Contamination of Water Supplies in Limestone Formation

By S. P. Kingston

FOR many years the Minnesota Department of Health has recognized the dangers associated with obtaining water supplies from wells and springs situated in limestone formations. The *Manual of Water Supply Sanitation* of the Department contains the following statement: "There is common belief that contamination may seep through the soil for long distances and get into a well in this way, but such is not generally true in Minnesota although it should always be considered a possibility." The possibility exists in a portion of southeastern Minnesota where cavernous and fissured limestone formations lie relatively close to the ground surface, particularly at higher elevations.

In that portion of Minnesota (Fig. 1) where limestone formations are situated close to the ground surface, special precautions must be taken to protect ground water supplies from underground contamination. The black portion of the map (Fig. 1) indicates an area in which sinkholes predominate. The sinkholes are generally situated over the Galena limestone formation and are nothing more than openings or broken down spots in the

loam or drift that connect directly to the limestone (Fig. 2, 3). They allow surface drainage, and in many cases domestic sewage and industrial waste, to enter the limestone. The sinkholes vary in diameter and depth from a few feet to over 100 ft.

The vertical and horizontal channels of the limestone quarry, indicate how easily contamination can travel great distances in the rock. In many cases contamination can, and has, entered municipal and private water supply systems.

A Typhoid Fever Outbreak

A little over five years ago, District No. 3 of the Minnesota Department of Health was organized with headquarters at Rochester. It was obvious at that time that one of the problems to be given special study was the possible contamination of municipal and private water supplies situated in the limestone area. Particular emphasis was given to the study when eleven cases of typhoid fever and one death occurred during the summer and fall of 1939 and the spring of 1940, in and adjacent to a village in Fillmore County (Fig. 4).

The first three cases developed at a farm in the southern portion of the village. The water supply for this farm was obtained from the village

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water supply system and from a drilled well situated on the farm. The farm well which may be designated as well "A" was apparently cased only to the

FIG. 1. Limestone and Sinkhole Area

first rock formation. This provided no protection from underground contamination.

A few weeks later five cases of typhoid fever occurred in the village. All of these persons had been using water supplied by the municipal system. The municipal supply is taken from two drilled wells which are designated as the old and new municipal wells. The old well is approximately 270 ft. deep and is cased only to the first rock formation. The new well is 1126 ft. deep and is cased to a depth of 400 ft. with 10-in. casing, to 340 ft. with 12-in. casing and to 20 ft. with 16-in. casing. All are cement-grouted in place for the purpose of excluding underground and surface contamination (Fig. 5).

In the spring of 1940, three more cases of typhoid fever occurred at a farm situated about two miles north-

west of the village. The water supply for this farm was obtained from a drilled well cased only to the first rock formation. This well is designated as well "B" (Fig. 4).

At the time the typhoid fever cases occurred it was known that the village was discharging partly treated sewage into a sinkhole situated about 1500 ft. south of well "A" and 4000 ft. south of the municipal wells.

A complete epidemiological investigation disclosed no typhoid fever carriers with whom any of the cases had been in contact and no common vector other than the water supplies was found. However, the public health engineering work done in connection with the investigation revealed the following facts:

(a) Fluorescein dye (about three pounds) was introduced into the sinkhole receiving approximately 60,000 gpd. of partly treated sewage from the village. Periodic sampling was carried out at wells "A" and "B," and the two municipal wells. Within four hours the fluorescein dye appeared in water samples collected from well "A," a distance of approximately 1500 ft. from the sinkhole. However, no indica-

FIG. 2. Typical Sinkhole

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tions of the dye were obtained from the samples of water collected from well "B" or the municipal wells. Bacteriological examination of water samples collected from well "A" showed a maximum concentration of 900,000 coliform organisms per 100 ml. as determined by the most probable number test.

(b) Just previous to the onset of the typhoid fever cases in the village, the

FIG. 3. Limestone Quarry

old municipal well had been used during an emergency. All bacteriological samples collected from the old well, over a period of several months, contained coliform organisms with a maximum concentration of 1600 per 100 ml. At no time was any contamination found in the water obtained from the new municipal well.

(c) Bacteriological examination of samples obtained from well "B"

showed a maximum concentration of 92,000 organisms per 100 ml. In addition, typhoid organisms (*Eb. typhosis*) were isolated directly from 20-gal. water samples collected from the well. This indicated that excreta from a typhoid case or carrier were getting into the well. However, the investigation did not reveal the exact location at which domestic sewage was entering the limestone formations.

The foregoing engineering findings indicate that the eleven typhoid fever cases probably were water-borne and that infectious organisms had been transmitted through the cavernous and fissured limestone formations. Engineering recommendations were made to the municipality and to the individuals affected, as to methods of providing satisfactory water supplies and proper methods of sewage disposal.

Investigation of Farm Water Supplies and Sewerage Systems

The field work in connection with the typhoid fever outbreak, indicated the desirability of investigating a large number of farm water supplies and sewerage systems in the township immediately adjacent to the village. This investigation was conducted during the summer of 1941. The principal objects were to discover additional sources of contamination that may have contributed to the typhoid fever outbreak; and to collect engineering data on each water supply system. A total of 145 investigations were made at 130 farms. A summary of this investigation revealed the following:

(1) The major portion of all water supplies was poorly constructed above and below ground surface. Well casings in general were terminated at the first rock formation, thus providing no

protection from surface contamination that might enter the limestone.

FIG. 4. Location of Wells, Typhoid Fever Cases, Sinkhole and Stone Quarry

(2) The bacteriological examination of 206 water samples collected during the course of the investigation showed 77 per cent of the supplies to contain coliform organisms; 20 per cent showed concentrations in excess of 100 organisms per 100 ml.; and 12 per cent were in excess of 1600 per 100 ml. In a few cases where it was possible to repeat sampling, there was an indication that the bacteriological counts increased after rains, showing that surface contamination was entering the wells.

(3) Approximately thirty-five of the farms were served with water-carriage toilet systems. Of these, 50 per cent were known to discharge sewage directly into the limestone formations, creating a serious hazard to the water supply for the farm, adjacent farms and municipalities.

(4) At a creamery, floor drainage was being discharged into a sinkhole approximately 150 ft. from the creamery well. Fluorescein dye (about 1 lb.) introduced into the sinkhole appeared in the well water within two hours, indicating a direct connection between the sinkhole and the well. It

is needless to say that bacteriological results on samples collected from this well showed the water to be grossly contaminated.

(5) In an attempt to locate the source of contamination for well "B" fluorescein dye was introduced into an opening in the stone quarry (Figs. 3, 4). The opening had been used as a place of excreta disposal by the quarry employees. Within less than six hours the fluorescein dye appeared in a large spring situated approximately 100 ft. from well "B" and 1600 ft. from the quarry. The spring had been used for a drinking water supply up until the time well "B" was constructed. While

FIG. 5. Section on Old and New Municipal Wells

the dye did not appear in well "B" it is possible that during heavy rains and spring thaws contamination from the stone quarry could enter well "B."

Contamination of Water Supply

Another very interesting case of water supply contamination occurred during the summer of 1942, at a large private residence in Olmsted County. The situation was brought to the attention of District No. 3 after several cases of gastro-enteritis developed in persons visiting the residence. The cases appeared to be of a water-borne nature.

Plans and specifications for the residence, completed in the fall of 1941, showed the proposed location of the well and specified only that a certain amount of water per minute be obtained. No other well specifications were given. The well driller provided a 6-in. well 198 ft. in depth, cased only 8 ft. into the Platteville limestone, thus giving very little protection from underground contamination.

The plans indicated a septic tank and leaching pit situated approximately 110 ft. from the well. The plumber installed the septic tank in the creviced Platteville limestone and to provide a method for final disposal of the effluent a leaching pit was blasted in the rock (Fig. 6).

FIG. 6. Platteville Limestone

The engineering investigation revealed the water supply to have an odor of organic matter, indicating the probability of sewage contamination from the leaching pit. Again fluorescein dye was used. About one pound of the dye was introduced into the leaching pit and in less than fourteen hours the well water turned a deep green, indicating a direct connection between the leaching pit and the well

(Fig. 7). This finding was substantiated by bacteriological results.

Immediate steps were taken to correct this situation. The use of this well was discontinued and a new drilled well was constructed (Fig. 8). The new well is 285 ft. deep and is cased with 8-in. casing to a depth of 145 ft. The 8-in. well casing was placed in a 16-in. drill hole and the annular space between the casing and the drill hole was filled with cement grout. A cast-iron sewer was provided for the effluent from the septic tank and a soil absorption system constructed in suitable soil about 250 ft. from the well. When all construction work was completed on the new well and sewerage system, the old well was filled with concrete and the old leaching pit filled with clay.

Contamination of Municipal Water Supply

The investigation of the contamination of water supplies situated in the limestone area, of course, included all of the municipal water supplies. Most of the municipal water supplies are obtained from deep wells but a few large springs are used. The springs are apparently subject to surface drainage through sinkholes, etc. This occurs during periods of heavy precipitation and spring thaws when the water becomes turbid and the concentration of coliform organisms increases. One very large spring, although not used for a municipal water supply, is clear during normal weather conditions but during periods of heavy rains becomes extremely turbid and occasionally straw and corn cobs appear in the water, indicating a direct connection to the ground surface.

In the spring of 1942 during an investigation made of a municipal water

supply derived from a typical limestone spring, it was reported that there had been several cases of gastro-enteritis during the preceding month, particularly during a period when the water had been turbid.

To confirm these reports a survey was made by visiting every fifth household in systematically selected sections of the village to determine the incidence of gastro-enteritis during the preceding month. Seventy-two households were visited and information obtained from 274 persons, or approximately 13 per

FIG. 7. Location of Well and Leaching Pit at Private Residence

cent of the population. The survey indicated that an outbreak of gastro-enteritis affected approximately 10 per cent of the population during a thirty-day period. Many of the individuals questioned associated their illness with the time when the water supply was turbid and unsatisfactory for domestic use.

Summary

The main purpose of this report has been to discuss some definite instances where municipal and private water supplies obtained from limestone formations, have been seriously contaminated,

and not to propose any detailed methods of correction. However, it is probably advisable to summarize the more salient features and to formulate broad corrective measures as follows:

(1) It is obvious that there is real danger of underground contamination of municipal and private water supplies situated in the fissured and cavernous limestone area of southeastern Minnesota. This is borne out by the fact that on four separate occasions underground sewage flow was traced, with the aid of fluorescein dye, up to

FIG. 8. Section of Old and New Wells at Private Residence

a maximum distance of 2000 ft. and in every case the dye was recovered from a water supply that had been used for drinking purposes. In connection with a typhoid fever outbreak it was possible to isolate pathogenic organisms (*Eb. typhosis*) directly from a well water supply.

(2) A very large portion of farm or private water supplies are of unsatisfactory construction and are further endangered by the practice of discharging sewage directly into the limestone formations.

(3) In the development of under-

ground water supplies great care should be exercised in the selection of well locations, the use of impervious overlying geological strata and special structural features to exclude underground contamination. Municipal water supplies should be provided with subsequent treatment as required.

(4) Water supplies that are obtained from springs in the limestone formations should be considered as surface water supplies and be provided with adequate treatment.

(5) The practice of discharging sewage into the limestone formations should be eliminated.