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Original Article

Infectious diarrheal disease caused by contaminated well water in Chinese schools: A systematic review and meta-analysis

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ABSTRACT

Background: In China, waterborne outbreaks of infectious diarrheal disease mainly occur in schools, and contaminated well water is a common source of pathogens. The objective of this review was to present the attack rates, durations of outbreak, pathogens of infectious diarrheal disease, and sanitary conditions of wells in primary and secondary schools in China, and to analyze risk factors and susceptibility of school children.
Methods: Relevant articles and reports were identified by searching PubMed, Web of Science, China National Knowledge Infrastructure, China Information System for Disease Control and Prevention, and the Chinese Field Epidemiology Training Program. Essential information, including urban/rural areas, school types, attack rates, pathogens, durations of outbreak, report intervals, and interventions were extracted from the eligible articles. Wilcoxon signed-rank test, Kruskal–Wallis *H* test, and Spearman correlation test were conducted in statistical analyses. Sex- and age-specific attack rate ratios were calculated as pooled effect sizes.
Results: We screened 2188 articles and retrieved data of 85 outbreaks from 1987 to 2014. Attack rates of outbreaks in rural areas (median, 12.63 cases/100 persons) and in primary schools (median, 14.54 cases/100 persons) were higher than those in urban areas (median, 5.62 cases/100 persons) and in secondary schools (median, 8.74 cases/100 persons) ($P = 0.004$ and $P = 0.013$, respectively). *Shigella*, pathogenic *Escherichia coli*, and norovirus were the most common pathogens. Boys tended toward higher attack rates than girls (sex-specific attack rate ratio, 1.13; 95% CI, 1.00–1.29, $P = 0.05$). Unsanitary conditions of water wells were reported frequently, and unhealthy behavior habits were common in students.
Conclusion: School children were susceptible to waterborne disease in China. Chinese government should make efforts to improve access to safe water in schools. Health education promotion and conscientiousness of school leaders and teachers should be enhanced.

Introduction

A majority of public health emergencies occur in schools in China. According to the published papers from 2010 to 2011, those occurring in schools accounted for 63.4% of all the public health emergencies in China, and about 61.8% of them occurred in rural areas.[1] The data of the China Information System for Disease Control and Prevention (CISDCP)[2] showed that school outbreaks accounted for 70.1% and 51.5% of all the public health emergencies in 2012 and 2013, respectively, in mainland China. In Zhejiang Province in eastern China, the percentage was 59.5% during 2012–2014. Many of these public health emergencies in schools were infectious disease events,[2] where infectious diarrheal disease outbreaks transmitted via water drew the attention of local governments and Centers for Disease Control and Prevention (CDCs).

The safety of drinking water has always been a health issue throughout the world, especially in developing countries. In China, water supply and sanitation have improved dramatically in urban areas, with the coverage of tap water (centralized water purified and sterilized by waterworks according to Sanitary Standard for Drinking Water in China and transported to citizens by water pipes) exceeding 90%, while in rural areas, the access to a tap water supply is less common.[3] According to a study investigating 100 schools in

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four provinces (Shaanxi, Guangxi, Hunan and Anhui) and one municipality (Chongqing), the coverage of tap water supply was only 50% in these schools. Self-contained water supplies (e.g., domestic water gathered from rivers, lakes, and wells and purified and sterilized by individuals or units) were more common in boarding schools and rural schools comparing to those in day schools and urban schools. In this study, well water was reported to account for 83.9% of all the self-contained water supplies.[4] The Chinese government has been concentrating on improving water supply in rural areas over the past decades.[5] According to the latest estimates of the Ministry of Health, by the end of 2013, 95.6% of the rural populations have benefited from improvements in rural water sources, with 76.4% and 74.1% having access to tap water and sanitary toilets, respectively.[6] The data on access is encouraging, and the incidence of diarrhea has also declined over the past 20 years.[7] However, the sanitary conditions in rural schools are still lacking. The investigation of 100 schools showed that less than half of the self-contained water sources met the disinfection standard.[4] Several surveys covering different provinces also reported the worrying situation of self-contained water left untreated or non-disinfected in Chinese schools.[8–10] Poor water supply conditions may expose school children to contaminated drinking water and infectious diarrheal disease.

Sanitation and water quality have always been health issues in developing and developed countries, and yet sanitation improvements are still inadequate.[11] A previous systematic review has demonstrated that water sources in rural areas and low-income countries had a higher risk of contamination,[12] and consumption of groundwater might increase the risk of diarrhea.[13] A review of 248 outbreaks associated with untreated groundwater sources in the United States showed that common sanitary conditions included unreasonable design, maintenance, or location of the groundwater source and sewage disposal system.[14] However, little was known about those in China, especially in schools, where waterborne outbreaks are prone to happen because children are more susceptible to infection with waterborne disease than adults[15] and diseases are transmitted readily in population clusters. Therefore, we conducted this systematic review to describe attack rates, durations of outbreak, pathogens of infectious diarrheal disease, and sanitary conditions of wells in primary schools (covering first to sixth grade) and secondary schools (including junior high schools covering seventh to ninth grade and senior high schools or technical secondary schools covering tenth to twelfth grade) in China. We also analyzed age and gender difference in the severity of outbreaks to assess susceptibility of primary and secondary school students. The results may be helpful for policy makers in China to improve drinking water conditions in primary and secondary schools and will provide information for controlling waterborne outbreaks in schools in other less developed areas.

Methods

Literature search

We performed a literature search in PubMed, Web of Science, and China National Knowledge Infrastructure (CNKI), with search terms limited to titles and abstracts. Search strategy in PubMed and Web of Science was (Diarrhea OR Waterborne Diseases) AND China AND (school OR student); and that in CNKI was (Diarrhea OR Waterborne Diseases) AND (school OR student) in Chinese. We also searched the CISDCP in Zhejiang Province and the investigation data from the Chinese Field Epidemiology Training Program (CFETP). The data retrieved from CISDCP, which contained detailed information throughout the outbreak, were all from the investigating and disposing reports of local CDCs. CFETP is a 2-year training program organized by the Ministry of Health every year to train China's future public health leaders from 2001,[16] and the data included one systematic survey report of each outbreak containing epidemiological investigation, sanitary investigation, laboratory test results, hypothesis, analysis and confirmation of etiology, interventions, and recommendations. The data was most recently updated on March 1, 2015. Reference lists of retrieved articles and relevant reviews were further reviewed to find additional eligible studies. This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[17]

Inclusion criteria of studies

Waterborne outbreak of infectious diarrheal disease in this study was defined as an infectious diarrheal disease epidemic in a school with more than five patients within a week. Two authors independently selected and evaluated relevant literature, first on basis of title and abstract screening and then on the basis of the full text. Inclusion criteria were: (1) waterborne outbreaks happened in primary or secondary schools in China; (2) patients had infectious diarrheal disease, diagnosed by clinics or laboratories; (3) contaminated well water was supposed to be the cause (or one of the causes) of the outbreak according to epidemiological survey and/or pathogen detection. Language was limited to Chinese and English.

Data extraction and quality assessment

Two authors extracted detailed information independently, including geographic regions, urban/rural areas, school types, attack rates, pathogens, durations of outbreak, report intervals, sanitary conditions of wells, investigations of risk factors, and interventions. Geographic region was classified into eastern (eight provinces: Hebei, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, and Taiwan; and three municipalities: Beijing, Tianjin, and Shanghai), central (six provinces: Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan), western (six provinces: Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, and Qinghai; one municipality: Chongqing; and five autonomous regions: Inner Mongolia, Tibet, Xinjiang, Guangxi, and Ningxia), and northeastern China (three provinces: Liaoning, Jilin, and Heilongjiang) according to geography and economics.[18] Attack rate was defined as the number of new cases in the population at risk divided by the number of persons at risk during the whole outbreak. Duration of outbreak refers to the time interval between the onset of the first patient and the onset of the last patient. Report interval means the time interval since the onset of the first patient to the first report completed, which can reflect the capacity of disease detecting and responding. Interventions included: (1) patient isolation; (2) disusing or disinfecting the contaminated well water; (3) disinfecting the environment; (4) morning check (quick health check for each student in the morning for early detection of infectious diseases); (5) health education; and (6) prophylactic use of drugs. Discrepancies were resolved through discussion to reach consensus. If two or more articles or reports shared the same original outbreak data, the one with more detailed information was chosen. We created the following criteria to assess the quality of studies: (1) explicitly described the time, place, and population of the outbreak; (2) explicitly described pathogen detection, sanitary investigation, and interventions; (3) described the investigation of risk factors for outbreak; (4) conducted scientific statistical tests; and (5) bias was controlled using randomization, stratification, and/or pairing, or any potential confounding was discussed. One point was added every time the answer was “Yes”. The total possible score was 5. Studies scoring 3 to 5 points were considered high quality, and those graded 0 points were considered low quality and excluded from the analysis.

Statistical analysis

In this analysis, attack rate and duration of outbreak were analyzed to reflect severity of outbreak and were described according to urban/rural areas and school types. Differences of attack rates and durations of outbreak between urban and rural areas or primary and secondary schools were analyzed using Wilcoxon signed-rank test, and those among the four geographic regions were analyzed using Kruskal–Wallis *H* test, since the data were not normally distributed. In order to determine potential factors influencing the severity of outbreaks, Spearman correlation analyses were performed between report interval or number of interventions and attack rate/duration of outbreak. Male:female ratio of attack rates and 95% confidence intervals (CIs) in each study were estimated as sex-specific attack rate ratios (ARRs). Junior:senior ratio of attack rates and 95% CIs in each study were estimated as age-specific ARRs. We defined students in the upper third of school grades as seniors and the rest as juniors in each outbreak. That is, fifth and sixth graders in primary school, ninth graders in junior high school, and twelfth graders in senior high schools were senior students; the rest were junior students. An I^2 value greater than 25% was defined as significant heterogeneity, and a random-effects model was used to estimate pooled ARRs after log-transformation; otherwise, a fixed-effects model was used. Stratified analyses were performed in investigations by rural/urban area and pathogen. In addition, we did restricted to high-quality studies (quality score $\geq$3) and across different data sources (electronic journal databases, including PubMed, Web of Science, and CNKI; and investigation reports from the CISDCP in Zhejiang Province and the CFETP) to perform sensitive analyses. Funnel plots were produced to detect publication bias. Statistical analyses were performed using SAS 9.2 software (SAS Institute Inc., Cary, NC, USA) and RevMan 5.3 software (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

Results

We identified 1985 articles from CNKI, 195 articles from PubMed, and 60 articles from Web of Science using the above search protocol. After removing 52 duplicates, we screened 2188 articles and retrieved 258 articles by reading titles and abstracts. Nineteen reports from CISDCP in Zhejiang Province and 74 reports from CFETP were also identified from titles. Then full texts were reviewed, reference lists or relevant reviews were screened, and repeated reports and low-quality articles were excluded. Ultimately, 85 studies were included (Fig. 1). Among the reported waterborne disease outbreaks, 23 outbreaks were in primary schools, 55 were in secondary schools, and 5 were in primary and

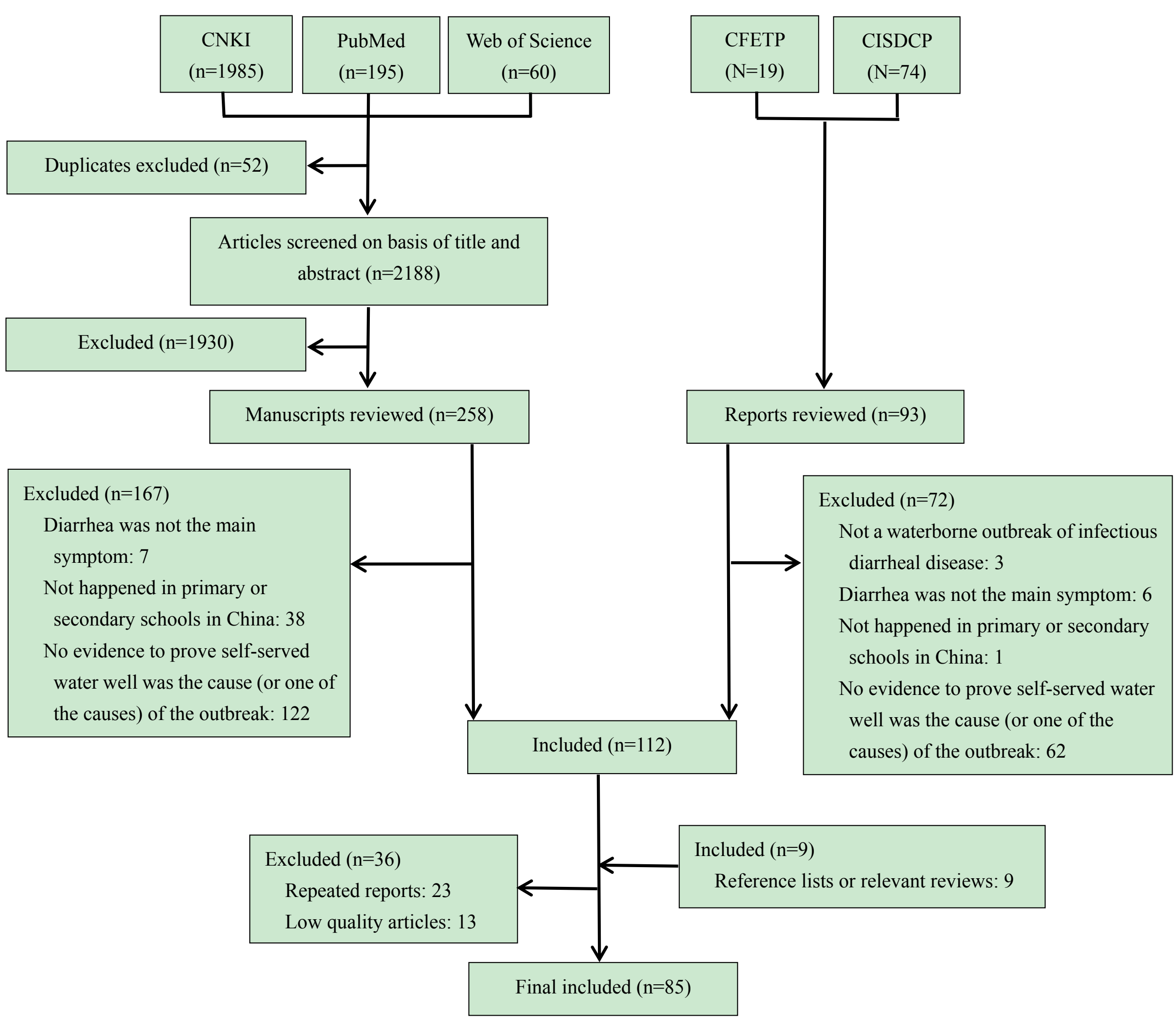

Fig. 1. Flow diagram of study selection. CFETP: Chinese Field Epidemiology Training Program; CISDCP: China Information System for Disease Control and Prevention; CNKI, China National Knowledge Infrastructure.

secondary schools; 53 outbreaks happened in rural areas and 18 in urban areas. The most common bacterial pathogens were *shigella* and pathogenic *Escherichia coli*, and the most prevalent viral pathogen was norovirus (eTable 1).

Attack rate

Attack rates were reported in all studies and ranged from 0.24 to 60.71 cases/100 persons. The median attack rate was 9.37 (95% CI, 7.96–11.09) cases/100 persons. Attack rates in 53 outbreaks occurring in rural areas ranged from 0.24 to 60.71 cases/100 persons (median, 12.63; 95% CI, 9.60–15.64 cases/100 persons), and those in 18 outbreaks occurring in urban areas ranged from 1.21 to 38.06 cases/100 persons (median, 5.61; 95% CI, 3.91–8.65 cases/100 persons). Wilcoxon signed-rank test showed that the attack rates in rural areas were significantly higher than those in urban areas ($Z = -2.88$, $P = 0.004$). Attack rates in 23 outbreaks in primary schools and in 55 in secondary schools ranged from 1.70 to 60.71 cases/100 persons (median, 14.54; 95% CI, 8.56–21.53 cases/100 persons) and 0.24 to 58.63 cases/100 persons (median, 8.74; 95% CI, 5.61–10.81 cases/100 persons), respectively; the attack rates in secondary schools were much lower than those in primary schools ($Z = 2.50$, $P = 0.013$). No differences existed across different geographic regions ($P = 0.148$). No correlation between report interval or number of interventions and attack rate was found (Table 1).

Duration of outbreak

Seventy-two studies reported the durations of outbreak, which ranged from 3 to 43 days, with a median of 8 (95% CI, 7–9) days. The durations of outbreak ranged from 3 to 31 days (45 studies; median, 8 days; 95% CI, 6–11 days) in rural areas and 4–17 days (17 studies; median, 8 days; 95% CI, 6–8 days) in urban areas, and no significant difference was found ($Z = -0.62$, $P = 0.537$). Twenty-one outbreaks in primary schools and 47 in secondary schools reported durations of outbreak, which ranged from 3 to 43 days (median, 7 days; 95% CI, 5–9 days) and 3–24 days (median, 8 days; 95% CI, 7–9 days), and there was no significant difference ($Z = -0.73$, $P = 0.460$). No difference existed among different geographic regions ($P = 0.592$). Correlation analyses indicated that report interval was related to duration of outbreaks ($r = 0.829$, $P < 0.001$), but number of interventions was not ($P = 0.293$) (Table 1).

Pathogens

In 40 investigations, *shigella* was detected in the anal swabs or stool samples of the patients or the water samples of the wells. The main strains were *Shigella sonnei* and *Shigella flexneri*. Attack rates differed in these investigations, which ranged from 1.21 to 46.39 cases/100 persons. Six investigations reported norovirus as the pathogen, with attack rates ranging from 1.84 to 47.71 cases/100 persons. Two investigations detected genotypes: one was GII, and the other was GI and GII. Pathogenic *E. coli* was detected in eight investigations, and the attack rates ranged from 5.61 to 27.91 cases/100 persons. Additionally, 15 investigations reported total bacterial count and/or *coliform* groups exceeding the Sanitary Standard for Drinking Water in China (GB5749-85 before 2006: Total bacterial count ≤100 colony-forming units [CFU]/mL, total *coliform* group ≤3 CFU/L; or GB5749-2006 after 2006: Total bacterial count ≤100 CFU/mL, total *coliform* group not detected), without any other pathogens detected. The attack rates were 0.24–58.63 cases/100 persons (eTable 1).

Table 1
Correlation between attack rate/duration of outbreak and some characteristics of outbreaks.

	Report interval			Number of interventions		
	Number of studies	r	*P*	Number of studies	r	*P*
Attack rate	42	0.028	0.862	47	0.029	0.848
Duration of outbreak	35	0.829	<0.001	45	−0.160	0.293

Sanitary condition and risk factors

Most of the included studies (78 of 85) reported sanitary condition of water wells. The most common conditions were that lavatories or septic tanks could be found nearby (reported in 30 investigations), or broken sanitary sewers were built nearby (reported in 29 investigations), and spilled waste water infiltrated the wells. Garbage heaps and pigpens were reported near the wells in ten and eight investigations, respectively. Twenty-six investigations revealed unreasonable construction of the water wells, such as low-lying placement, damaged side walls, and lack of protection and partition. Further, it was revealed that many wells lacked sterilizing facilities, or the sterilizing facilities were not utilized properly and regularly (reported in 32 investigations) (Fig. 2). Among 78 articles, 18 outbreaks were in urban areas and 47 were in rural areas (rural or urban status was not reported in 13 outbreaks); 14, 39, 17, and 8 outbreaks were in central, eastern, western, and northeastern China, respectively. Although the proportions of outbreaks with unsanitary lavatories/septic tanks and nearby garbage heaps in urban areas were slightly higher than in rural areas and the proportions of broken sanitary sewers in rural areas were slightly higher than in urban areas, no great difference existed between rural and urban areas (Fig. 3). In central China, sanitary conditions of pigpens were more often found near the outbreak sites than other regions; while in western China, broken sanitary sewers were more common and lavatories/septic tanks were less common compared to other regions. The most common condition in northeastern China was unreasonable construction of wells, which was reported by 50% of the studies; in eastern China, the most common conditions were lavatories/septic tanks nearby and lack of sterilizing facilities (Fig. 4). These poor sanitary conditions place well water at a high risk of contamination, and using contaminated water as domestic water can increase the hazard of infection. Fifty-three articles mentioned that some students had the habit of drinking unboiled water, and 22 studies conducted epidemiological investigations and found that drinking unboiled water was a risk factor for disease.

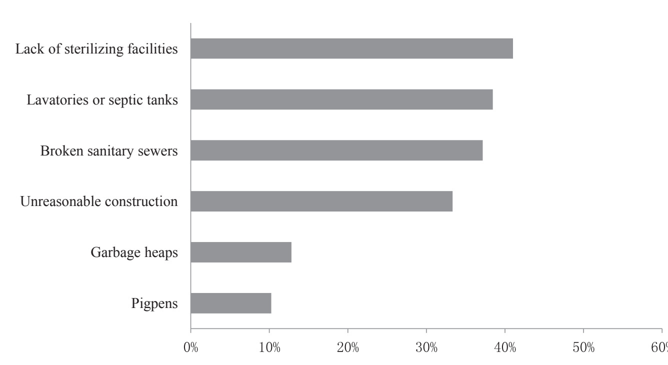

Fig. 2. Proportions of sanitary conditions of wells and its surroundings.

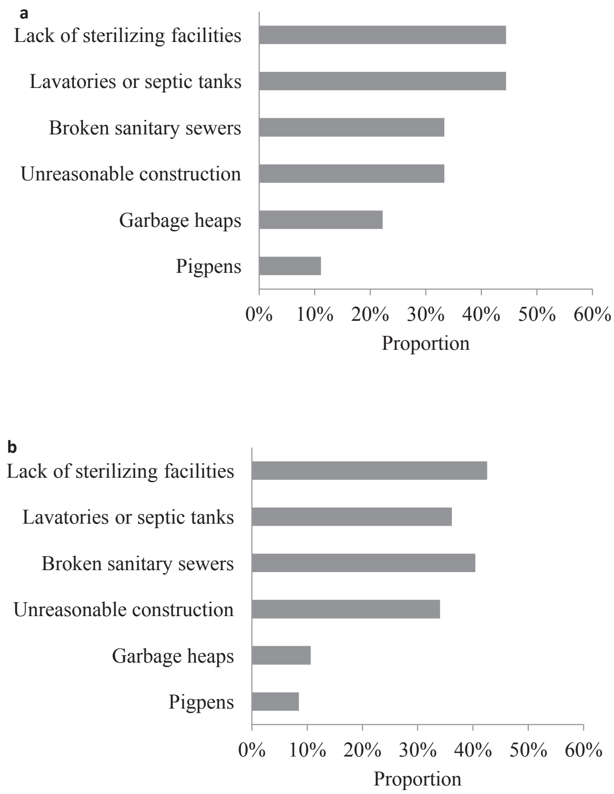

Fig. 3. Proportions of sanitary conditions of wells and its surroundings in a) urban areas and b) rural areas.

Sex-specific susceptibility and age-specific susceptibility

Among the included studies, 32 investigations with 3920 cases reported attack rates separately for boys and girls. The pooled ARR (male vs. female) was 1.13 (95% CI, 1.00–1.29, $P = 0.05$). Significant heterogeneity existed between studies ($I^2 = 64\%$, $P < 0.001$) (Fig. 5). Significant results in the 18 high-quality investigations were also found, in which the pooled ARR (male vs. female) was 1.22 (95% CI, 1.01–1.46; $I^2 = 68\%$, $P < 0.001$). The pooled ARR (male vs. female) across 22 published articles was 1.20 (95% CI, 1.00–1.43, $P = 0.04$; $I^2 = 73\%$, $P < 0.001$), and the pooled ARR in 10 investigation reports retrieved from the CISDCP and CFETP was 1.01 (95% CI, 0.89–1.15; $I^2 = 0\%$, $P = 0.61$). The pooled ARR (male vs. female) across 18 investigations in rural areas was 1.08 (95% CI, 0.95–1.24; $I^2 = 49\%$, $P = 0.009$), and the pooled ARR (male vs. female) from 10 investigations in urban areas was 1.44 (95% CI, 1.01–2.07; $I^2 = 81\%$, $P < 0.001$). The pooled effects for investigations that detected *shigella* (17 reports), norovirus (3 reports), and pathogenic *E. coli* (4 reports) as pathogens were 1.02 (95% CI, 0.93–1.12; $I^2 = 15\%$, $P = 0.28$), 1.11 (95% CI, 0.83–1.48; $I^2 = 0\%$, $P = 0.98$), and 1.03 (95% CI, 0.89–1.20; $I^2 = 0\%$, $P = 0.49$), respectively, with remarkably decreased heterogeneity, although the results were statistically insignificant. Twelve investigations with 1580 cases reported attack rates by school grades. The result was not significant (ARR [junior vs. senior] 1.16; 95% CI, 0.81–1.67), and great heterogeneity existed ($I^2 = 87\%$, $P < 0.001$) (Fig. 6). The analysis restricted to eight high-quality investigations also did not show any significant results (ARR [junior vs. senior] 1.33; 95% CI, 0.96–1.86; $I^2 = 75\%$, $P < 0.001$). The pooled ARR (junior vs. senior) across nine published articles was 1.19 (95% CI, 0.75–1.87; $I^2 = 89\%$, $P < 0.001$), and that across three investigation reports from the CISDCP and CFETP was 1.08 (95% CI, 0.56–2.11; $I^2 = 82\%$, $P = 0.004$). Funnel plots of sex-specific susceptibility and age-specific susceptibility did not reveal publication bias (not shown).

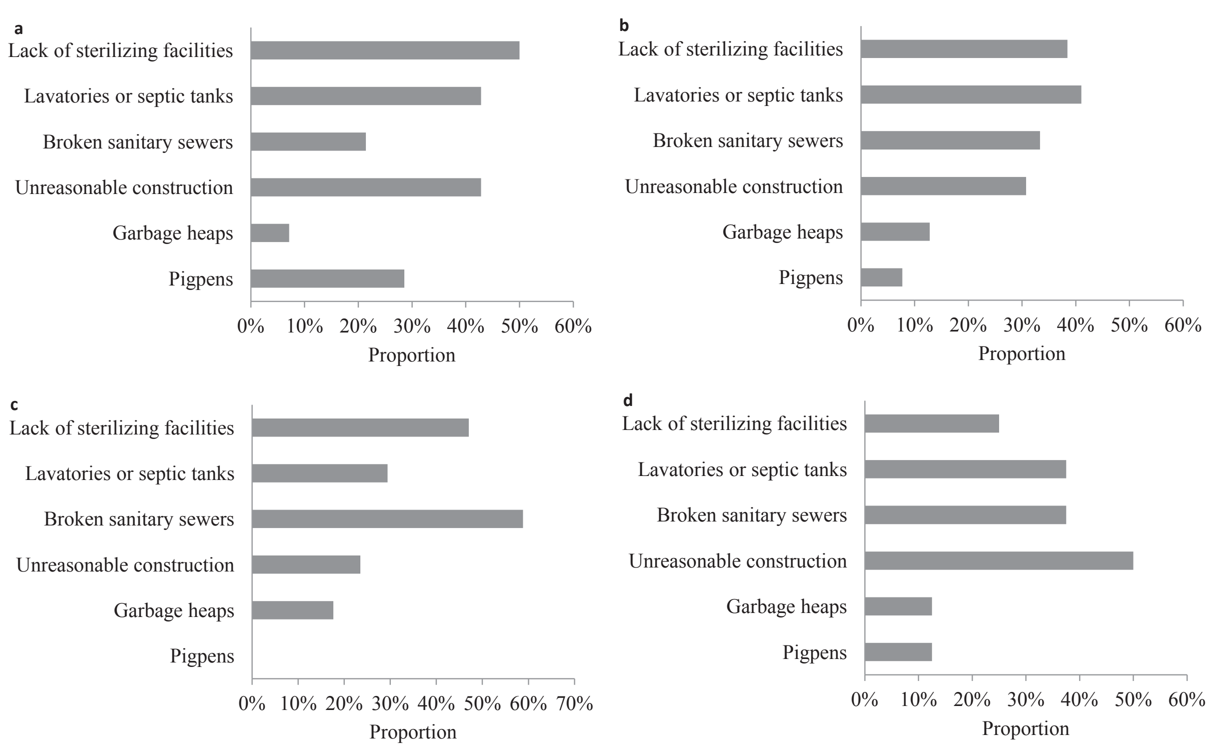

Fig. 4. Proportions of sanitary conditions of wells and its surroundings in a) central China, b) eastern China, c) western China, and d) northeastern China.

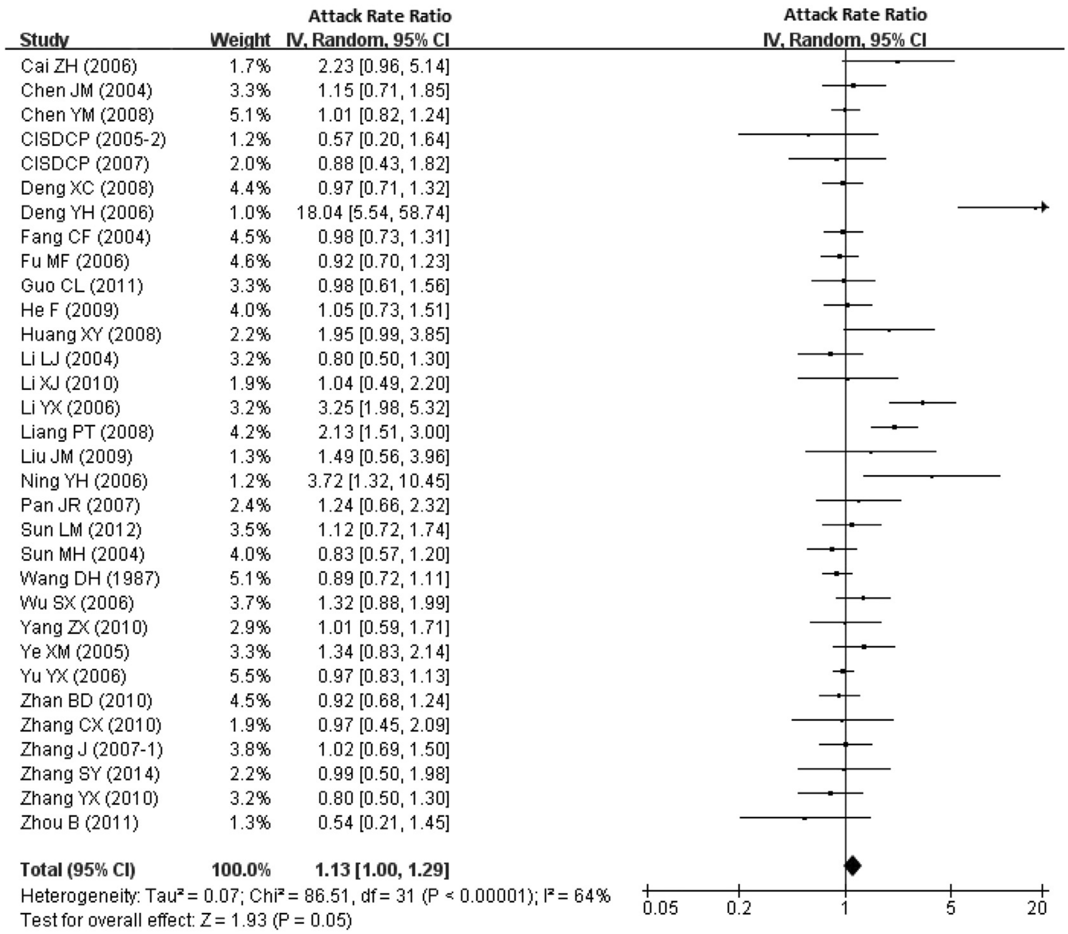

Fig. 5. Forest plot of male:female attack rate ratio. Attack rate: the number of new cases divided by the number of persons at risk during the whole outbreak.

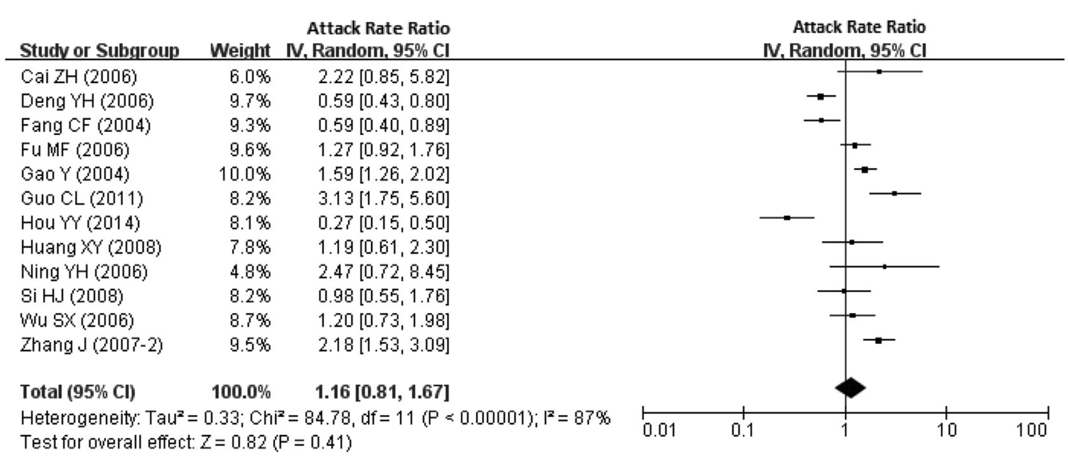

Fig. 6. Forest plot of junior:senior attack rate ratio. Attack rate: the number of new cases divided by the number of persons at risk during the whole outbreak.

Discussion

Waterborne outbreaks of infectious diarrheal disease in schools possessed a various characteristics because of a wide range of outbreak severity and diversified pathogens. In this review, the attack rates and durations of outbreak caused by contaminated well water were found to range widely. Outbreaks in rural areas had higher attack rates than those in urban areas, and the attack rates in secondary schools were lower than those in primary schools. The most common pathogens were *shigella*, pathogenic *E. coli*, and norovirus. Unsanitary conditions of water wells, such as being close to lavatories or septic tanks, broken sanitary sewers, garbage heaps, and pigpens; unreasonable construction; and lack of sterilizing facilities, put water sources at risk of contamination. The habit of drinking unboiled water is common among students and is frequently reported as a risk factor of infection.

In the present study, we found a wide range of attack rates, which can be partially attributed to the disparities of drinking water sources and sanitation across areas. In China, sanitary conditions vary markedly throughout the country,[3] as well as between rural and urban areas.[4,19] Moreover, in rural areas, disparities also exist in coverage rates of improved sanitation across socioeconomic groups.[20] Therefore, different population groups bear different risk of waterborne disease. Our results also revealed that attack rates in rural areas were higher than those in urban areas, indicating that rural students may be particularly vulnerable to infectious diarrheal diseases transmitted via contaminated well water. Although rural areas are likely to lack a safe water supply, the condition of urban areas is also concerning. In the past three decades, China's rapid urbanization and rural-to-urban migration has led to rapid growth of the number of cities and the urban population, which has resulted in water scarcity in some urban areas.[21] This scarcity is one of the reasons that some schools in urban areas still use well water as a water source.

Well water is a common water source in underdeveloped areas.[4] Several included investigations in the present review mentioned that some schools had access to tap water, while the common condition was that well water was used because the tap water source was not enough to supply all the students.[22–24] Additionally, dry latrines, septic tanks without covers, and fecal sewage drained directly into ponds and rivers were common in many areas.[8] The present study revealed that lavatories or septic tanks and broken sanitary sewers close to water wells were the major causes of contamination; unreasonable construction of the water wells and seasonal rainfalls facilitated contamination, and lack of sterilization facilities contributed to infection. Differences existed across different geographic regions, which could be attributed to different climate features and economic development. Eastern China is more humid, developed and has a large population, while western China is arid and dry latrines are common. However, since the sample size in each region was small, the proportions of each sanitary condition may not accurately reflect the regional distributions. Therefore, it is difficult to draw conclusions about regional differences.

Our results showed boys had higher attack rates than girls. Sensitive analysis in high-quality articles also confirmed these sex differences. Stratified analysis by pathogens showed remarkably decreased heterogeneity, indicating that heterogeneity mainly existed across outbreaks caused by different pathogens. The higher attack rates in boys might be attributed to behavior differences between boys and girls. Men are inclined to engage in health-damaging behaviors, while women tend toward health-protecting behaviors, which is due to cultural prescriptions for both genders.[25] Therefore, boys might be more likely to have unhygienic habits than girls, such as drinking unboiled water, washing hands infrequently, and not using soap to wash hands. Drinking unboiled water seemed to be the major unhealthy behavior responsible for the sex difference in attack rates, since many of the included papers conducted epidemiological investigations and found that drinking unboiled water was a risk factor for infectious diarrhea. However, no articles investigated or reported the reason for gender difference in attack rates. Further research is needed to confirm the results. This review did not find any difference in attack rates between seniors and juniors, indicating that school students share the same vulnerability to infectious diarrhea transmitted via well water. The lack of difference by school grade category may be due to the slight age difference between seniors and juniors, and because school-age children possess similar immunity and behavioral characteristics.

Shigella, pathogenic *E. coli*, and norovirus were the most common pathogens in diarrheal disease outbreaks caused by well water in schools. Bacterial agents were more dominant than viral agents. It is not surprising that several investigations have not detected the pathogen, since many challenges exist in waterborne pathogen detection, such as physical differences between pathogens, low concentration of pathogens, impurity and co-concentrated inhibitors processing. Further, no single method can cover the collection, processing, and analysis of a water sample for all pathogens,[26,27] so pathogen detection is technologically limited. Pathogen detection is also time-consuming and costly, while common interventions, like patient isolation, water source disuse, and environment disinfection, are efficient and convenient in quick control of outbreak. Additionally, epidemic investigation is quicker than pathogen detection to identify the possible source of a pathogen. Thus, pathogen detection was limited to some extent in China. Fast, cheap, and convenient diagnostic technologies of pathogens are needed.

We found that the celerity of detecting and responding was critical to control waterborne outbreaks of infectious diarrheal disease, because the duration of outbreaks was highly related to report interval. As mentioned in one included article,[28] in some cases the epidemic situation cannot be reported to local CDCs or local health departments in time, since some school leaders and teachers are not aware of the severity of the disease. Quick reporting always means quick control,[29] and this may be a good aspect to concentrate on to decrease outbreak severity. Our analyses did not find associations between the number of interventions and attack rates/durations of outbreak. These findings are reasonable because interventions are only involved in the second half of the outbreaks and severity of outbreak is mainly determined by virulence of pathogens, immune state of hosts, and transmission conditions. The associations between the number of interventions and outbreak severity may be influenced by confounders. However, interventions are clearly important in outbreak control. An investigation in China showed combined usage of interventions like isolation, antibiotics, prophylactics, and water disinfection was predicted to lower the attack rate and duration of diarrheal outbreak,[30] indicating the crucial role of interventions on quick control. Preventive interventions were also very important to prevent diarrhea outbreaks. Systematic reviews have revealed that water, sanitation, and hygiene interventions (e.g., handwashing with soap), improved water quality, and excreta disposal were all helpful in reducing the risk of diarrhea and were recommended, especially in less developed countries.[31,32] Handwashing promotion programs and health education are cost-effective, widely available interventions to implement among school children.[33,34] Prevention and control of infectious diarrheal disease outbreaks in schools is not only a problem in China, but also in many developing countries or even in developed areas. These preventive and control interventions have great health implications in coping with infectious diarrheal disease.

This review has several limitations. First, substantial variation existed in case definition. The diagnostic criterion of infectious diarrheal disease was: patients had diarrhea $\geq$ three times per day, and this necessary criterion may be accompanied by abdominal distension, abdominal pain, nausea, vomiting, fever, chills, or tenesmus. However, some studies did not provide any diagnostic criteria. Thus, we could not ensure the accuracy of case definition in all included papers. Second, since we only have the access to the data of Zhejiang Province in the CISDCP, the data from other provinces were more likely to be missing than those from Zhejiang Province. Therefore, selection bias may exist. Third, differences of details existed across the data derived from published articles, CISDCP, and CFETP, so potential information bias might be unavoidable. Though sensitive analyses were conducted, conclusions should be drawn cautiously. In addition, lack of reporting details also limited detailed analyses. Out of the 85 included reports, 40 were outbreak investigations, which were descriptive studies without any epidemiological analyses. Besides the incomplete information of areas, attack rates, pathogens, and durations of outbreak, we also lacked information on illness severity, outbreak severity, effects of interventions, and factors influencing them. As a result, in-depth analyses were precluded. Only 32 investigations reported attack rates by sex, and only 12 investigations reported rates by grade, so we could not make definitive conclusions about sex-specific or age-specific susceptibility. Fourth, this review also suffered from inaccuracy of outbreak data. The attack rates and outbreak severity were probably underestimated because of under-reporting. The school-age population might be more vulnerable than indicated.

More attention should be paid to access to safe water for school children, especially for those in rural areas. We recommend that the Chinese government make great efforts on water improvement in schools and provide tap water to school children as far as possible. Well water in schools should be inspected and disinfected regularly, and improperly constructed water wells should be abandoned or reconstructed. Lavatories, septic tanks, garbage heaps, and pigpens close to drinking water sources should be removed to avoid contaminating water source. Health education promotion is essential to make children aware of hand hygiene and encourage them to drink boiled water. Additionally, school leaders and teachers should be responsible for the health of students and act to reduce the potential risk of infectious diarrhea outbreaks with the least possible delay. We also hope the present study could provide reference and experience to other countries and regions for prevention and control of waterborne outbreaks in schools.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors. This study has been approved by the Ethics Committee of Zhejiang Provincial Center for Disease Control and Prevention.

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Conflicts of interest

None declared.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.je.2016.07.006.

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