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Outbreak of Acute Fluoride Poisoning Caused by a Fluoride Overfeed, Mississippi, 1993

Alan D. Penman, MBChB MSc
Bruce T. Brackin, MPH
Randal Embrey

At the time of this study, Dr. Penman, an Epidemic Intelligence Service Officer with the Centers for Disease Control and Prevention (CDC), was assigned through CDC's Division of Field Epidemiology to the Bureau of Preventive Health, Mississippi State Department of Health, Jackson; he is currently with the Division of Adult and Community Health, CDC, Atlanta. Mr. Brackin and Mr. Embrey are with the Mississippi Department of Health, Jackson. Mr. Brackin is the Deputy State Epidemiologist in the Bureau of Preventive Health, and Mr. Embrey is the Director of the Monitoring, Training and Certification Branch, Division of Water Supply, Bureau of Environmental Health.

Address correspondence to Dr. Penman, c/o Office of Community Health Services, Mississippi State Health Dept., 2423 North St., Jackson MS 39215; tel. 601-960-7725; fax 601-354-6061; e-mail <adp2@cdc.gov>.

SYNOPSIS

Objective. To determine the extent and confirm the cause of an August 1993 outbreak of acute fluoride poisoning in a small Mississippi community, thought to result from excess fluoride in the public water supply.

Methods. State health department investigators interviewed patrons of a restaurant where the outbreak first became manifest and obtained blood and urine samples for measurement of fluoride levels. State health department staff conducted a random sample telephone survey of community households. Public health environmentalists obtained water and ice samples from the restaurant and tap water samples from a household close to one of the town's water treatment plants for analysis. Health department investigators and town water department officials inspected the fluoridation system at the town's main water treatment plant.

Results. Thirty-four of 62 restaurant patrons reported acute gastrointestinal illness over a 24-hour period. Twenty of 61 households that used the community water supply reported one or more residents with acute gastrointestinal illness over a four-day period, compared with 3 of 13 households that did not use the community water supply. Restaurant water and ice samples contained more than 40 milligrams of fluoride per liter (mg/L), more than 20 times the recommended limit, and a tap water sample from a house located near the main treatment plant contained 200 mg/L of fluoride.

An investigation determined that a faulty feed pump at one of the town's two treatment plants had allowed saturated fluoride solution to siphon from the saturator tank into the ground reservoir and that a large bolus of this overfluoridated water had been pumped accidentally into the town system.

Conclusions. Correct installation and regular inspection and maintenance of fluoridation systems are needed to prevent such incidents.

According to the 1992 Fluoridation Census, a survey conducted by the Centers for Disease Control and Prevention (CDC) for the purposes of determining the status of water fluoridation in the United States, fluoridated drinking water is currently provided to approximately 145 million people in 10,496 communities in the United States. All but 10 million of these people use public water supplies in which the fluoride level is adjusted to the CDC standard of 0.7 mil-

ligrams per liter (mg/L) to 1.2 mg/L (Personal communication, Thomas G. Reeves, MS PE, Division of Oral Health, National Center for Prevention Services, CDC, Atlanta). The remaining 10 million people have naturally high levels of fluoride in their water.

Fluoridation has been credited with a 45% to 94% reduction in the prevalence of dental caries in children since it was first introduced in this country in 1945.[1]

According to Reeves, fluoride overfeed incidents resulting in illness are relatively infrequent. Only four reports have been published of community outbreaks of acute fluoride poisoning resulting from overfluoridation of public water supplies.[2–5] Nevertheless, concern remains about the safety of fluoridated water.

This report describes an outbreak of acute fluoride toxicity in August 1993 in a small Mississippi community. The initial signs and symptoms of those affected were unusual and potentially misleading; however, prompt action by local town officials and state health personnel detected the incident, which could easily have been overlooked.

Background

The August 1993 outbreak of acute fluoride poisoning occurred in a small, relatively isolated rural community in southwest Mississippi with a population of 2600. The outbreak first came to the attention of the local health department when 14 people reported to the treatment room of the local hospital between 9 p.m. and 10 p.m. on August 10 with acute nausea or vomiting or both; all had become acutely ill while at the same local pizza restaurant earlier that evening, between 6 p.m. and 8 p.m., during the restaurant's weekly family evening.

Of the 14, eight were male and six female, with a median age of 28 (range 7 years to 59 years). All received symptomatic treatment (intravenous rehydration and anti-emetics) and were discharged later that night. Food poisoning was suspected initially but seemed unlikely because of the rapid onset of illness (within minutes in some instances) after the patrons had started to eat, to drink beverages made from tap water, or both. As word spread through the community that evening, suspicion of a problem with the public water supply was heightened by reports of acute illness among residents on a street on the north side of the town, close to one of the water treatment plants (Plant A, Figure 1). Several of the people who became ill, including one who was a town Alderman, connected the onset of their illness to drinking tap water and described the water as having a strange taste.

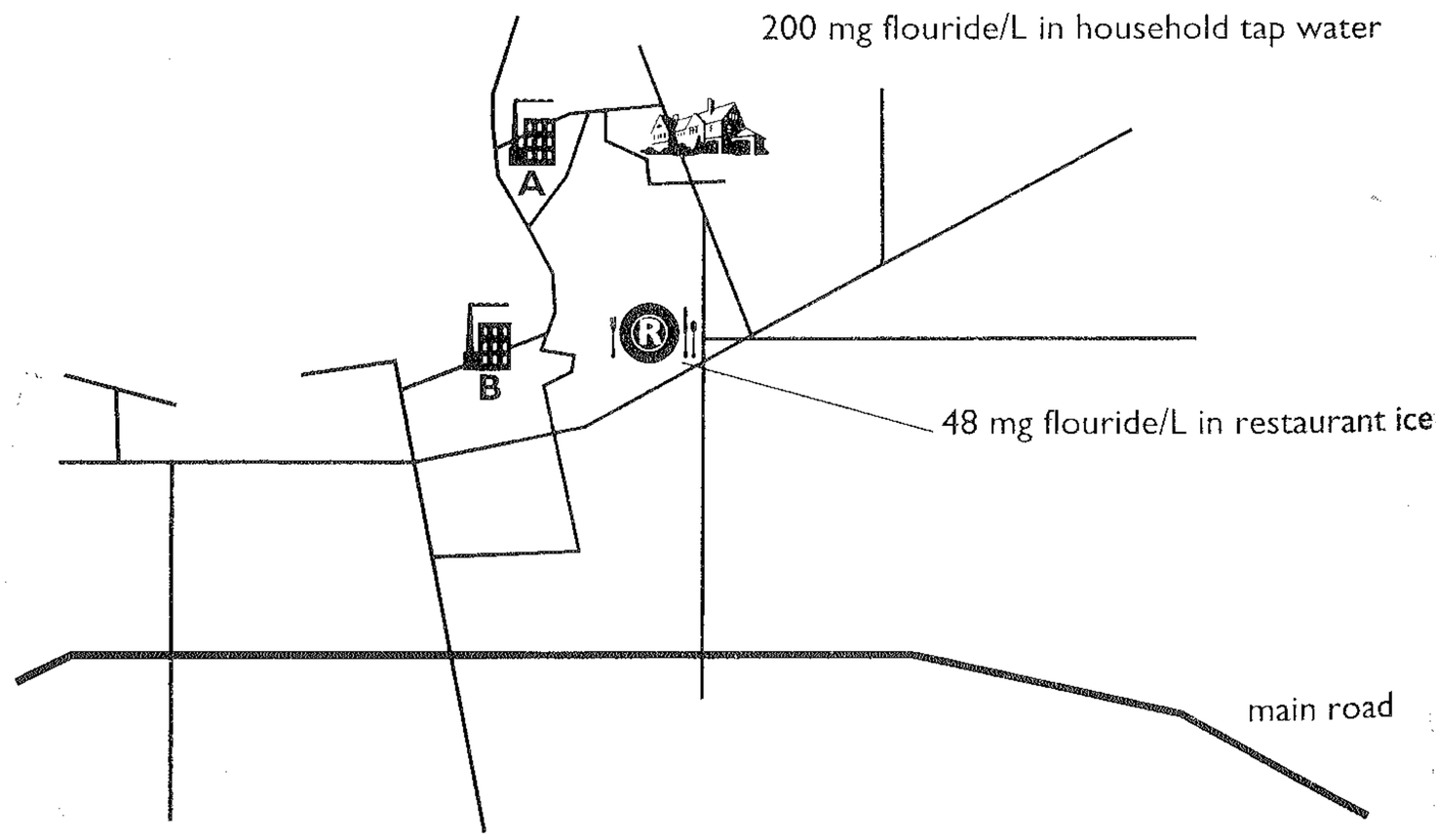
The following morning, one of the town's water engineers inspected one of the town's two water treatment plants—the plant nearest the area of town where residents were ill—and discovered that 4% fluoride solution was being siphoned from the fluoride saturator tank into the ground reservoir. Overfluoridation of the water system was immediately suspected, and a water main flushing program was started throughout the town. On August 12, the Office of Epidemiology of the Bureau of Preventive Health, Mississippi State Department of Health (MSDH), was notified, and an epidemiologic investigation was begun to assess the extent of illness and to confirm the cause.

Methods

Epidemiologic study. State health department investigators conducted an epidemiologic study to determine the nature and extent of illness, first, among restaurant patrons, and second, in the wider community.

Restaurant investigation. We compiled a list of all those who had visited the restaurant on August 10 by interviewing the 14 patients and the restaurant manager and by reviewing credit card slips and take-out orders for that day. The four local physicians were questioned about recent cases of gas-

Figure 1. Diagram of town in which outbreak of acute fluoride poisoning occurred, showing main streets, water treatment plants A and B, and restaurant (R), Mississippi, 1993



The restaurant is about equidistant from each water treatment plant, but the high fluoride in tap water from one house near Plant A suggested that Plant A was the source of the overfeed.

troenteritis, and the treatment room log of the only hospital in the town was reviewed in order to ascertain other possible cases. We used a standard questionnaire to ask all restaurant patrons about the onset and duration of illness, symptoms, treatment, and food and drink history for the period August 9 through August 11, including use of ice in drinks. A restaurant-associated case was defined as an instance of illness (acute nausea, vomiting, abdominal cramps, or diarrhea) in a person who had visited the restaurant on August 10. No cases were reported of people who became ill before going to the restaurant.

Community survey. To determine whether there had been wider contamination of the community, we selected a systematic random sample of community residents from the 1992–1993 telephone book of a multitown area: beginning from a randomly selected page and line, we selected every 30th telephone number. Over the course of a week, three attempts were made to contact someone at each number; if the 30th number was a business, the next number in the phone book was called. Using a standardized questionnaire, three interviewers asked respondents about their symptoms, health care visits, water consumption, and water use inside and outside the home for showers, baths, laundry, and the garden. A community case was defined as an instance of illness (acute nausea, vomiting, abdominal cramp, or diarrhea) in a person who resided in the community from August 10 through August 13 and who was not already classified as a restaurant case. A case household was defined as any household in which one or more members met the community case definition. All interviews were completed within two weeks of the initial outbreak.

Laboratory investigation. Restaurant case patients were asked to provide blood and urine samples for measurement of fluoride levels. All urine samples were kept frozen until the time of analysis. Urinary fluoride concentrations were measured by direct ion-specific electrode potentiometry and were corrected for the creatinine content (Personal communication, John A. Liddle, PhD, Environmental Health Laboratory, National Center for Environmental Health, CDC, Atlanta). Blood samples were spun down and kept refrigerated until analysis. Serum fluoride concentrations were determined using the ion-specific electrode following the hexamethyldisiloxane-(HMDS-)facilitated diffusion method of Taves[6] as modified by Whitford.[7]

Environmental investigation. The restaurant manager provided samples of ice and water taken from the restaurant kitchen around 9 p.m. on the evening of the outbreak and a tap water sample taken the following morning. Samples of various food items served on the day of the outbreak were also collected by county public health environmentalists. One sample of tap water from a house less than one mile from the restaurant and close to Plant A was also analyzed; this had been collected on the evening of August 10 by the resident, who had become ill immediately after drinking the water. Town officials collected water samples at various sites around the town on the morning of August 11, after the main system had been flushed. Water fluoride concentrations were measured by the Public Health Laboratory at the Mississippi State Department of Health using the fluoride-specific-ion electrode test.[8]

The water treatment plant (Plant A, Figure 1) was inspected jointly by the state health department and the local water engineer on August 13 and again on August 17. Particular attention was paid to the condition and operation of the feed pump and the feed line between the saturator tank and the ground reservoir.

Statistical analysis. Data were analyzed using Epi-Info, Version 5,[9] to calculate rate ratios with 95% confidence intervals. Contingency tables were analyzed using the chi square test or Fischer's Exact Test. To avoid statistical bias from nonindependence of cases within each household, data from the community survey were analyzed at the level of the household.

Results

Epidemiologic study.

Restaurant investigation. A total of 62 people visited the restaurant on August 10 to eat or drink; of the 39 people who consumed tap water or ice, all but five met the definition for a restaurant-associated case. We could not identify any common factor to explain why five people who consumed tap water did not become ill.

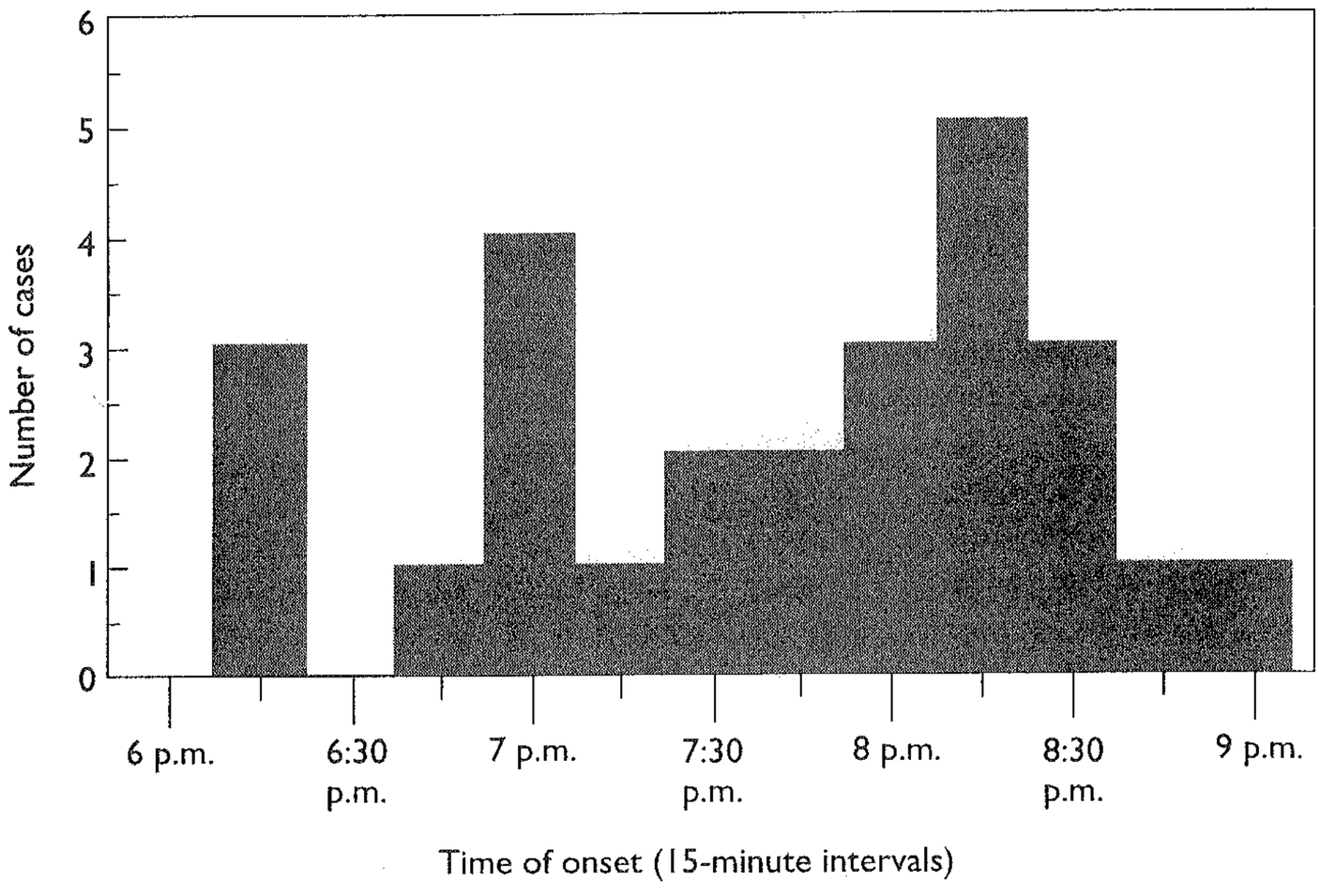
The median age of the 34 people who met the case definition was 29 years (range 4 years to 71 years); 49% were male, and—reflecting the racial composition of the community—94% were white. Those who became ill did not differ from those who did not become ill with respect to age, sex, and ethnicity. The most common symptoms were nausea (97%), vomiting (68%), diarrhea (65%), and abdominal cramps (53%); 14 people (41%) reported headaches, four (12%) reported burning sensations in the throat or chest, and one person reported excessive salivation. None recalled an abnormal taste to the water. Although many of the patients were acutely ill for a short time, there were no serious complications and none required intravenous rehydration or hospital admission.

The graph of restaurant-associated cases by time of onset (eight people could not give a time of onset) indicates onset of illness in all cases to be between 6 p.m. and 9 p.m., with a peak around 8:15 p.m. (Figure 2). Two smaller peaks occurred, one at 6:15 p.m. and one at 7 p.m. Using time of first eating or drinking (in five-minute increments) as a starting point of exposure, the median incubation period was calculated to be 15–20 minutes (range <1 minute to 90 minutes).

The food- and drink-specific attack rates (see Tables 1 and 2) strongly suggested a waterborne toxicant. Exposure to tap water accounted for all but two of the restaurant cases. One

of the two people who did not drink any beverages at the restaurant and did not drink tap water anywhere else yet became ill was a 19-year-old man with a medical history of anxiety attacks and hyperventilation; his story strongly suggested to us a hysterical reaction to the events around him. The other person was felt to be an unreliable historian whose recall was probably poor. We tried to obtain quantitative data on the amount of water consumed by each person, but nearly all affected people became ill immediately after starting to drink and no useful dose estimates could be made.

Figure 2. Number of restaurant-associated cases of gastrointestinal illness by time of onset, August 10, 1993 (*N* = 26)



The graph shows that onset of illness in all cases was between 6 p.m. and 9 p.m., with a peak at approximately 8:15 p.m. Two smaller peaks occurred, one at 6:15 p.m. and one at 7 p.m.

Univariate analysis revealed a strong association between consumption of restaurant tap water or a drink made with restaurant tap water (soda, juice, or tea)—with or without ice—and illness (relative risk [RR] = 10.8; 95% confidence interval [CI] 2.8, 41.1). The association between consumption of salad and illness was weaker (RR = 2.0; 95% CI 1.3, 3.1), and the relative risk for eating salad fell from 2.0 to 1.0 after we controlled for consumption of tap water (Table 2).

Community survey. Out of a systematic random sample of 176 phone numbers taken from the telephone book, we obtained information on 74 households within the city limits in which residents had been at home during the week of the incident. This represented a 42% response rate. Eighteen phone numbers were disconnected or listed incorrectly, there was no answer at 25 of the numbers on all three attempts, and 13 were businesses. Forty-three of the numbers reached households that were outside the city limits or in which the occupants had been out of town during the week of the incident, two people refused to answer, and one was excluded because the resident was a known restaurant case.

Table 1. Unadjusted attack rates and relative risks of acute fluoride poisoning among restaurant patrons, Mississippi, 1993

Food or beverage	*Number of people*	*Became ill*		*RR*	*95% CI*
		Number	*Percent*		
Pizza[a]					
Ate	54	29	54	1.0	0.5,1.9
Did not eat	7	4	57		
Salad[a]					
Ate	21	17	81	2.0	1.3,3.1
Did not eat	40	16	40		
Beverage with or without ice[b]					
Drank	37	32	86	10.8	2.8,41.1
Did not drink	25	2	8		

[a]Data missing on one person.
[b]Includes tap water and beverages made from tap water.
RR = Relative risk
CI = Confidence interval

Table 2. Adjusted relative risks of acute fluoride poisoning among restaurant patrons, Mississippi, 1993

Food or beverage consumed	*Food or beverage controlled for*	*Mantel-Haenszel summary relative risk*	*95% CI*
Salad	Beverage with or without ice	1.0	0.8,1.2
Beverage with or without ice[a]	Salad	7.1	2.6,20.0
Beverage with or without ice[a]	Pizza	12.5	2.9,50.0

[a]Includes tap water and beverages made from tap water.
CI = Confidence interval

Of the 74 households, 61 depended on the public water supply. Twenty (33%; 95% CI: 21, 45) of the 61 households that used the community water supply reported one or more residents with recent acute gastrointestinal illness, as did 3 (23%) of 13 households that did not use the community water supply. None of these ill residents had sought medical attention or reported their illness before the survey.

Using a railway line and a main road to divide the town arbitrarily into three zones, we found that the case household attack rate decreased slightly with increasing distance from Plant A, but this trend was not statistically significant. Among those households that relied on the public water supply, we found no statistically significant difference between ill households and well households during the four days August 10 through August 13 in rates of tap water consumption (100% versus 80%), use of ice in drinks (100% versus 82%), or use of non-drinking water (90% versus 80%). Apart from the hospital, which is on the other side of town from Plant A, no high-volume water users operated in the town during August. The town has no large businesses, dairies, or bottling plants, and the local college and high school were closed.

Laboratory results. Urine and blood samples were not obtained until the third day—or later—after the onset of illness. Urine samples were provided by 17 of the 34 restaurant patrons who became ill; urine fluoride levels were elevated above normal limits in only three of these people (5.3 mg/L, 5.5 mg/L, 6.1 mg/L; the normal upper limit for the general population is 3 mg/L [Personal communication, John A. Liddle]). Only four of the 34 restaurant patrons who became ill submitted blood for examination; none had detectable fluoride levels. No follow-up samples of blood or urine were obtained.

Environmental investigation. Food samples from the restaurant kitchen collected on the evening of August 10 showed no pathogenic growth on cultures.

A public water fluoridation system should normally produce a fluoride level in the range of 0.7 mg/L to 1.2 mg/L.[8] Ice from the restaurant kitchen collected by the manager around 9 p.m. on August 10 contained 42.7 mg fluoride/L, and tap water collected at the same time contained 48.0 mg fluoride/L. The tap water sample collected by the homeowner at about 3 p.m. on August 10 contained 200 mg fluoride/L. Water samples collected by town water department officials from multiple points in the main system on August 11, after the town system had been flushed, were within normal limits. Restaurant tap water collected on August 11 contained 4.7 mg fluoride/L.

The town is served by two water treatment plants, Plants A and B (Figure 1), which pump water into a common distribution system. A small number of people who live just outside the city limits obtain their water privately from individual or community wells. The main plant, Plant A, is located in the center of town; the sole elevated tank, which maintains water pressure in the system, is also located there. Plant B, which operates on a demand basis, was also in use on August 10. There was no documented history of operational problems at either plant.

The restaurant involved in this outbreak uses the community water supply and is approximately equidistant between the two plants; a main eight-inch pipeline runs almost directly from Plant A past the restaurant. Both water treatment plants have the same type of sodium fluoride (NaF) upflow saturator system (Figure 3). A mechanical diaphragm metering pump delivers 4% NaF solution into the ground reservoir, where dilution results in a final fluoride concentration of approximately 1 mg/L. On July 27, the fluoride saturator tank at Plant A was routinely replenished with 100 lb of NaF. Two days later, the plant was shut down for maintenance work; the ground reservoir was left standing at full capacity (approximately 20,000 gallons) from July 29 through August 10.

When repair work began on August 10, city workers decided to empty part of the stored ground reservoir water into the main system instead of dumping it, and an estimated 8000 gallons were pumped into the distribution system around 2 p.m. on August 10. The maximum pumping capacity of Plant A is 500 gallons per minute, and it would have taken less than 20 minutes to pump 8000 gallons. This water, which was high in fluoride ion, is believed to have passed as a bolus, or "slug," through the town system. Drawn into the restaurant water supply, it led to the outbreak of illness among the restaurant patrons who were dining that afternoon and evening.

At an inspection of Plant A on the morning of August 11, the day after the restaurant outbreak, fluoride solution