Outbreak of Cryptosporidiosis after Contamination of the Public Water Supply in Saitama Prefecture, Japan, in 1996

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Abstract

An outbreak of cryptosporidiosis occurred in Ogose Town, Saitama Prefecture, Japan, in June 1996. Of 12,345 respondents to a questionnaire sent to households in the town (population: 13,809), 8,812 (71.4 \%) reported an acute gastrointestinal illness some time between May and July. In addition, 274 traceable visitors at local inns, golf courses, and the like during this period and 54 employees from out of town were infected. Cases of cryptosporidiosis were estimated to 9,140. Of these, 2,856 subjects were treated at outpatient clinics and 24 subjects were hospitalized (some subjects counted twice). No deaths were attributed to the outbreak. Among the visitors to Ogose who were traced, 7 persons who stayed only one day during the outbreak and drank half a glass to 2 glasses (100 to 360 ml) of tap water had cryptosporidiosis confirmed by laboratory tests. The median incubation period for the 14 persons for whom this calculation was possible was 6.4 days (range, 5 to 8 days). Of 469 pupils reporting details of their fever and diarrhea, abdominal cramps, or these combined signs and symptoms, the median maximum body temperature was 37.8°C (range, 36.7 to 40.3°C). The duration of illness, reported by 608 of the pupils, was 5.2 days (range, 1 to 15 days), and that reported by 187 employees was 4.8 days (range, 1 to 18 days). The longest known time for discharge of oocysts after onset was 44 days. Blood was not found in the 609 stool specimens examined.

The outbreak was caused by contamination of the town’s potable water by Cryptosporidium parvum oocysts. The town’s water treatment plant treated river water by coagulation, sedimentation, sandfiltration, and chlorination. Contamination arose because of various natural and artificial factors: one was that the monthly precipitation in May was much lower than average, causing the river water level to drop. Another factor was heavy rainfall one night in May that increased water turbidity. The amounts of
the coagulant added seemed to be insufficient. There are two inns, three public lavatories, and two small-scale wastewater treatment plants upstream 400 m and 1,200 m of the intake point of the town’s water treatment plant. However, there are no farms with livestock in the area. We suggest that the location of the water treatment facilities was inappropriate, and that oocysts had circulated from the potable water to humans to sewage to the river and back to the potable water.


Introduction

*Cryptosporidium parvum*, a coccidian parasite, is a serious human and livestock pathogen\(^1\), and the most important contaminant in drinking water in the United States, England\(^{2–5}\), Canada\(^6\)\(^{7}\) and Japan\(^8\). *C. parvum* oocysts are resistant to most disinfectants\(^9\)\(^{10}\) and are widespread in rivers, streams, lakes, and reservoirs\(^11\). In the early summer of 1996, an outbreak of waterborne cryptosporidiosis occurred in Ogose Town, Saitama Prefecture, Japan (Fig. 1)\(^12\)\(^{13}\). On Monday, June 10, about 10% of pupils were absent from school, and gastroenteritis was widespread among the adults of the town. On June 11, our institute was asked to identify the cause of the diarrheal outbreak. This report describes the results of an epidemiological investigation done during the epidemic, and the countermeasures taken during and after the outbreak.

Materials and Methods

1. Laboratory examinations

On June 11, specialists in bacteriology and virology at our institute began their study. In all, 30 swab specimens of the three school kitchens facilities and the fingers of the cooking staff were made. Also examined was food kept because of public health regulations in school refrigerators from recent meals, and

Fig. 1 Location of Ogose Town.

Saitama Prefecture

Tokyo

Ogose: population 13,809 (as of July 1, 1996)
tap water were obtained from the three school kitchens for bacterial examination. On June 12 and 13, stool specimens were collected from pupils and teachers who had diarrhea and from all 14 of the cooking staff (asymptomatic) at school. Swab specimens of the pharynx for viral examination were obtained on June from 10 pupils with diarrhea. On June 14, the portions remaining of 39 stool specimens after bacterial examination were brought to our laboratory, for inspection for ova and protozoa by direct microscopy, a formalin-ether concentration method, sucrose centrifugal flotation, and a acid-fast staining method. In all, we examined 609 stool specimens collected from persons with diarrhea and all employees of eating places and inns some asymptomatic, some without symptoms at the time, between June 12 and July 30.

We examined 367 water samples for C. parvum oocysts. Tap water from the town’s water treatment plant (WTP), schools, and from several sites in residential areas, raw water going into the WTP from the Oppe River, river water, well water of houses and hotels, effluent from two small-scale wastewater treatment plants, and the like were sampled between June 10 and November 27. Samples were analyzed by methods of the US Environmental Protection Agency, in its information collection rules14) and other published techniques15). In brief, 2–20 l of water was filtered through a nitrate and cellulose ester membrane 47 mm in diameter and with a nominal pore size of 1 μm. The filtered membrane was dissolved in acetone and centrifuged at 1,300 × g for 5 min, and the supernatant was reduced to 5 ml. The pellet was suspended next in acetone, 95% ethanol, 70% ethanol, and 2 ml of phosphate-buffered saline (PBS, pH 7.2) with 0.2% Tween 80, in that order. The concentrated samples were stained for an indirect immunofluorescent assay with a commercial kit (Hydrofluoro-Combo, Ensys Inc., NC), and examined under a microscope.

2. Survey of pupils, residents, visitors, and out-of-town employees

A questionnaire was given to 1,409 of the pupils 6 to 15 years old at the three schools, so that the prevalence of diarrheal disease from June 15 to 18 could be calculated. The pupils or their parents were asked to record age, sex, source of home water, symptoms, and dates of onset and recovery.

In addition, a questionnaire was sent to all 4,187 households in the town between June 30 and July 15. Adult respondents were asked for the age, sex, place of employment of all household members, and whether any household members had been ill with diarrhea, abdominal cramps, or both, since early May. The survey for out-of-town visitors who played golf, had a meal, played on the visiting team at a basketball game at a school, or stayed in an inn was done in June by the staff of the Sakado Public Health Center. Visitors were traced mainly from records of their reservations at a golf course, restaurant, or the like. Employees (16 to 76 years old) who worked in Ogose also were asked about their health between May 25 and June 23.

3. Investigation of the water treatment system

The three treatment facilities were inspected and information about their policies, procedures, data on the monthly maximum turbidity of untreated and treated water, and amounts of coagulant added to the raw water were gathered.

4. Investigation of the watershed

There is no meteorological observatory in Ogose, but the monthly precipitation was recorded at two observatories near the town, one 15 km above of the WTP, and the other 7 km below this plant. The mean monthly river flow was measured at another observatory 15 km below the WTP.
Results

1. Laboratory examinations

Pathogens searched for were *Vibrio* spp., *Shigella* spp., *Salmonella* spp., enterohemorrhagic *Escherichia coli*, small round structured viruses, rotaviruses, and adenoviruses. However, none of these were detected in stool specimens as of June 14. Thereafter, we focused on examinations for ova and protozoa, and detected *C. parvum* oocysts in the specimens.

Of 522 individuals checked, 125 (23.9%) had oocysts. This group included 32 (91%) of the 35 pupils checked, 45 (60%) of the 75 outpatients checked, and 26 (62%) of the 42 visitors checked (June 15–21). From the 14 patients checked more than once, oocysts were discharged for 22 to 44 days after onset. None of the 609 stool specimens examined contained gross blood.

Tap water samples contained oocysts until July 4, as did raw-water samples of the WTP until July 8, and effluent samples treated by the wastewater treatment plants contained oocysts until September 18.

2. Survey of pupils, residents, visitors, and out-of-town employees

In the period June 15–18, a total of 1,409 (96.1%) pupils responded to the questionnaire. 1,013 (71.9%) reported diarrhea, abdominal cramps, or both. Of the 1,013 pupils with symptoms, 936 (92.4%) had diarrhea, 952 (94.0%) had abdominal cramps (Table 1). Of the 469 pupils with reporting a fever for which the temperature was stated, the median maximum body temperature was 37.8°C (range, 36.7 to 40.3°C) (in this group, seven pupils referred to 36.7°C as a fever). Nineteen pupils (4.1%) had a fever of 36.7–36.9°C, 264 pupils (56.3%) had a fever of 37.0–37.9°C, 150 (32.0%) had a fever of 38.0–38.9°C, 33 pupils (7.0%) had a fever of 39.0–39.9°C, and 3 pupils (0.6%) had a fever of 40.0–40.3°C. The median duration of illness of the 608 pupils reporting was 5.2 days (range, 1 to 15 days). The estimated frequency of diarrheal episodes per day was reported by 86 pupils: once or twice for 16 (19%) pupils, 3 or 4 times for 30 (35%), 5 or 6 times for 20 (23%), 7 or 8 times for 7 (8%), 9 or 10 times for 4 (5%), and more than 10 times for 9 (10%).

Of the 12,345 respondents to the questionnaire sent to households in Ogose, 8,812 (71.4%) reported and acute gastrointestinal illness including diarrhea or abdominal cramps between May 1 and July 7. Fig. 2 shows the reported dates of onset. Of 2,856 individuals seen at outpatient clinics, 24 were hospitalized. In all, 2,878 missed school or work. No deaths were attributed to the outbreak. Of the 459 employees at inns, golf courses, and eating places, 279 (60.8%) had an acute gastrointestinal illness, including 54 residing out of town. The median duration of illness of 187 employees reporting was 4.8 days (range, 1–18 days). Of the 1,496 traceable visi-

<table>
<thead>
<tr>
<th>Signs and symptoms</th>
<th>No. of Respondents (n = 1,013)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal cramps</td>
<td>952</td>
<td>94.0</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>936</td>
<td>92.4</td>
</tr>
<tr>
<td>Headache</td>
<td>488</td>
<td>48.2</td>
</tr>
<tr>
<td>Fever</td>
<td>478</td>
<td>47.2</td>
</tr>
<tr>
<td>Nausea</td>
<td>349</td>
<td>34.5</td>
</tr>
<tr>
<td>Sore throat</td>
<td>114</td>
<td>11.3</td>
</tr>
<tr>
<td>Vomiting</td>
<td>110</td>
<td>10.9</td>
</tr>
<tr>
<td>Sluggishness</td>
<td>9</td>
<td>0.9</td>
</tr>
<tr>
<td>Cough</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>Stomachache</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Chills</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

*Respondents with diarrhea, abdominal cramps, or both.

1. Duration of illness (days), 1-15 (mean, 5.2 for 608 respondents).
2. Maximum temperature (°C), 36.7–40.3 (mean, 37.8 for 469 respondents).
Fig. 2  Number of cases, date of onset, and maximum kaolin turbidity units (KTU) of raw water from May 1 to July 7, 1996 in Ogose.

Table 2  Traceable out-of-town visitors who drank tap water in Ogose and became infected.

<table>
<thead>
<tr>
<th>Case</th>
<th>Gender</th>
<th>Age</th>
<th>Site Visited</th>
<th>Incubation Period (Days)</th>
<th>Evacuations per Day</th>
<th>Tap Water Ingested (Glasses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>11</td>
<td>School</td>
<td>7</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>11</td>
<td>School</td>
<td>6</td>
<td>NK</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>11</td>
<td>School</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>11</td>
<td>School</td>
<td>6</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>12</td>
<td>School</td>
<td>6</td>
<td>8</td>
<td>NK</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>12</td>
<td>School</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>11</td>
<td>School</td>
<td>6</td>
<td>Many</td>
<td>NK</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>10</td>
<td>School</td>
<td>NK</td>
<td>4</td>
<td>NK</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>10</td>
<td>School</td>
<td>NK</td>
<td>NK</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>32</td>
<td>Eating place</td>
<td>7</td>
<td>6</td>
<td>NK</td>
</tr>
<tr>
<td>11</td>
<td>F</td>
<td>NK</td>
<td>Eating place</td>
<td>6</td>
<td>4</td>
<td>NK</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>48</td>
<td>Eating place</td>
<td>8</td>
<td>5</td>
<td>NK</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>46</td>
<td>Eating place</td>
<td>5</td>
<td>NK</td>
<td>NK</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>20</td>
<td>Eating place</td>
<td>7</td>
<td>NK</td>
<td>NK</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>35</td>
<td>Golf course</td>
<td>6</td>
<td>NK</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>NK</td>
<td>Golf course</td>
<td>6</td>
<td>5</td>
<td>NK</td>
</tr>
</tbody>
</table>

*NK = Not known.

tors, 274 (18.3%) had been ill with diarrhea or abdominal cramps at some time from May 25 to June 23. Of the visitors visiting Ogose for only one day between June 15 and 20, 14 reported the incubation period, and the median was 6.4 days (range, 5–8 days; Table 2). Seven visitors who drank half a glass to 2 glasses (100 to 360 ml) of tap water had laboratory-confirmed cryptosporidiosis.

3. Investigation of the water treatment system

The WTP had supplied 5,800 m³/day of potable water to the town. About 75% of the water had been
purified by at this plant and the remaining 25% had been purified by the prefectural water wholesaler. The WTP had treated Oppe River raw water (3,300 m³/day) and Mugihara River (1,000 m³/day) by coagulation, sedimentation, sand-filtration, and chlorination in a routine manner. Polyaluminum chloride, used as coagulant by the plant, was supposed to be added into both of the sedimentation basins each day when water was turbid, but in fact some such days between May 1 and June 15 may have been missed. There are two small-scale wastewater treatment plants with capacities to treat waste from 300 and 185 persons. They were 400 and 1,200 m above the intake point of the WTP (Fig. 3). They treated sewage by contact aeration and chlorination, and emptied into the Oppe River.

Turbidity of water treated at the WTP, on June 13, June 19, and from June 21 to June 29 was less than 0.1 kaolin turbidity unit (KTU); data for other days between May 1 and June 30 were not recorded. One unit is equivalent to 1.7 nephelometric turbidity units. The concentration of residual chlorine was 0.1 mg/l at the water treatment plant on both May 16 and June 13.

4. Environmental investigation of watershed

Compared with the previous year, the mean monthly flow of the river was reduced by 22% in May and 2% in June. The monthly precipitation measured 7 km below the WTP was 86 mm in May and 43 mm in June. With the mean precipitation in the past 12 years taken to be 100%, these amounts were 80% and 29% of the mean.

During May and June, only 5 days had maximum precipitation of 10 mm or more. The maximum hourly precipitation was 16 mm at the upper point of measurement at 10 p.m. on May 24. This rainfall increased turbidity of the raw water; the maximum turbidity was 92 KTU, recorded at 4 a.m. on May 25 (Fig. 2). To June 5-6, construction work to change the weir of water for agricultural use was done at the upstream site nearer the WTP, because of an inadequate raw water supply for the plant. The riverbed was stirred up by construction equipment.

No cattle or swine farms were in the neighborhood. There were two inns and three public lavatories above the wastewater treatment plants and emptying sewage into the Oppe River.

Discussion

The outbreak in Saitama Prefecture was caused by C. parvum oocysts that passed through the filtration system of the public water treatment plant. We estimated at least 9,140 individuals to be affected by the outbreak. In this report, we counted as patients with cryptosporidiosis any subject reporting diarrhea or abdominal cramps and any subject with a laboratory-confirmed case.

Okhuysen et al. reported that 10 oocysts can cause infection in human volunteers. In the Saitama outbreak, visitors who drank 100 to 360 ml of tap water on only one day became infected. We collected tap water at the same site on June 19 and found 12 oocysts/l. The number of oocysts in the water on June
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16 could not be ascertained, but this finding suggests that fewer than 10 oocysts can cause an infection. The median duration of illness for subjects of all age groups was about 5 days (range, 1 to 18 days).

The efficiency of removal of C. parvum oocysts by wastewater treatment with activated sludge is 80–84%\(^\text{17}\). The wastewater treatment plants in Ogose were likely not to be superior in such removal. Moreover, oocysts can pass through a WTP and gain entry into the distribution system even if the water is processed according to regulations\(^\text{16}\). There were operational deficiencies in Ogose before the outbreak; coagulant was added only on days when water turbidity was high. Therefore, we suggest that the location of the water treatment facilities was inappropriate, and that oocysts had circulated from potable water to humans to sewage to the river and back to the potable water (Fig. 3). Although data at the WTP were not recorded every day, both the turbidity of treated water and the concentration of residual chlorine met Japanese water quality standards. Contamination of the potable water was traced to various natural and artificial factors; one was the very low precipitation, which lowered the river water level. Second, although a heavy rainfall increased raw water turbidity, coagulant was not added as needed. Moreover, the riverbed had been stirred above the WTP. These factors may have contributed to the spread of infection.

In Ogose, on June 19, after identification of the pathogen, a headquarters to control the outbreak was set up in the town office. The town’s public health officials urged all residents to use boiled water for drinking and cooking during the outbreak. Instead of water supplied by the WTP, uncontaminated water from the prefectural water wholesaler was used. However, some food manufacturers and eating places had to close until the contaminated water was replaced by clean water. On July 19, the mayor of Ogose declared the drinking water to be safe. The declaration was based on there being no oocysts detected in samples of potable water after three consecutive examinations at 10 sites. Later, in April 1998, a membrane-filtration facility was constructed in the WTP, to ensure water quality after the step of sand filtration. Although such facilities are desirable everywhere, the cost is high.

The Ministry of Health and Welfare in Japan issued a directive for corrective measures to all local governments after the Saitama outbreak. First, they established guidelines concerning risk management at water purification plants. Second, they provided technical training in the detection of Cryptosporidium oocysts and Giardia cysts in water. Third, they investigated the prevalence of oocysts and cysts in raw water throughout Japan. In Japan, with its many livestock farms and pastures, avoidance of fecal contamination in sources of drinking water is extremely important.

Acknowledgments

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References

水道水によるクリプトスポリジウム症の大規模な集団感染が1996年6月に埼玉県越生町で発生した。この事件の疫学的調査の結果と対応を総括した。全住民（13,809名）に対する健康調査を実施した結果、回答者12,345名のうち8,812名（71.4%）が下痢や腹痛を発病し、2,856名が病院で外来診療を受け、24名が入院した。町外からの来訪者も感染し、感染者の総数は9,140名に達した。流行時に1日だけ町内に滞在し、感染した14名の潜伏期間は平均6.4日（5日〜8日）であり、7名はコップに半分〜2杯の水道水を飲用して感染した。小・中学生の発症例1,013名の発症期間は平均5.2日（1〜15日）であり、発熱した469名の体温は平均37.8℃（36.7〜40.3℃）であった。また、成人187名の発症期間は平均4.8日（1〜18日）であった。

*Cryptosporidium parvum*のオーシストは患者便から検出され、水道水、浄水場の原水（河川水）、浄水場のすぐ上流に位置する下水処理施設の放流水からも検出された。流行の発生前、渇水により河川水の水量が著しく減少していたが、夜間の豪雨で原水の濁度が急上昇した。しかし、不適切な浄水処理により水道水が汚染されたことが、集団感染の発端となった。また、患者便に含まれる大量のオーシストが下水処理場から河川水（水道原水）に流入し、水道水を介してさらに感染者が増加するという循環が流行の規模を拡大させた。

【感染症誌 74：518〜526、2000】