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Investigation on an outbreak of bacillary dysentery due to infection of *Shigella sonnei* in a town of Guangxi Province

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ABSTRACT

Objective: To provide a scientific basis for identifying the causes of an outbreak and providing preventive and control measures to prevent the recurrence of similar outbreaks.
Study design: A case-control study.
Methods: We defined a suspected case as residents living in the affected town presented with inexplicable diarrhea (≥3 times/24 h) and at least with fever (above 37.5) or abdominal pain or vomiting from June 20 to July 14, 2016. The confirmed case was *Shigella sonnei* isolated from feces or rectal swabs of the suspected case. Cases were identified by reviewing medical records in different medical facilities in the affected town and interviewing physicians and cases using a questionnaire. The local water supply was checked on site. An age-matched case-control study was conducted. Epi-Info 7.0 software was used for data analysis.
Results: 133 cases aged from 1 to 77 were identified with 102 suspected and 31 confirmed. The attack rate was 0.7% (133/18131). The majority of clinical manifestations were diarrhea (100%), fever (83.5%) and abdominal pain (40.6%). Among 64 case-control pairs, 64.1% cases and 18.8% of controls drank non-boiled water (OR = 7.7, 95% CI 3.5–17.0) within 15 days before their onset. 42.2% cases and 10.1% controls had the illness in family members (OR = 6.5, 95% CI 2.5–16.3). 18 samples of *Shigella sonnei* were isolated from 50% (4/8) faces, 40% (13/33) rectal swabs and 14% (1/7) tap water. 8 were strain-typed by PFGE and showed 100% homology in the typing pattern. No disinfection was routinely implemented for water supply, 1household latrine was found to discharge directly into the river which is used as the local water source.
Conclusion: This outbreak was caused by contaminated drinking water supply with household exposure helped facilitate further transmission. Water sources should be kept clear of defecation discharge and disinfected before supply, unboiled water drinking habits need to be addressed through health promotion.

1. Introduction

Outbreaks of waterborne infection occur frequently in rural Chinese schools. According to data from the China Information System for Disease Control and Prevention, over 60 outbreaks of water-borne diseases, including hepatitis A, typhoid and cholera, were reported each year in rural Chinese schools during 2003–2009. More than 80% of these outbreaks were caused by contaminated well water (see Figs. 1–3) (see Tables 1–3).

On June 30, 2016, 32 cases with fever, diarrhea and abdominal pain were reported from a township **hospital** in Guangxi Province, China. All cases were residents from the same town, most of were students. Rectal swab samples from four of the patients were culture-positive for Shigella. We investigated to verify the suspected outbreak, mode of transmission, and risk factors for this shigellosis outbreak and implement control and preventive measures. We also sought to elucidate the more general issues related to waterborne disease outbreaks in rural China.

2. Materials and methods

We defined a suspected case as residents living in the affected town presented with inexplicable diarrhea (≥3 times/24 h) and at least with fever (above 37.5) or abdominal pain or vomiting from June 20 to July

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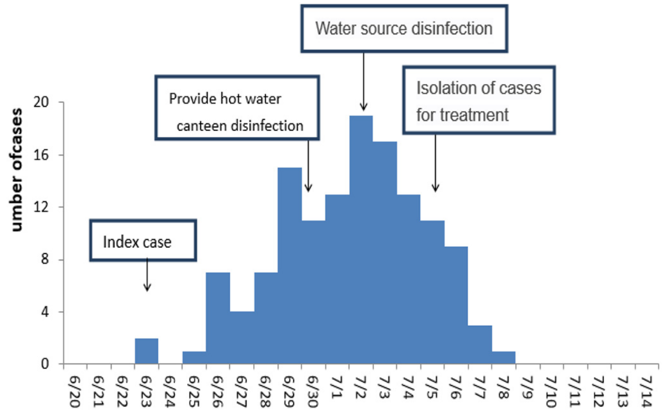

Fig. 1. Time distribution of bacterial dysentery epidemic in P town, Guangxi in 2016.

14, 2016. The confirmed case was *Shigella sonnei* isolated from feces or rectal swabs of the suspected case.

For case finding, we systematically reviewed medical records at the township hospital. We reviewed medical records of patients with vomiting, diarrhea, abdominal pain and fever, and applied the case definitions to identify cases. We also asked the teachers to report illness in their students from June 20 to July 14. We also asked the residents to report their own and any family members' illnesses.

We took 8 feces 33 rectal swabs specimens from the suspected case and 12 food samples from the canteen or fast food shop, all of them were tested for Salmonella, diarrheagenic Escherichia choli and Shigella. We also collected 73 water samples (32 directly from the Wells, 34 from taps that drew water and tested for the same organisms including total plate count, total coliform and thermotolerant coliform bacteria. In order to identify whether the pathogenic factor came from wells, Pulsed Field Gel Electrophoresis (PFGE) was used for serological test among Shigella isolates of 7 cases and 1 untreated tap water directly from the Well. Laboratory testing was conducted following standard practices.

In a case-control investigation, we enrolled probable or confirmed cases in aged 10 or above, and conducted face-to-face interviews. Residents aged below10 could not understand the questions adequately and were excluded. We selected the first case into case control study whose family have more than one case. Controls were randomly selected among asymptomatic residents under 1:1 ratio as controls. We collected data about the onset time, symptoms and duration of illness, and history of exposure to suspected water and food items.

Cases were identified by reviewing medical records in different medical facilities in the affected town and interviewing physicians and cases using a questionnaire. The local water supply was checked on site. An age-matched case-control study was conducted. Epi-Info 7.0 software was used for data analysis. Univariate analysis (Pearson chi-square test) was used to compare the age and sex distributions between the case and control presidents. Mantel-Haenszel chi-square test was used to assess the risk factors. The chi-square trend test was used to analyze dose-response relationships. Statistical analyses were performed using R. Statistical significance was defined as $P < 0.05$.

3. Results

The P town was in the north of Guangxi with a population of 18,131. There were 6 schools in the center of town (1middle school, 1 primary school, 4 kindergarten schools. The water of center and nearby P town was supplied by town government collectively (Water supplied area), other far away from town center areas were Self-supplied (Non-supplied area).

There were 133 cases (6 suspected, 96 probable, and 31 confirmed), all among the 18,131 presidents (attack rate: 0.7%). Among 133 case students, all of them had diarrhea at least 3 times per day (watery 65%, mucous bloody stool 26%, mucous stool3%). Other common symptoms included fever (84%), abdominal pain (41%), nausea(21%), tenesmus (21%),and vomiting (17%). Some patients reported their diarrhea as initially being bloody, then turning watery.

The index case had onset on June 23; the number of cases rose gently, peaking on July 2. The epidemic curve suggested a common-source exposure. Because the patients were first found in P town primary school, the

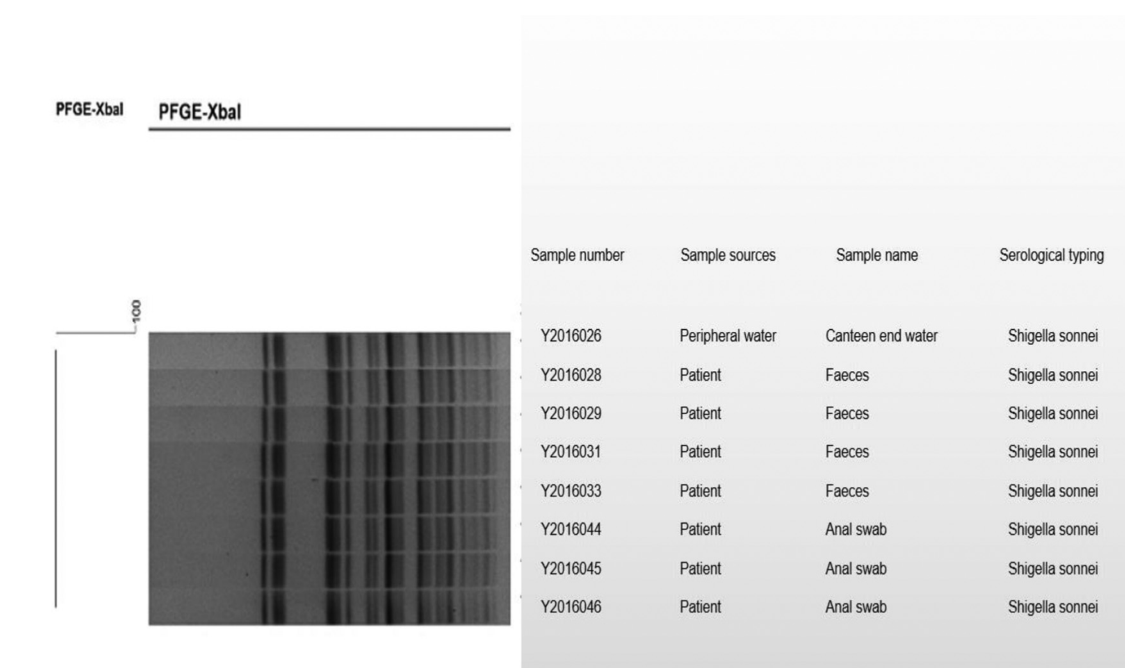

Fig. 2. PFGE identification of bacillary dysentery outbreak samples in P Town, Guangxi in 2016.

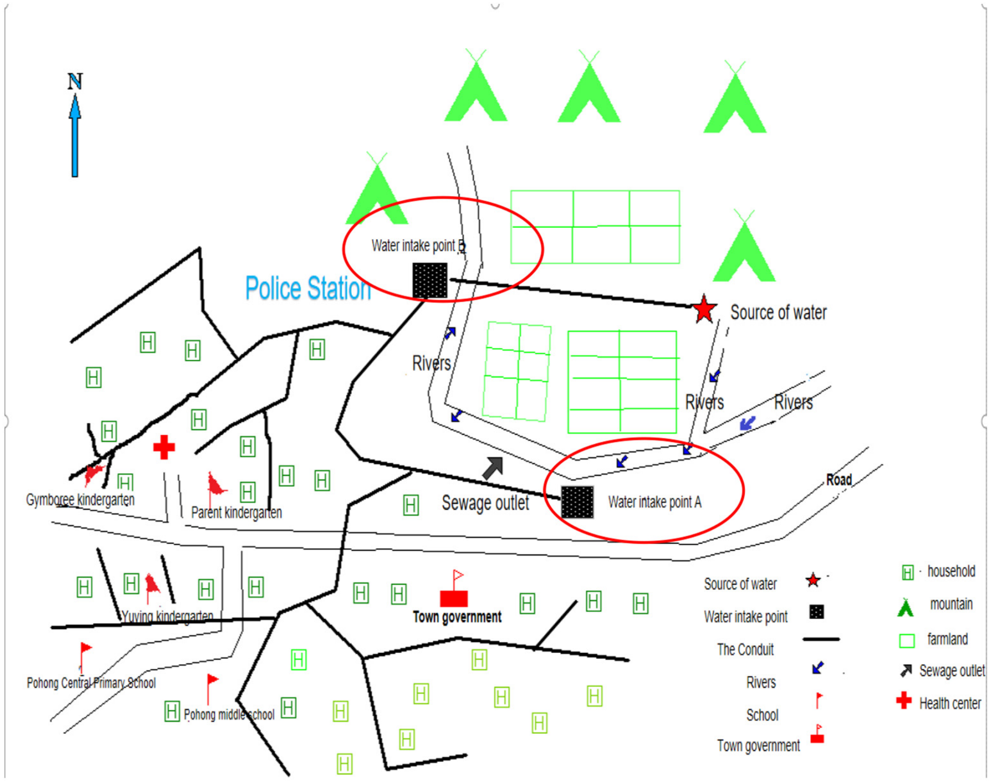

Fig. 3. Water supply distribution of residents and schools in P town of Guangxi in 2016.

local public health authority disinfected the school's environment on June 30 after the detection of the outbreak and supplied boiled water instead of bottled water. But the number of patients was increasing during the next three days. Also, starting on July 2, water in the two water towers was chlorinated daily and presidents were instructed not to drink water from the taps directly, the number of new cases declined. Starting on July 4, all patients were put into isolation ward for treatment, the number of new cases declined rapidly.

The residents of P town were supplied with bottled water, part of them drank boiled water. There were two types of daily water in P town. The town center and around were supplied by government unified water supplied the other village which far from P town center was self-water supplied. There was one primary school, four kindergarten schools, and one middle school in the P town center. Both the primary school and kindergarten schools which water supplied by the government had patients, while the middle school which water supplied by self-well had no patients. According to the occupation, we divided cases into kindergarten, primary school students, residents. The attack rate of kindergarten students was 5.4% (39/721), the attack rate of primary school students was 4.3% (60/1392), the attack rate of residents was 0.2% (34/15581). The attack rates of kindergarten students and primary school students were significantly different to presidents. (RR = 20.6, 95% CI 13.5–32.5; 26.1,95% CI 16.4–41.7). The attack rate differs significantly between Water supplied area and Non-supplied area ($P < 0.05$). The attack rate between Water supplied area and Non-supplied area of kindergarten, primary school students, residents were also significant difference ($P < 0.05$, kindergarten OR = 3.9, 95% CI 1.2–13.0; primary school RR = 12.6, 95CI% 3.1–52.0; residents RR = 5.9, CI 2.5–13.6), and both cases peaked on June 2. Suggesting that they had shared another common source of exposure between primary school and kindergarten. There was the flow of cold drinks (direct use of

Table 2
Results of Collaborative analysis results of exposure of bacillary dysentery outbreak in P town Guangxi in 2016.

Exposure link	Number		%		OR(95%CI)
	Case n = 64	Contrast n = 69	Case	Contrast	
0	7	36	10.9	52.2	reference group
1	26	31	40.6	44.9	4.3 (1.6–11.3)
≥2	31	2	48.4	2.9	79.7 (15.4–412.2)

*Trending $\chi^2 = 42$, $P < 0.01$.

Table 1
Results of a case-control study about the bacillary dysentery outbreak in P town Guangxi in 2016.

Exposure link	Number		%		Single-factor analysis OR(95%CI)	Multifactor analysis RR(95%CI)
	Case *n* = 64	Contrast *n* = 69	Case n = 64	Contrast n = 69		
Family member onset	27	7	42.2	10.1	6.5(2.5–16.3)	16.1 (4.9–53.2)
Drink raw water	19	6	29.7	8.7	4.4(1.6–12.0)	4.1(1.1–16.6)
Ready made cold drinks and cold dishes	41	13	64.1	18.8	7.7(3.5–17.0)	6.0 (2.2–16.5)
Finger sucking	19	9	29.7	13.0	2.8(1.2–6.8)	4.2(1.3–13.9)
Swimming	14	8	21.9	11.6	2.1(0.82–5.5)	/
Wash your hands before meals	58	59	90.6	85.5	1.6(0.6–4.8)	/
Wash your hands after toilet	62	62	96.9	89.9	3.5(0.7–17.5)	/

Table 3
Laboratory test results of bacillary dysentery outbreak in P Town, Guangxi in 2016.

Sample category	Sample quantity(part)	Shigella
Food	12	Not detected
Anal swab	33	13
Feces	8	4
Pipe network end water	34	1
Reservoir water	32	1
River water	7	1

domestic water for sale), Salad on sale, which was popular by residents in summer. 43 cases (32%) were distributed in 20 households, 3 of which had 2 or more cases, and 9 other families were more likely to have an average latency (3 days) between the first cases and the last cases. It suggested that some cases were secondary infections.

We enrolled 64 cases and 69 control residents for the case-control study. During 8–23 June, 29.7% (19/64) of cases drank unboiled water while control residents were 8.7% (6/69) (OR = 4.4, 95% CI: 1.6–12.0). 64.1% (41/64) of cases and 18.8% (13/69) controls drank cold drinks or eat salad (OR = 7.7, 95% CI: 3.5–17.0). 42.2% (27/64) of cases and 10.1% (7/69) of controls had other families got shigellosis (OR = 6.5, 95% CI: 2.5–16.3). 29.7% (19/64) of the case and 13.0% (9/69) of controls suck the finger in daily life (OR = 2.8, 95% CI: 1.2–6.8). All of the above factors were significant risk factors for developing shigellosis.

To verify whether the exposure has a close relationship to the outbreak, we selected "family members to developing disease", "drinking raw water", "'consuming drinks made with locally sourced water or salads washed in locally sourced water" and "sucking fingers" as the exposures to analyze, with levels of exposure defined as 0 times, 1 time, … etc. Exposures were classified as 0, 1, 2, or more times. When a single exposure, OR = 4.3 (95% CI), two or more than two exposures, OR = 80. The trend chi-square test was statistically significant (trend $\chi^2 = 42$, $P < 0.01$).

12 foods samples, 41 anal swabs or feces samples, 34 tap pipe water samples, 39 river or reservoir water samples were collected for Salmonella, Shigella, diarrhea-causing *Escherichia coli*, *Vibrio parahaemolyticus* testing. Water samples from the river or reservoir were also tested for the Total number of colonies, coliform bacteria, heat-resistant coliform bacteria. According to the result, Shigella bacteria was detected in 13 anal swabs, 4 feces/stools, and 1 tap pipe water. 5 tap ripe water, 3 reservoir water, and 3 river water samples were a total number of colonies, coliform bacteria and heat-resistant coliform bacteria positive, which were collected before disinfection.

The bacterial sample of 4 feces, 3 anal swabs, and 1 tap water were sent to Guangxi CDC and be identified by PFGE [1]. The results showed 100% homology.

Environmental investigation revealed that there were A and B reservoirs that were connected by a pipe before supplying water to schools and residents of P town. The A and B wells supplied water to A and B reservoirs. Both of them are about 5 m deep and less than 5 m from the river. There is sewage discharge around A well. B well is located downstream about 500 miters from A well, there were civil toilets and animal carcasses around B well (less than 50 m). For due to the lack of disinfection equipment, the water was supplied to P town schools and residents without treatment all the time.

4. Discussion

Shigellosis is a highly infectious diarrheal disease [2] that can lead to explosive, common-source [3–5] or prolonged propagated epidemics [6]. Studies have linked unboiled water [7,8] contaminated food [9], and household contacts [10] with shigellosis. In this investigation, we documented a school outbreak of shigellosis caused by drinking untreated water from a contaminated well.

In China, many private wells supplying water to schools are built near pollution sources, including toilets, septic tanks, sewer ditches, lakes, and ponds being discharged of sewage. Water from these wells is often not treated before being piped into schools. Consequently, waterborne outbreaks with various pathogens, such as hepatitis A, Shigella, Salmonella, and norovirus frequently occurred.

In this incident, the rural and urban water supply is not disinfected, which is mainly the source of pollution. It involved residents, primary schools, and kindergartens of the town, of which primary schools and kindergartens account for 74% (99/133). It is uncommon to see bacterial outbreaks caused by water pollution in Chinese schools. In this epidemic situation, the prevalence rate of primary schools and kindergartens was higher than residents, and the difference was statistically significant (OR values were 21, 95% CI 14–33; 26, 95% CI 16–42). It had a close relationship with students' activities, limited self-control ability and less access to health knowledge. In addition, unhealthy living habits often trigger bacterial outbreaks like Shigellosis or Norovirus, in which pathogenic doses were low and contact transmission can be realized, so it is easy to onset outbreak in a lower grade school or child care institution. During the summer, people tend to consume cold food or salad, which may lead to gastrointestinal infections, in addition to flies, climate and suitable for the growth of dysentery bacilli, all of which may cause summer bacillary epidemics. Students have a favorable attitude to cold drinks and cold foods, which were contaminated by polluted water was extremely easy to spread germs and enhance the opportunity to increase infection Shigellosis, similar incidents occurred in Baoding. In addition, because the water source is polluted, students who always wash their hands do not decrease infection of Shigellosis. However, as an effective measure to prevent many contact-borne diseases, hand-washing habits should continue to promote good hygiene practices in schools.

In recent years, the township water improvement project has made China dramatically change, however, lacking corresponding supporting measures may not be able to adapt to the demands. In China, regulations on the location, design and construction of private wells exist. These regulations require that the location and design of wells serving as a source of drinking water need to be approved by public health authorities. However, these regulations are rarely implemented due to insufficient enforcement and a lack of coordination between public health and educational departments. In this outbreak, the implicated well, Well A, was not only shallow (5 m), but also very close to a contaminated pond in which school and residential sewage is discharged. This is a gross violation of those regulations.

Waterborne outbreaks also occurred frequently during the first half of the 20th century in Europe and North America [11]. After the implementation of community water treatment during the second half of the 20th century, waterborne infections declined sharply [12]. A major advantage of community water treatment is its cost-effectiveness, i.e., successful implementation of this strategy can prevent infections by many different pathogens, as well as chemical agents.

In light of the findings from this investigation, we recommend that inspections of all existing wells should be conducted, especially of those serving school children, who due to their young age are especially prone to waterborne communicable diseases; Also, all water provided to presidents should be treated and chlorinated. Additionally, sewage, especially that surrounding schools, should be treated properly before discharge to prevent drinking water sources from being polluted.

5. Conclusion

This incident is an outbreak caused by a contaminated water source of Shigella. The non-sterile of the reserve water, the drinking habit of unboiled water, unhealthy eating habits like cold salad and drinks were the main reasons for the outbreak. In addition, attention should also be paid to the selection and discharge of drinking water sources.

Ethical approval

We conducted this outbreak investigation immediately after the outbreak was reported on June 30. This investigation was in response to an acute public health emergency event, hence was exempted from ethics approval and informed consent.

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Declaration of Competing Interest

None declared.

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