepage, east, M. . . . .	" "	4	-	-	-	-
" northeast, M. . . . .	" "	3	-	-	-	-
" west, M. . . . .	" "	3	-	-	-	-
" southeast, B. . . . .	" 20	1,000	-	+	-	+
" east, B. . . . .	" "	1,200	+	+	+	+
" northeast, B. . . . .	" "	80	+	+	+	+
" west, B. . . . .	" "	10	-	-	-	-
" southwest, B. . . . .	" "	8	-	+	-	+
" southeast, M. . . . .	" "	15	+	+	+	+
" northeast, M. . . . .	" "	7	-	-	-	-
" north, M. . . . .	" 21	7	-	-	-	-
" south, M. . . . .	" "	4	-	-	-	-
" east, M. . . . .	" "	25	-	-	-	-
" east, M. . . . .	" "	1	-	-	-	-
" east, 1, B. . . . .	" 22	2,000	+	+	+	+
" east, 2, B. . . . .	" "	220	+	+	+	+
" east, 3, B. . . . .	" "	110	+	+	+	+
" east, 4, B. . . . .	" "	4	-	-	-	-
" southeast, B. . . . .	" "	8	-	-	-	-
" northeast, B. . . . .	" "	10	-	-	-	-
" east, 1, B. . . . .	" 23	1,185	+	+	+	+
" east, 2, B. . . . .	" "	190	-	-	-	-
" east, 3, B. . . . .	" "	575	+	+	+	+
" east, 4, B. . . . .	" "	305	+	+	+	+
" east, 5, B. . . . .	" "	365	-	+	-	-
" east, 1, M. . . . .	" "	4	-	-	-	-
" east, 2, M. . . . .	" "	15	-	-	-	-
" east, 3, M. . . . .	" "	5	-	-	-	-
" east, 1, B. . . . .	" 24	540	+	+	+	+
" east, 2, B. . . . .	" "	1,260	+	+	+	+
" east, 3, B. . . . .	" "	435	+	+	+	+
" east, 4, B. . . . .	" "	135	-	-	-	-
" east, 1, M. . . . .	" "	8	-	-	-	-
" east, 2, M. . . . .	" "	38	-	-	-	-
" east, 3, M. . . . .	" "	30	-	-	-	-
" east, 1, B. . . . .	" 27	450	+	+	-	+
" east, 2, B. . . . .	" "	500	+	+	-	+
" east, 3, B. . . . .	" "	370	+	+	+	+
" east, 1, B. . . . .	" 28	140	+	+	+	+
" east, 2, B. . . . .	" "	55	-	-	-	-
" east, 3, B. . . . .	" "	250	+	+	-	+
" east, 4, B. . . . .	" "	100	-	+	-	-
" east, 1, M. . . . .	" "	70	-	-	-	-
" east, 2, M. . . . .	" "	25	+	+	-	-
" east, 3, M. . . . .	" "	35	-	-	-	-
1912						
" east, 1, B. . . . .	Dec. 2	1,500	-	+	-	+
" east, 2, B. . . . .	" "	100	+	+	-	-
" east, 3, B. . . . .	" "	1,250	+	+	+	+
" east, 4, B. . . . .	" "	325	+	+	-	+
" east, 1, M. . . . .	" 5	25	-	-	-	-
" east, 1, B. . . . .	" "	80	+	+	-	-
" east, 2, B. . . . .	" "	75	-	-	-	-
" east, 3, B. . . . .	" "	35	-	+	-	-
" east, 4, B. . . . .	" "	150	-	+	-	-
Average. . . . .		301				
Percentage, positive. . . . .		.....	56	68	30	50

## INVESTIGATION OF SECOND EPIDEMIC.

On the 14th of December, 1911, a sudden and explosive outbreak of a more or less severe intestinal disease took place in Lincoln. Opinions as to what it was and from whence it had arisen were many. The following names were given to it: "winter grip," "influenza," "ptomaine poisoning," and "winter cholera." A number asserted with no uncertain positiveness that it was caused by a change in weather conditions and was transmitted through the air. The city physician vehemently declared that it was due to the eating of "tainted veal." Since the individuals affected were even more closely confined to the area presumably supplied with water from the Rice well than in the first epidemic of typhoid fever, some asserted, including myself, that it was most probably due to a contaminated water supply in the area involved. The 14th of December was chosen arbitrarily as the date of the beginning of the outbreak of "winter cholera," since the number affected on this date seems to have been greater than upon any other date and few, if any, were affected before this time. That influenza or a similar infection was also epidemic at this time is beyond question. This latter infection, however, certainly began before December 14 and was quite generally distributed over the entire city. No history of diarrhea was obtained in any of those who were afflicted with "influenza."

On the 18th of December the City Council of the city of Lincoln requested me to investigate this outbreak and determine its cause if possible. A canvass of about 50 individuals who were afflicted or had been afflicted with this intestinal trouble revealed the fact that more than 90 per cent had not partaken of veal within a week or more before the outbreak. This would eliminate veal from consideration in the majority of those who had the disease.

*Description of the disease.*—The number of individuals living in the area where the outbreak occurred is approximately 15,000. Of this number it would be conservative to estimate that 3,000 or more were affected to a greater or less degree. While collecting water from 11 houses in the district involved, three families numbering collectively 27 were all affected and nearly all of these dated the beginning of their trouble on December 14. In nearly all the

other houses one or more were affected. In making a detailed investigation of 50 cases of typhoid fever which subsequently developed, data were obtained concerning the outbreak of "winter cholera." Thirty-three of the typhoid patients had suffered an antecedent attack of "winter cholera," making for the number investigated a total of 66 per cent.

In the majority of those affected no temperature occurred or was so slight that it was not observed. In two it was said to have reached  $104^{\circ}$ . One had a maximum temperature of  $102^{\circ}$ , 37 had a slight temperature, 67 had none at all. The duration of the trouble was one or two days in the majority of cases, in some it lasted for two weeks. A duration of more than five days was infrequent. The attack was sudden in most instances. The pains varied in intensity from slight to severe. They were described as occurring in periodic, griping paroxysms. The stools were frequent, watery, and contained mucus. In a few cases blood was present in the evacuations. In one instance there was prolapse of the rectum.

The date of attack in 107 cases was as follows:

1911		1911		
December	14.....	34	December 21.....	5
"	15.....	24	" 22.....	4
"	16.....	10	" 24.....	2
"	17.....	1	" 25.....	6
"	18.....	3	" 29.....	3
"	19.....	1	" 31.....	4
"	20.....	10		
			Total.....	107

The numbers given above were practically definite for the 14th, 15th, and 16th of December. The numbers and dates for the other cases were not so definitely determined. Death occurred only in those at the extremes of life. The ages and sex of those who died were as follows:

AGE	SEX	
	Male	Female
83 years.....	..	1
78 ".....	..	1
73 ".....	..	1
72 ".....	..	1
1 year.....	1	..
7 months.....	1	..
3 ".....	1	..
Total.....	3	4

During the four months July, August, September, and October, 1911, 161 cases of typhoid fever were reported in the city of Lincoln. Of this number 141 were investigated and 144 were considered in detail. The results of this investigation appear in Dr. Lumsden's report of the first epidemic.

In November, 1911, the following cases of typhoid were reported in Lincoln:

November 7.....	1 case	November 21.....	1 case
" 13.....	1 "	" 26.....	1 "
" 17.....	1 "		
Total.....			
5 cases			

In December the first reported case was on the 15th. This case should not be included in the second epidemic, its onset having occurred before the cause of this outbreak had originated.

The individuals affected were according to sex and age as follows:

AGE AND SEX OF PERSONS AFFECTED IN FIVE-YEAR PERIODS, IN LONGER PERIODS, AND OF THOSE WHO DIED.

Numbers Affected in Five-Year Periods	Male	Female	Total	Age in Years	Percentage	
0 to 4.....	8	12	20	0 to 14.....	39.7	
5 to 9.....	20	32	52	10 to 29.....	67.3	
10 to 14.....	33	26	59	0 to 29.....	89.1	
15 to 19.....	38	34	72	30 to 69.....	10.9	
20 to 24.....	32	32	64	DEATHS		
25 to 29.....	16	11	27	Age	Male	Female
30 to 34.....	9	9	18	5.....	1	1
35 to 39.....	2	6	8	11.....	1	0
40 to 44.....	3	1	4	14.....	0	1
45 to 49.....	1	1	2	15.....	2	0
50 to 54.....	1	1	2	16.....	0	1
55 to 59.....	0	0	0	18.....	2	0
60 to 64.....	0	1	1	20.....	1	1
65 to 69.....	0	1	1	24.....	0	1
Totals.....	163	167	330	28.....	0	1
				29.....	1	0
				43.....	1	0
				53.....	1	0
				Total.....	10	6
				Mortality.....	4.85 per cent	

GEOGRAPHICAL DISTRIBUTION IN THE TWO EPIDEMICS OF TYPHOID FEVER.

Of all the cases reported and investigated which occurred during July, August, September, and October, 1911, about 84 per cent were in the district north of J Street and east of 14th Street. Of the

cases reported from July 1 to December 1, 1911, 76.5 per cent occurred in the area north of Randolph Street and east of 14th Street. Of the cases reported in the second epidemic from December 1, 1911, to March 1, 1912, 86 per cent occurred in this same area. The geographical distribution of cases alone would indicate that the cause of the trouble was definitely localized. Since the second epidemic occurred in the winter months, contact, flies, etc., played a lesser rôle than they did in the first epidemic and hence we have a larger percentage confined to the area bounded on the south by Randolph Street and on the west by 14th Street.

#### SOURCE OF INFECTION.

On the 18th of December, 1911, samples of water were collected from 1619 R Street, 1645 R Street, 2109 Q Street, 2625 P Street, and from the Rice well which is located between 23d and 24th Streets near N Street. All of these samples contained colon bacilli in 10 cubic centimeter amounts and that from 1619 R Street in one cubic centimeter. Never before in the numerous examinations of samples of water from the Rice well had the colon bacillus been encountered. A search was made to find out if possible where the contamination came from and it was discovered that water was being discharged into the well from a six-inch pipe situated a little north of west in the wall of the Rice well about 15 feet below the surface. Samples taken directly from this pipe showed gross pollution. No information could be obtained as to where this pipe came from and for what purpose it entered the well.

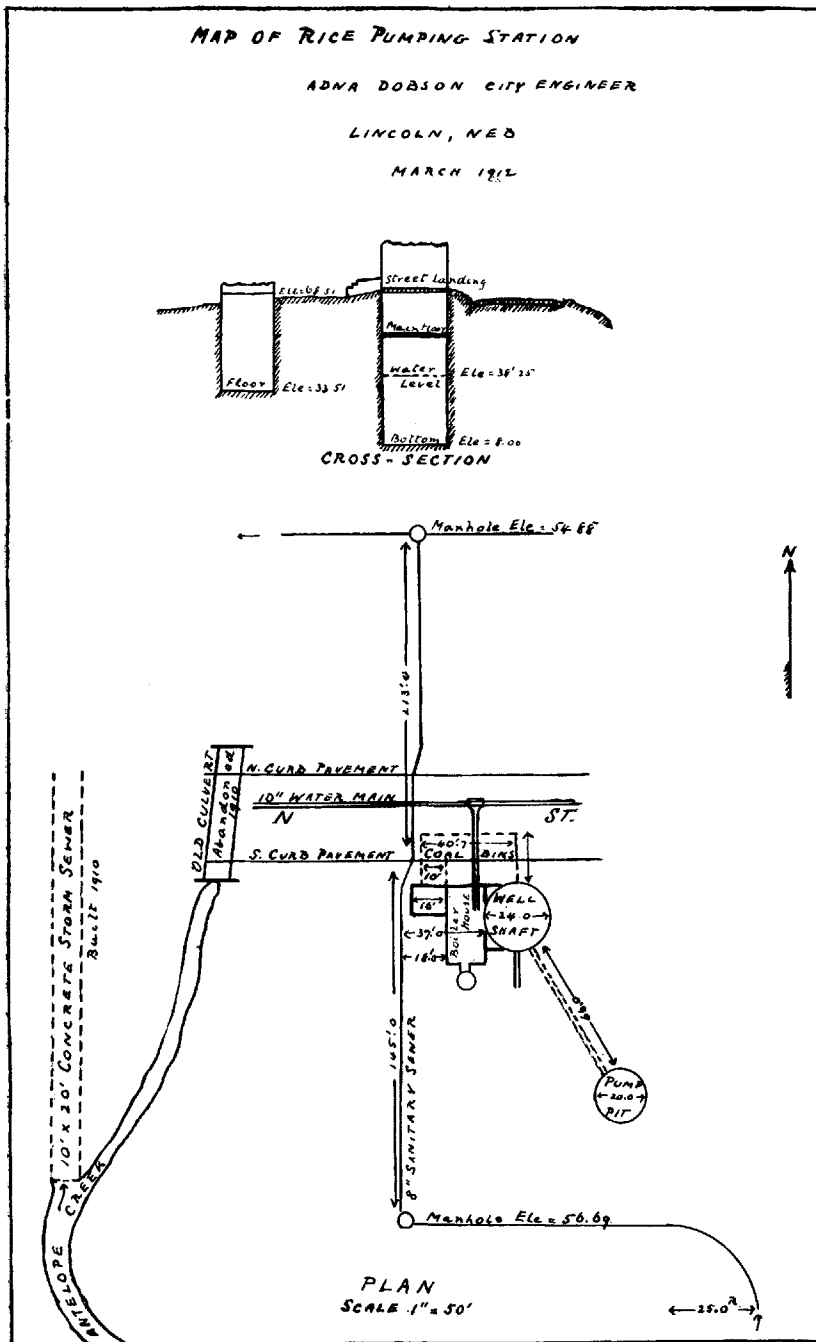
On December 20, it was found that this pipe was certainly the main source of contamination of the Rice well, and the latter was permanently abandoned as a source of water supply. A large part of the wall of the well was moist, the moisture being due to seepage; though at no place was there enough trickling to obtain a sample of the seepage water.

On December 21, excavation was begun for the purpose of ascertaining the whereabouts of the pipe outside the well through which polluted seepage was entering. It was found to end about 14 or 15 feet outside the well. The end outside the well was open. Earth had entered this open end for a few inches, otherwise the

inside of the pipe was clear. Samples of water taken from the seepage which collected at the open end as well as along the pipe showed evidence of gross pollution. Notwithstanding the fact that the water level toward the west was apparently lower than the open end of the pipe outside the well, suspicion was aroused that the seepage water which collected around the open end of the pipe outside the well might come from the sewer which ran from south to north on the west side of the well. This sewer pipe was at a distance of only 37 feet from the wall of the well and consequently only 22 or 23 feet from the open end of the pipe which entered the well. Besides this sewer there were other things in the immediate surroundings of this well of a very objectionable character. At a relatively short distance from this well to the south and east there is a low spot which the city has been filling with street sweepings for a considerable period of time. It has also served as a dumping-ground for other refuse. In the immediate vicinity of this dumping-ground there are still a number of open privies in use at the present time. Rain water or water from any other source not only might but probably would carry material from this dumping-ground and from these privies into the well.

The combined rainfall of December 9 and 10 was 1.40 inches. It is highly probable that this precipitation was the chief cause which brought about the contamination of the Rice well. At no time when the investigation of the water was being made from August 29 to December 18 was anything of a suspicious character found in the Rice well. Why contamination did not occur after some of the heavy rainfalls during August, September, October, and November is difficult to explain.

At the time the first sample of water was taken from the pipe which was contaminating the Rice well it was estimated that the amount of seepage which was entering the well through this pipe was one quart per hour. This estimated amount was determined from the amount which was actually collected and measured after an interval of 10 minutes, on December 19. The amount was certainly greater on the 19th than it was on any subsequent date and it was probably much greater in amount on the days immediately following the rainfall of December 9 and 10.



Early in the investigation of the first epidemic the treatment of the water in the mains by the hypochlorite method was advised, since colon bacilli were continuously present in samples of water collected from faucets. This advice was not accepted at this time. Instead of this, after considerable discussion, the Council directed the water commissioner to open up the water hydrants for the purpose of flushing out the mains. This was done about December 21. The number of colon bacilli in the water mains began to diminish after the closure of the Rice well. It is probable that the flushing contributed to some extent in the lessening of the numbers of colon bacilli in the mains but the factor which contributed to the greatest extent was certainly the abandonment of the Rice well.

The following is from the report of Mr. George W. Fuller, the data for which were obtained by Mr. James C. Harding:

*"Sterilization of A well.*—In the latter part of December Mr. H. A. Whittaker, of Minneapolis, arrived at Lincoln at the request of Mayor Armstrong and installed temporary devices for the introduction of hypochlorite of lime into the water of the A well.<sup>1</sup>

*"Pollution of Rice well.*—As stated, there is an eight-inch sewer leading directly through the water works grounds and within about 30 feet of this well. Examinations of the manholes of this sewer line indicated that at some previous time sewage had risen in the manhole in the alley between N and O Streets to a point some two feet above the top of the sewer. The records in the sewer office were looked over and it was found that a stoppage had occurred on this sewer below this manhole on December 12 and 13. With the assistance of the engineering and sewer departments this sewer was blocked at the manhole and the sewage allowed to rise until it reached the ring of grease and other matters left there by the earlier stoppage of December 12 and 13. An excavation was made inside the areaway leading to the boiler house.

"A short time after the sewage had reached the level above indicated it was seen to enter this excavation from the side next to the sewer. Later two joints of this sewer were uncovered. It was found that they leaked in both cases, giving an opportunity for sewage to escape into the surrounding earth. To the south of the excavation the pipe had apparently been laid on firm material, but to the north of this point it was laid on filling composed mostly of cinders and ashes. There was apparently a slight settlement at one of these joints, and here the earth had been washed away, showing that at some time considerable sewage had leaked out from the pipe at this point.

"Whether or not there are other joints which are in the same condition, we do not know, but it is quite likely that this may be the case. It is also possible that sewage may find its way out of the sewer pipe at the offset made in the sewer just north

<sup>1</sup> Mr. Whittaker arrived in Lincoln at 5:45 P.M., January 15, 1912. The administration of hypochlorite was begun on January 17, 1912. The temporary device which was installed at that time was in no way essentially different from the device which has been in continuous operation since it was installed in January up to the present date, September 1, 1912.

of the wall of the coal chamber. In any event it was apparent that sewage could leak from faulty sewer joints within two feet of the wall of the boiler room areaway.

"Excavations were then made to determine if possible by what route this sewage found its way into the well. It was found that just east of the areaway wall there had been in the past a hydraulic hoist for raising the ashes out of the coal chamber. At the time the sewer was blocked on January 24, 1912, this chamber was found to be filled with sewage. From this chamber there was a drainpipe leading into a small manhole near the corner of the boilers. At the time of the investigation the end of this pipe was plugged in the hoist chamber. Whether or not this was the case during August and December, we do not know. But regardless of this there was a reasonably direct passage for the sewage either through this pipe or through the trench in which the pipe was laid along the south wall of the areaway. From the manhole spoken of above there were numerous ways in which the sewage could find ready entrance to the well. There was an abandoned 10-inch drainpipe from this manhole which formerly took the waste water from some sinks located in the boiler house. Directly below this pipe was a six-inch pipe open at both ends and leading directly into the well.

"There was also apparently a free passage beneath the boilers and along the boiler wall to a chamber beneath the end of the east boiler and one side of which was formed by the masonry wall of the well. From this chamber there were four small pipes which led directly into the well. The masonry around the discharge pipe which passes into this chamber was also in poor condition and would also easily admit the passage of sewage. There were also other pipes, used at the time the plant was steam-operated, which have been buried in the ground and long since forgotten.

"That there were many opportunities for the sewage to reach the well was readily apparent, and it was not thought necessary to go further into the matter. Later, if desired, after the frost is out of the ground, it might be possible to block the sewer in the same manner as previously done, and the course of the sewage could perhaps be determined in precise detail.

#### CONCLUSIONS AS TO DECEMBER EPIDEMIC.

"The epidemic of typhoid fever during December, 1911, and January, 1912, can be definitely attributed to the following rather remarkable combination of circumstances, the absence of any one of which might have prevented the trouble:

"On December 9 and 10 there was a rainfall of 1.40 inches, the first of any importance since October 12, when there was a rainfall of 0.92 inch. On December 12 and 13 the sewer passing the well was working under a head, owing to a stoppage in the sewer below. This sewer has at least two faulty joints where the pipe adjoins the west wall of the areaway. The sewage leaking from these joints found its way through the ash hoist chamber and from there through pipes or other routes to the well.

"*August pollution.*—From the appearance of the soil surrounding the sewer joints examined, it was evident that there had been leakage of the sewage in small quantities for some time. The joints were unusually well made, but their condition would indicate that owing to the extreme cold weather at the time this sewer was laid (December, 1910) some of the mortar in the bottom of the joints fell out before the cement had thoroughly set.

"On August 2, 3, and 4, 1911, there were heavy rainfalls which filled the hollow just south of the well to a point somewhat higher than the manhole located at the angle in the sewer line at this point. There is no outlet to this hollow, except as the

water may follow the sewer trench previously referred to or by percolating through the ground. Probably the water during these rain storms followed both courses. Whether the pipe leaked before this time or whether the water following along the trench caused the settlement of the sewer at this time, we do not know.

*"Infection of sewage.*—It was not only necessary to determine that the sewage found its way into the Rice well, but it was also necessary to prove beyond reasonable doubt that there were typhoid bacilli in the sewage. As to the last epidemic, there could be no question but that this condition existed, as there were at least nine authentic cases reported on these sewer lines. For the first epidemic, however, the Health Department had no records as to typhoid in this district, as it has only been during the last six months that the physicians have been compelled by the Health Department to report all cases of typhoid of which they had knowledge. On the request of Mr. Harding the Health Department made a house-to-house canvass of the entire district which drained into the sewer system leading past the well. The result of this canvass proved conclusively that there were typhoid patients in houses connected with this sewerage system."

#### RESULTS OF THE EXAMINATIONS OF THE CITY WATER FROM DECEMBER 18 TO DECEMBER 28, 1911.

It had been intended to incorporate in this record the result of all the examinations of city water made from December 18, 1911, up to and including the time when hypochlorite was first introduced into the water mains. Through accident the record for the first half of the month of January, 1912, was lost. In general it agreed with that for the latter part of December, 1911, the only difference being that the degree of contamination became continuously less. (See table on p. 33.)

#### HYPOCHLORITE TREATMENT OF THE CITY WATER SUPPLY.

On the 15th of January, 1912, Mr. H. A. Whittaker, chemist and bacteriologist of the Minnesota State Board of Health, arrived in Lincoln in response to a request received from A. H. F. Armstrong, mayor of the city of Lincoln, to treat the water with the hypochlorite method.

The quotation is from Mr. Whittaker's report to the mayor and City Council of the city of Lincoln.

#### INSTALLATION OF THE EMERGENCY PLANT.

"The place selected for installing the plant and administering the hypochlorite was the A Street pumping-station, since a large proportion of the water was distributed from this source. The F Street station at this particular time was used only intermittently and furnished a small part of the city supply. It was therefore assumed that during the

RESULTS OF THE EXAMINATIONS OF THE CITY WATER FROM DECEMBER 18 TO  
DECEMBER 28, 1911.

SOURCE	DATE OF EXAMINA- TION	NUMBER OF BACTERIA PER CUBIC CENTI- METER ON AGAR, AFTER 48 HOURS, INCUBATION AT 37.5° C.	GAS IN LACTOSE BROTH FROM		<i>B. coli</i> IN	
			I C.C.	10 C.C.	I C.C.	10 C.C.
2625 P Street.....	Dec. 18	2	—	+	—	+
2109 Q ".....	" "	4	—	+	—	+
1619 R ".....	" "	10	+	+	+	+
1645 R ".....	" "	3	—	+	—	+
Rice well.....	" "	20	—	+	—	+
2144 B Street.....	" 19	4	—	—	—	—
A Street well.....	" "	15	—	—	—	—
East faucet A Street well.....	" "	4	—	+	—	—
F Street well.....	" "	3	—	—	—	—
Drip from lower platform in Rice well.....	" "	{ Colon 3,550	+	+	+	+
Pump at Rice well.....	" "	{ Colon 300	—	—	—	—
Exhaust pipe in Rice well.....	" "	{ Colon 40	+	+	+	+
Laboratory faucet.....	" "	{ Colon 17	—	+	—	—
1811 L Street.....	" 20	{ Colon 130	—	—	—	—
Rice well.....	" "	{ Colon 20	+	+	+	+
Exhaust pipe in Rice well.....	" "	{ Colon 1	+	+	+	+
Seepage in soil outside Rice well. . .	" 21	{ Colon 100	+	+	+	+
Seepage inside near old engines of Rice well.....	" "	{ Colon* 375	+	+	+	+
Seepage in coal room.....	" "	No plates	—	—	—	—
Exhaust pipe in Rice well.....	" "	{ Colon 10	+	+	+	+
216 North 26th Street.....	" "	{ Colon 6	—	+	—	+
2715 R Street.....	" "	{ Colon 1	—	+	—	+
2727 P ".....	" "	{ Colon 2	—	+	—	—
2701 P ".....	" "	{ Colon 5	—	+	—	—
170 South 28th Street.....	" "	{ Colon 4	—	+	—	+
3090 R Street.....	" "	{ Colon 1	—	+	—	—
Outer end of pipe outside Rice well..	" "	{ Colon* 3,550	+	+	+	+
430 North 26th Street.....	" 27	{ Colon 10	+	+	+	+
558 " ".....	" "	{ Colon 2	—	+	—	+
2509 Vine Street.....	" "	{ Colon 0	—	+	—	—
2346 " ".....	" "	{ Colon 0	—	+	—	+
2212 " ".....	" "	{ Colon 0	—	—	—	—
320 North 26th Street.....	" "	{ Colon 0	—	—	—	—
337 South " ".....	" 28	{ Colon 1	+	+	+	+
403 " ".....	" "	{ Colon 4	—	+	—	+
235 " ".....	" "	{ Colon 6	—	+	—	+
2332 N Street.....	" "	{ Colon 2	—	+	—	+
205 South 25th Street.....	" "	{ Colon 2	—	+	—	+

\* Too numerous to count in 1 c.c. of water. Colon colonies counted from cultures grown on separate lactose, litmus agar plates. Colonies producing both gas and acid on these plates were considered colonies of the *B. coli*.

periods the F Street station was not in operation the treated water from the A Street station would reach a large portion at least of the section supplied from the F Street station. Furthermore, bacteriological examinations showed the absence of contamination at the two sources and its presence only in the distribution system on dates just preceding the date of installation of this plant.

"With the assistance furnished by the officials through the various municipal departments, the emergency plant was installed and began to administer chemical at 3:00 P.M., January 17.

"In the emergency disinfection of public water supplies it is advisable to add more hypochlorite or chloride of lime than would ordinarily be used for a continuous treatment of the same water. This excess amount prolongs the disinfecting power of the chemical in solution, thereby destroying the vegetative forms of bacteria in parts of the system remote from the point of addition. Such addition, although harmless, often causes odor and taste in the water, such as was true in Lincoln, especially during the first few days of treatment. In confining the treatment to the destruction of organisms at the point of addition, much smaller quantities can be used which should not give rise to a disagreeable odor and taste. This point is mentioned here to make clear the fact that strong odor and taste is not usually necessary where a continuous treatment is applied.

"Table 1 gives a record of the amount of chemical added to the water each day the work was under my supervision. The term 'available chlorine' is used in the table to designate the active part of the chemical or that present in the form of hypochlorite. These figures represent the amounts as closely as could be determined under existing conditions. As indicated by the table, the amount of chemical applied was reduced considerably during the period of the treatment, as it was found that good results could be secured with less hypochlorite. On January 23 the amount of chemical was reduced to one-half of the amount indicated on the last date mentioned in the table. As the previous treatment had shown such excellent results and the bacteriological examinations were to be continued on the water, it was considered safe to reduce the amount to this point and thus eliminate the odor and taste as much as possible.

TABLE 1.  
AMOUNT OF CHEMICAL ADDED TO THE WATER.

DATE	GALLONS OF WATER PUMPED	POUNDS PER MILLION GALLONS		AMOUNT OF AVAILABLE CHLORINE ADDED	
		Chemical	Available Chlorine	Grains per Gallon	Parts per Million
3:00 P.M. to 3:00 P.M.					
Jan. 17 to Jan. 18.....	3,312,925	25.9	7.4	0.049	0.84
" 18 " 19.....	3,270,556	20.6	5.9	.039	.68
" 19 " 20.....	3,313,676	16.0	4.5	.030	.52
" 20 " 21.....	3,066,184	17.2	4.9	.032	.56
" 21 " 22.....	3,124,520	16.4	4.7	.031	.54

#### BACTERIOLOGICAL CONDITION OF WATER BEFORE AND AFTER TREATMENT.

"In order to understand clearly the bacteriological results, it will be necessary to outline briefly the methods used in carrying out this work. The samples of water examined were collected from flamed taps, either in bottles or flasks especially sterilized for that purpose. The medium used was made in accordance with the standards prescribed by the Laboratory Section of the American Public Health Association for the bacteriological examination of water. The bacterial counts were made on plates incubated at room temperature or at 37.5° C. for 48 hours. The presumptive test for *B. coli* consisted in inoculating the stated amount of water into lactose broth, the total absence of gas formation at the end of 48 hours' incubation at 37.5° C. being considered a negative test for *B. coli*. Such tubes as showed gas were plated on litmus, lactose agar, and incubated for 24 hours at 37.5° C., the absence

of red colonies being also considered a negative test for *B. coli*. These samples stated as positive for *B. coli* showed gas formation and also gave red colonies on litmus, lactose agar. As from 10 to 14 days is required to isolate and identify the colon organisms, it was impossible to make complete examinations on these samples giving positive presumptive tests.

"Before taking up the discussion of the results, I wish to state that a large share of the bacteriological work was done in co-operation with Dr. H. H. Waite, who at all times rendered me valuable assistance.

"In order to determine analytically whether or not indications of contamination were present in the system, samples were collected from various parts of the city before chemical treatment of water was commenced. These results are tabulated in detail in Table 2 attached to this report.

"Samples 1 to 12 inclusive were collected on January 17 before the chemical was added or had time to affect the water in the system. As indicated by these results, presumptive tests for *B. coli* were obtained on samples 2 and 5 in 1 c.c. amounts and on samples 1, 3, 4, 6, 9, 10, 11, and 12 in 10 c.c. amounts.

"The bacterial counts on the samples just mentioned are relatively low, yet the indication of *B. coli* in this low count points analytically to the bacteria present being largely of fecal origin. An opinion based on the presumptive test for *B. coli* shows the presence of contamination at the points mentioned in the system before treatment began. Attention should be called to sample 7 from the A street well and sample 8 from the F Street well, which show the absence of *B. coli* in 100 c.c. amounts and the total absence of bacteria in 1 c.c. plates made for the bacterial count. This fact is significant, as it indicates that on the date these samples were collected the infection appeared to be in the distribution system, but not in the wells.

"Samples 13 to 48 inclusive, collected after the chemical had been added to the water, show the total absence of bacteria in 1 c.c. amounts in most of the samples collected, and the presumptive test for *B. coli* did not indicate the presence of this organism in 100 c.c. amounts. These samples, as Table 2 indicates, were distributed quite thoroughly over the entire distribution system, and an attempt was made to collect samples from dead ends after flushing to determine if the infection had been removed from these remote parts of the system.

"It is interesting to note that the contamination on January 17, in samples 1, 2, 3, 4, 5, 6, 9, 10, 11, and 12, had entirely disappeared on January 18 about 24 hours after treatment had begun, as shown by samples 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, and 24, collected from the same points on the system. These results would justify the opinion that the distributing system had been freed from all evidences of contamination at these points. The results obtained from the examination of 24 additional samples, 25 to 48 inclusive, from other points scattered widely over the system, justified this assumption.

#### CONCLUSION OF RESULTS ON TREATMENT OF THE WATER.

"It was decided, on the basis of the excellent bacteriological results secured by treatment of the city water by hypochlorite, that it was unnecessary for me to remain in Lincoln. The permanent safety of the wells seemed to be questionable as judged from local data, and it appeared best to leave the emergency plant in operation until such a time as the city could replace this plant or be assured that the city wells could be depended upon to furnish a water of safe sanitary quality.

"On January 22 I appeared before the City Council and explained the work which had been done during the week and stated that the disinfection work on the system was practically completed.

TABLE 2.  
BACTERIOLOGICAL CONDITION OF WATER BEFORE AND AFTER TREATMENT.

NUMBER	COLLECTED		SOURCE	BACTERIA PER C.C.		PRESUMPTIVE TEST FOR <i>B. coli</i>		
	Date	Hour		R.T.*	37.5° C.	1 C.C.	10 C.C.	100 C.C.
1.....	I-17-12	11:30 A.M.	635 S. 29th Street	..	0	0	+	+
2.....	"	11:45 A.M.	149 S. 29th "	..	1	+	+	+
3.....	"	11:55 A.M.	2839 R "	..	7	0	+	+
4.....	"	12:10 P.M.	2501 R "	..	45	0	+	+
5.....	"	12:20 P.M.	2110 R "	..	8	+	+	+
6.....	"	1:30 P.M.	2144 B "	..	0	0	0	+
7.....	"	2:00 P.M.	A Street well	..	0	0	0	0
8.....	"	3:00 P.M.	F Street well	..	0	0	0	0
9.....	"	3:10 P.M.	843 S. 10th Street	..	2	0	+	+
10.....	"	3:30 P.M.	1408 F "	..	2	0	+	+
11.....	"	3:40 P.M.	1537 F "	..	2	0	+	+
12.....	"	4:30 P.M.	Laboratory faucet	..	0	0	+	+
13.....	I-18-12	11:30 A.M.	709 S. 29th Street	0	..	0	0	0
14.....	"	11:35 A.M.	635 S. 29th "	0	..	0	0	0
15.....	"	11:45 A.M.	149 S. 29th "	0	..	0	0	0
16.....	"	12:10 P.M.	2839 R "	0	..	0	0	0
17.....	"	12:20 P.M.	2501 R "	0	..	0	0	0
18.....	"	12:30 P.M.	2110 R "	0	..	0	0	0
19.....	"	1:30 P.M.	2144 B "	0	..	0	0	0
20.....	"	2:00 P.M.	A Street well	0	..	0	0	0
21.....	"	2:30 P.M.	1537 F Street	0	..	0	0	0
22.....	"	2:45 P.M.	1408 F "	0	..	0	0	0
23.....	"	3:00 P.M.	F Street well	1	..	0	0	0
24.....	"	3:15 P.M.	Laboratory faucet	0	..	0	0	0
25.....	I-19-12	4:30 P.M.	17th and A Streets	0	0	0	..	0
26.....	"	4:35 P.M.	17th and A "	12	4	0	..	0
27.....	"	4:50 P.M.	29th and Randolph "	0	0	0	..	0
28.....	"	4:50 P.M.	14th and G "	0	0	0	..	0
29.....	"	5:00 P.M.	35th and P "	0	0	0	..	0
30.....	"	5:15 P.M.	27th and R "	0	0	0	..	0
31.....	"	5:25 P.M.	35th and T "	0	0	0	..	0
32.....	"	5:40 P.M.	30th and Oak "	0	7	0	..	0
33.....	"	5:45 P.M.	27th and Hitchcock "	2	28	0	..	0
34.....	"	5:50 P.M.	23d and Holdredge "	3	1	0	..	0
35.....	I-20-12	3:15 P.M.	9th and Wood "	0	0	0	..	0
36.....	"	3:45 P.M.	14th and Marion "	0	0	0	..	0
37.....	"	4:10 P.M.	26th and South "	0	0	0	..	0
38.....	"	4:20 P.M.	33d and Vine "	0	0	0	..	0
39.....	"	4:25 P.M.	27th and Holdredge "	0	0	0	..	0
40.....	"	4:35 P.M.	25th and T "	0	0	0	..	0
41.....	"	4:40 P.M.	445 S. 25th Street	0	0	0	..	0
42.....	"	4:45 P.M.	25th and Q Streets	0	0	0	..	0
43.....	"	5:00 P.M.	25th and O "	0	0	0	..	0
44.....	"	5:05 P.M.	25th and N "	0	0	0	..	0
45.....	"	5:10 P.M.	25th and M "	0	0	0	..	0
46.....	"	5:15 P.M.	22d and Vine "	0	0	0	..	0
47.....	I-21-12	5:35 P.M.	30th and Oak "	0	0	0	..	0
48.....	"	5:45 P.M.	1805 N. 30th Street	0	0	0	..	0

\*R.T. indicates room temperature.

The (+) sign indicates a positive and the (o) sign a negative presumptive test for *B. coli*.

"On January 23 arrangements were made for leaving the plant under the supervision of local authorities in immediate charge of men trained for this purpose during my stay in Lincoln.

#### RECOMMENDATIONS.

"1. Since the hypochlorite treatment of the city water of Lincoln has proven so efficient in removing the indicated infection from the system, I recommend that the

treatment be continued as long as there is any doubt concerning the sanitary quality of the water furnished from the various sources of supply.

"2. I recommend that daily bacteriological examinations be made of the city water to check the hypochlorite treatment and that frequent examinations should be continued in case chemical treatment is stopped, in order to immediately indicate subsequent contamination.

"3. I recommend that the amount of chemical added to the water be maintained at a point having a reasonable factor of safety to care for unforeseen contaminations.

"In concluding this report I wish to express my sincere thanks to the mayor and City Council for their support and confidence during the prosecution of this work. I wish to express my appreciation to the heads of the municipal departments for their efficient help and for the courtesy and assistance of their subordinates. I am much indebted to the University of Nebraska for placing at my disposal . . . the laboratories in which the bacteriological work of this report was conducted."

(Signed) H. A. WHITTAKER

During the past six months there have been reported at the health office of the city of Lincoln 11 cases of typhoid fever. There is every reason to believe that a greater number of cases than have been reported has not existed in the city during this interval. Only one death from typhoid fever has been reported. The cause of death in this instance was very probably not typhoid fever.

The following table gives the number of cases reported as typhoid fever, by months, as recorded at the city health office from March 1, 1912, to September 1, 1912:

CASES REPORTED AS TYPHOID FEVER, BY MONTHS, FROM MARCH 1, 1912, TO  
SEPTEMBER 1, 1912.

March	April	May	June	July	August	Total
2	2	1	1	3	2	11

It is highly probable that this number would have been much greater had not the use of the Rice well been discontinued. The continuous use of hypochlorite may also have had something to do in diminishing the number of reported typhoid fever cases.

In conclusion I wish to thank Mr. John J. Putnam for the assistance which he gave me while making these investigations. I wish also to acknowledge my obligations to Dr. L. L. Lumsden, passed assistant surgeon, Public Health and Marine Hospital

Service, to Mr. H. A. Whittaker, chemist and bacteriologist to the Minnesota State Board of Health, and to Mr. James C. Harding. From the report of the latter I have obtained much of my engineering data. Dr. Lumsden's report of the first epidemic has furnished me much valuable material. The description of the installation and operation of the hypochlorite plant has been taken almost verbatim from Mr. Whittaker's report to the Lincoln City Council.