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Did a Severe Flood in the Midwest Cause an Increase in the Incidence of Gastrointestinal Symptoms?

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Severe flooding occurred in the midwestern United States in 2001. Since November 2000, coincidentally, data on gastrointestinal symptoms had been collected for a drinking water intervention study in a community along the Mississippi River that was affected by the flood. After the flood had subsided, the authors asked these subjects (n = 1,110) about their contact with floodwater. The objectives of this investigation were to determine whether rates of gastrointestinal illness were elevated during the flood and whether contact with floodwater was associated with increased risk of gastrointestinal illness. An increase in the incidence of gastrointestinal symptoms during the flood was observed (incidence rate ratio = 1.29, 95% confidence interval: 1.06, 1.58), and this effect was pronounced among persons with potential sensitivity to infectious gastrointestinal illness. Tap water consumption was not related to gastrointestinal symptoms before, during, or after the flood. An association between gastrointestinal symptoms and contact with floodwater was also observed, and this effect was pronounced in children. This appears to be the first report of an increase in endemic gastrointestinal symptoms in a longitudinal cohort prospectively observed during a flood. These findings suggest that severe climatic events can result in an increase in the endemic incidence of gastrointestinal symptoms in the United States.

communicable diseases; diarrhea; gastrointestinal tract; natural disasters; water

Abbreviations: CI, confidence interval; IRR, incidence rate ratio; RDD, random digit dialing; WET, Water Evaluation Trial.

While there is clear potential for increased transmission of infectious gastrointestinal illness following flooding (1–3), there is little direct epidemiologic evidence of this association. Attempts to study increases in the rates of illness in communities affected by a flood have been limited by the lack of accurate or comparable illness incidence data from the period before the flood, making quantification of the impact of the flood difficult or impossible.

In the United States, reports of outbreaks of or increases in illness following a flood are rare. Epidemiologic investigations following massive flooding in the Midwest in 1993 found no evidence of outbreaks or increased levels of gastrointestinal illness, and no mortality associated with gastrointestinal symptoms was identified (4, 5). However, a recent analysis of the occurrence of waterborne disease outbreaks in the United States found that such outbreaks were likely to be preceded by periods of extreme precipitation (6). In these outbreaks, the route of exposure was ingestion of contaminated drinking water, and the rainfall or flooding probably washed contamination into water sources.

Severe flooding occurred in the midwestern United States during April and May of 2001. At the time of the flooding, a randomized trial of in-home drinking water treatment (the Water Evaluation Trial or "WET" Study) was being conducted in a community along the Mississippi River. As part of this study, household members completed daily

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diaries detailing their incidence of gastrointestinal symptoms. This allowed us to evaluate the impact of flooding on the incidence of gastrointestinal symptoms.

The principal objectives of this investigation were to determine whether rates of gastrointestinal symptoms were elevated during the flood and whether contact with floodwater was associated with increased risk of gastrointestinal symptoms.

MATERIALS AND METHODS

The WET Study

Rates of gastrointestinal symptoms were determined from subjects enrolled in the WET cohort. Enrollment in the WET Study began in fall 2000, and enrollment was completed in May 2001. Follow-up of the WET cohort was completed on June 29, 2002. A total of 456 households (1,296 persons) were enrolled, and the follow-up period was 1 year. In brief, each household was randomly assigned to receive either an active water treatment device or an outwardly identical inactive (placebo) device installed at the kitchen tap. After 6 months, the devices were removed, and after a 1-week washout period, the devices were replaced with a device of the alternate type. Subjects maintained a daily health diary and recorded any occurrence of gastrointestinal symptoms (diarrhea, vomiting, nausea, or abdominal cramps). The WET cohort was restricted to persons without serious immune-compromising conditions (i.e., human immunodeficiency virus/acquired immunodeficiency syndrome) and residents whose source of home tap water was municipal water.

Immediately following the flood, subjects were sent a survey asking them about the extent to which they had come into contact with floodwater or flood-contaminated items. Questions about contact included the extent to which subjects had walked through, played in, touched, or been directly exposed to floodwater, participated in flood control activities (i.e., sandbagging), and cleaned up flood-contaminated items.

Water quality data were provided to investigators by the local water utility. Additional water quality data were also collected and provided to the investigators by American Water as part of a related study. Source water was tested weekly for *Cryptosporidium parvum* by both cell culture/polymerase chain reaction (7) and filtration/microscopy using Method 1623 (8). The raw-water occurrence of *Giardia* subspecies was evaluated weekly by filtration/microscopy using Method 1623 (8). The recovery efficiency for the cell culture/polymerase chain reaction test averaged 52.2 percent (standard deviation, 39.2) ($n = 7$). The recovery efficiencies for *Giardia* and *Cryptosporidium* using Method 1623 were 38.0 percent (standard deviation, 26.8) and 52.7 percent (standard deviation, 35.0), respectively ($n = 9$). Male-specific coliphages were enumerated weekly using the single agar overlay method, and culturable enteric viruses were enumerated in raw and finished water monthly with the buffalo green monkey cell line, using methods proposed by the Environmental Protection Agency for water and wastewater (9). Numbers of total and fecal coliforms in raw and finished (treated) water were analyzed using standard membrane filter methods (10). Full details on the water quality monitoring program have been presented by LeChevallier et al. (11).

Telephone survey

Concurrently with the WET Study, a random digit dialing (RDD) telephone survey was conducted in the study area. Survey data from 3,506 respondents were available for analysis. The goal of the survey was to obtain population-based estimates of the use of various home water treatments, water consumption, and the monthly occurrence of gastrointestinal illnesses. Following the flood, questions were added for assessment of the frequency with which respondents came into contact with floodwater and flood-contaminated items. The sampling frame was defined by the zip codes for the communities participating in the WET Study. Once a household had been contacted, one subject from the household was selected at random using a household roster. Parents or guardians were asked to complete surveys for children aged ≤12 years. Results from the RDD survey were used to determine the population attributable risk percentage (12) and to estimate the total number of cases of gastrointestinal symptoms in the community attributable to contact with floodwater. Because the RDD survey did not collect detailed data on daily incidence of symptoms, the results were used to calculate population attributable risks but were not used to determine the impact of flooding on symptom rates.

Outcome definition

Symptom rates were determined for the WET cohort by season and for the flood period. The primary symptom outcome, "highly credible gastrointestinal symptoms," was defined as the occurrence of any of the following during a single 24-hour period: vomiting, liquid diarrhea, diarrhea (not liquid) with cramps, or nausea with cramps. This definition is consistent with previously published work (13–15). A secondary outcome was a more specific definition of diarrhea: three or more loose stools during a single 24-hour period. For an instance of diarrhea to be considered a unique episode, six consecutive symptom-free days were required. Other secondary outcomes evaluated included number of days hospitalized for gastrointestinal symptoms; visits to a health care provider for diarrhea; severe diarrhea (six or more loose stools in 24 hours); and number of days of work or school missed because of gastrointestinal symptoms.

Data analysis

The flood period was defined as the period between April 14, 2001, and May 30, 2001. This period included the time during which the Mississippi River was above the 15-foot (4.6-m) flood stage and 1 additional week to account for the incubation periods of some gastrointestinal pathogens. Counts of episodes, symptoms, and person-time were collapsed for each subject by season and flood period, so that each subject with complete data had five observations (one for each of the four seasons and one for the flood period).

Note that seasonal data included combined observations for two seasons for the follow-up period between fall 2000 and spring 2002, with the exception of summer, for which data were only available for 2001.

The outcome of interest was number of gastrointestinal symptom episodes. A variable indicating the flood period was the primary independent variable of interest. Poisson extensions of generalized estimating equations (16) were used to model the outcome and to account for the multiple-correlation structure. Models were fitted with an exchangeable (i.e., equal) correlation structure with robust specification for the standard error. The household was the unit of nonindependence (i.e., models were clustered on household). Since gastrointestinal illness has a distinct seasonal component (17), indicator variables for season (spring, summer, fall, winter) were included in all models. Other covariates included in the model were indicators for cycle (first or second 6-month cycle) and type of water treatment device (active or placebo). Models were offset by the person-time contribution of each individual. Incidence rate ratios (IRRs), defined as the rate in the exposed divided by the rate in the unexposed, were estimated directly from the models by exponentiating the coefficients.

All analyses were conducted using Stata 7.0 (18). Graphs were created in S-Plus, version 4.5 (19).

All protocols, consent forms, and study materials for the randomized trial and the RDD survey were reviewed and approved by the institutional review boards of the University of California, Berkeley, the state of California, and the Centers for Disease Control and Prevention. Subjects enrolled in the randomized trial signed a written consent form, and RDD respondents consented verbally.

RESULTS

Flood description

Late, rapid snowmelt combined with heavy rain caused severe flooding throughout the Midwest in spring 2001. Flooding occurred in Minnesota, Wisconsin, North Dakota, Iowa, and Illinois, primarily along the Mississippi River and its tributaries.

Flooding began in the study area when the Mississippi River reached the 15-foot flood stage of the study community on April 15. The river remained above flood stage through May 23. The flood crested in the study area at 22.33 feet (6.85 m) on April 24, the third-highest level in recorded history (20). The river receded below flood stage on May 23. During part of this time, sewage treatment processes were bypassed, and untreated sewage and wastewater were discharged directly into the river at the study site as well as upstream and downstream (21).

During the flood, there was marked deterioration in source water quality, as illustrated by coliform levels in the source water (figure 1). Source water concentrations of *Giardia* cysts increased 330 percent (mean = 0.4 cysts/liter during the flood), and concentrations of male-specific coliphages increased 270 percent (mean = 11.6 plaque-forming units/100 ml during the flood) during this period. However, *Cryptosporidium* subspecies oocysts and culturable viruses were not detected in the source water. Despite the source water conditions during the flood, treated water continued to meet all regulatory standards for quality. Additional measures taken by the local water utility to ensure that treated water was safe included the addition of extra chlorine (hyperchlorination) and additional monitoring for water quality indicators and pathogens. The individual filter turbidities and combined filter effluent turbidities were consistently less than 0.1 nephelometric turbidity units during this period. The plant effluent was consistently free of coliforms, *C. parvum*, and viruses. No "boil water" alerts were issued for persons using municipal water (22).

Rates of gastrointestinal symptoms

Health data were available for 1,257 (from 445 households) of the 1,296 subjects enrolled in the WET cohort (the remaining subjects enrolled in the WET cohort did not return health diaries because they dropped out or were noncompliant). These subjects contributed a total of 1,116 person-years of observation. Of these, 1,204 subjects (contributing 130 person-years of observation) were enrolled in the WET Study at the time of the flood. The remaining subjects who were not enrolled during the flood were retained in the analysis, since they represented unexposed persons.

Rates of highly credible gastrointestinal symptoms and diarrhea episodes among the WET participants were higher in winter than in any of the other seasons (table 1). Crude rates of both highly credible gastrointestinal symptoms and diarrhea were higher during the flood than in any other season, including winter. After adjustment for season, cycle, and device type, the number of episodes of highly credible gastrointestinal symptoms remained significantly elevated: Rates of highly credible gastrointestinal symptom episodes were 1.29 times higher during the flood than during the rest of the WET cohort follow-up period (95 percent confidence interval (CI): 1.06, 1.58). Numbers of diarrhea episodes were also elevated, although the 95 percent confidence interval included the no-effect value of 1 (IRR = 1.23, 95 percent CI: 0.94, 1.62).

Rates of the following conditions were not elevated during the flood period: diarrhea that resulted in a doctor's visit; days of missed work or school due to gastrointestinal symptoms; and days of vomiting. Six subjects were hospitalized for a total of 29 days during the flood for gastrointestinal conditions, but specific reasons for the hospitalizations were not available. Hospitalizations for gastrointestinal conditions were elevated during the flood (IRR = 8.10, 95 percent CI: 0.77, 85.01), but the 95 percent confidence interval included 1, probably because of the low statistical power resulting from the small number of hospitalizations.

Impact on sensitive individuals

To examine whether the impact of the flood was greater in certain potentially sensitive groups, we stratified the data in the models by age (≤12 years and ≥50 years), frequency of gastrointestinal symptoms during the past year, and the presence of a chronic gastrointestinal condition. A chronic gastrointestinal condition included any of the following: irri-

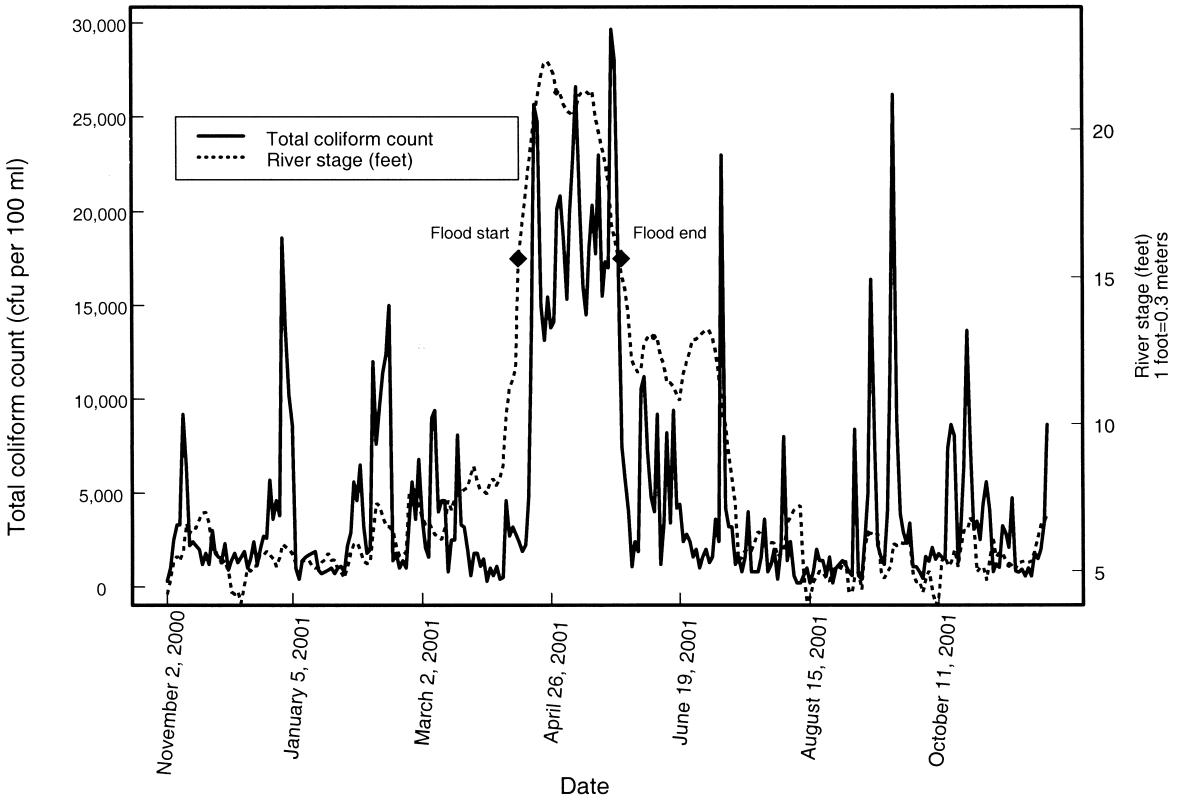

FIGURE 1. Total coliform counts in raw water from the Mississippi River, November 2000–November 2001. cfu, colony-forming units.

table bowel syndrome, lactose intolerance, diverticulitis, ulcerative colitis, and Crohn's disease. Table 2 shows IRRs for gastrointestinal symptoms for the flood period compared with the rest of the study period, stratified by these factors. As the table illustrates, the IRR for the flood was greater among persons who were potentially sensitive to gastrointestinal illness than among those who were not. For cases of severe diarrhea (six or more loose stools in 24 hours), the effect was even more pronounced among persons with chronic gastrointestinal conditions (IRR = 7.05, 95 percent

TABLE 1. Crude rates of gastrointestinal illness in the Water Evaluation Trial cohort, by season and during the 2001 flood, Mississippi River, 2001

	No. of illness episodes per year			
	Highly credible gastrointestinal symptoms*	95% CI†	Diarrhea‡	95% CI
Flood period§	2.82	2.54, 3.12	0.87	0.72, 1.05
Season				
Spring (excluding flood period)	1.95	1.74, 2.18	0.63	0.51, 0.77
Summer	2.07	1.91, 2.24	0.60	0.52, 0.70
Fall	1.64	1.40, 1.91	0.61	0.47, 0.70
Winter	2.19	2.06, 2.33	0.68	0.60, 0.76
IRR† (flood period vs. other times)¶	1.29	1.06, 1.58	1.23	0.94, 1.62

* "Highly credible gastrointestinal symptoms" included any of the following: liquid diarrhea, soft diarrhea and cramps, nausea and cramps, or vomiting.

† CI, confidence interval; IRR, incidence rate ratio.

‡ Three or more occurrences in a 24-hour period.

§ April 14, 2001–May 30, 2001.

¶ Results were controlled for cycle, water treatment device, season, and household clustering effects.

TABLE 2. Incidence rate ratios for interactions between chronic gastrointestinal conditions, health status, and flooding in the Water Evaluation Trial cohort, Mississippi River, 2001

	Highly credible gastrointestinal symptoms*		Diarrhea†		Severe diarrhea‡	
	IRR§	95% CI§	IRR	95% CI	IRR	95% CI
Chronic gastrointestinal condition¶						
Yes (n = 140)	1.47	1.00, 1.26	1.69	0.82, 3.49	7.05	0.80, 61.9
No (n = 1,112)	1.26	1.00, 1.57	1.15	0.84, 1.57	1.41	0.74, 2.69
Self-reported "frequent" gastrointestinal symptoms during the past year¶						
Yes (n = 70)	2.03	1.15, 3.57	2.78	1.05, 7.36	—#	
No (n = 1,182)	1.22	0.99, 1.50	1.10	0.83, 1.48	1.41	0.73, 2.72
Self-reported health status¶						
Excellent or very good (n = 934)	1.30	1.02, 1.66	1.18	0.82, 1.70	1.37	0.62, 3.03
Good, fair, or poor (n = 318)	1.25	0.91, 1.73	1.30	0.86, 1.97	2.57	1.03, 6.41
Age (years)						
≤12 (n = 307)	1.20	0.78, 1.85	0.91	0.41, 1.99	—#	
≥50 (n = 266)	1.47	1.01, 2.13	1.76		2.92	1.04, 8.25

* "Highly credible gastrointestinal symptoms" included any of the following: liquid diarrhea, soft diarrhea and cramps, nausea and cramps, or vomiting.

† Three or more loose stools in 24 hours.

‡ Six or more loose stools in 24 hours.

§ IRR, incidence rate ratio; CI, confidence interval.

¶ There were five missing values for this variable.

Model estimates did not converge; one or more of the parameter estimates were infinite.

CI: 0.80, 61.9). Severe diarrhea was also more frequent in persons with good, fair, or poor health than in those with excellent or very good health. IRRs were not elevated to a greater extent in children; however, persons aged ≥50 years had elevated rates of highly credible gastrointestinal symptoms (IRR = 1.47, 95 percent CI: 1.01, 2.13), and this was more pronounced for severe diarrhea (IRR = 2.92, 95 percent CI: 1.04, 8.25). The rate of highly credible gastrointestinal symptoms was elevated still further among persons aged ≥60 years (IRR = 1.89, 95 percent CI: 1.06, 3.38), but there were too few subjects to evaluate severe diarrhea in this age group.

Association between gastrointestinal symptoms and contact with floodwater

A total of 1,118 subjects in the WET cohort completed the flood survey, of whom 1,110 provided health data. Of the 1,118 participants, 143 (13 percent) reported some type of direct (e.g., touching or walking through floodwater) or indirect (e.g., cleaning up items contaminated by floodwater) contact with floodwater. Table 3 shows rates of highly credible gastrointestinal symptoms and IRRs related to the various types of flood exposure. Among all subjects, having the house or yard flooded was a strong risk factor for highly credible gastrointestinal symptoms. None of the other types of flood exposure were associated with symptoms among all subjects. Although few episodes of diarrhea occurred during the flood, the IRR estimate for those whose homes or yards were flooded was similar to that for highly credible gastrointestinal symptoms (IRR = 2.41, 95 percent CI: 0.84, 6.94).

Among children aged ≤12 years, all types of flood contact were associated with elevated IRRs, with the exception of having a septic tank on the home property (table 3). Living in a home where the house or yard was flooded was significantly associated with highly credible gastrointestinal symptoms among children aged ≤12 years (IRR = 2.42, 95 percent CI: 1.22, 4.82), and the IRR for any flood contact was of borderline significance (IRR = 1.90, 95 percent CI: 0.93, 3.85). The association between highly credible gastrointestinal symptoms and any flood contact was even more pronounced among children aged ≤5 years (eight exposed children; IRR = 3.18, 95 percent CI: 1.79, 5.66). No episodes of diarrhea were experienced by children aged ≤12 years during the flood among those exposed to floodwater.

There were few data for persons aged ≥50 years, but symptom rates were elevated among those who had had any flood contact (23 persons exposed; IRR = 1.46, 95 percent CI: 0.65, 3.27) and among those whose homes or yards had been flooded (five persons exposed; IRR = 6.20, 95 percent CI: 3.34, 11.51).

Among persons with potential sensitivity to gastrointestinal illness, those in excellent or very good health who had had any contact with floodwater had slightly lower relative rates of gastrointestinal symptoms (IRR = 1.08, 95 percent CI: 0.82, 1.43) compared with those in good, fair, or poor health (IRR = 1.39, 95 percent CI: 0.94, 2.95). IRRs for any contact with floodwater were similar among persons with and without chronic gastrointestinal conditions and among

TABLE 3. Relation between contact with floodwater and flood-contaminated items and gastrointestinal illness in the Water Evaluation Trial cohort, Mississippi River, 2001*

Exposure	All subjects				Children aged ≤12 years			
	No. exposed (n = 1,110)	%	IRR†	95% CI†	No. exposed (n = 266)	%	IRR	95% CI
Floodwater touching any part of body	56	5	0.79	0.35, 1.75	11	4	1.59	0.51, 4.90
Walking through floodwater	37	3	1.13	0.66, 1.94	5	2	1.94	0.26, 14.4
Sandbagging (during flood)	89	8	0.83	0.53, 1.31	12	5	1.91	0.70, 5.18
Participating in flood cleanup	22	2	0.32	0.08, 1.27	2	1	1.40	1.07, 1.82
House or yard getting flooded	31	3	2.36	1.37, 4.07	13	5	2.42	1.22, 4.82
Any flood exposure‡	153	14	1.14	0.80, 1.63	29	11	1.90	0.93, 3.85
Septic tank on the home property	50	5	1.17	0.64, 2.12	10	4	0.66	0.20, 2.13

* Categories are not mutually exclusive.
† IRR, incidence rate ratio; CI, confidence interval.
‡ Includes having one's home or yard flooded, touching an object that was in contact with floodwater, walking through floodwater, sandbagging, touching floodwater with any body part, or cleaning up objects contaminated by floodwater.

persons who reported gastrointestinal symptoms at baseline. Relevant covariates that potentially could have confounded the association between floodwater contact and gastrointestinal symptoms for which data were available included age, sex, self-rating of health, and presence of a chronic gastrointestinal condition. For highly credible gastrointestinal symptoms, separate models including these covariates were fitted for each of the types of flood exposure (small numbers of illnesses prevented complete multivariate analyses for diarrhea as the outcome and for children aged ≤12 years). Inclusion of covariates did not have an impact on the estimated IRR for contact with floodwater.

Cases of illness attributable to flood contact

Using the population data collected from the RDD telephone survey, we were able to estimate the actual numbers of illnesses caused by the flooding. These calculations assumed that the observed increase in symptoms was, in fact, due to the flood and not a result of underlying differences between the exposed and unexposed groups. Eleven percent of the RDD survey respondents aged ≥12 years reported at least some contact with floodwater or flood-contaminated items. These children had rates of gastrointestinal symptoms 1.9 times greater than those of children whose homes or yards were not flooded. From these figures, it can be estimated that 9 percent of episodes of highly credible gastrointestinal symptoms among children aged ≤12 years during the flood were attributable to contact with floodwater (population attributable risk percentage (12)). Using the incidence rate in unexposed children aged ≤12 years (2.47 episodes per person-year) and 2000 US Census figures of a total population of approximately 159,000 in the study county, approximately 20 percent of whom are children aged ≤12 years (23), an estimated total of 6,546 highly credible gastrointestinal symptom episodes occurred among children aged ≤12 years during the 1-month flood period. Approximately 589 of these episodes ($0.09 \times 6{,}456$) can be attributed to exposure to floodwater and flood-contaminated items.

Two percent of all respondents in the RDD survey reported having their house or yard flooded. Using the same calculations as above, an estimated 202 excess episodes of highly credible gastrointestinal symptoms (including both children and adults) were specifically attributable to having a home or yard flooded.

DISCUSSION

Based on the daily health diaries of 1,257 persons in 445 households collected over a 19-month period, an increased rate of gastrointestinal symptoms was observed during a severe midwestern flood in the spring of 2001. There was evidence that the effect of the flood was more severe among persons with potential sensitivity to gastrointestinal illness (those with a chronic gastrointestinal illness; those in poor, fair, or good health; those aged ≥50 years; and those with frequent gastrointestinal symptoms), particularly for severe illness.

Because of the longitudinal structure of the data, factors related to gastrointestinal illness that remain relatively constant within an individual over time (age, sex) were unlikely to have biased the observed result. When factors associated with gastrointestinal illness, such as age, sex, and the presence of a chronic gastrointestinal condition, were included in the model, the effect of the flood remained unchanged. Factors that vary over time, such as travel and number of weeks enrolled in the study, are more likely to have biased the result. These factors were also evaluated as potential confounders, but including them in the model did not affect the association between the flood period and symptoms.

Consumption of increased amounts of tap water was unrelated to gastrointestinal symptoms during the flood. For persons in the top quartile of water consumption compared with those in the bottom quartile, the IRR was not significantly elevated (IRR = 1.14, 95 percent CI: 0.79, 1.66). Furthermore, we observed no difference in the relation between the effectiveness of the "active" water treatment device and gastrointestinal symptoms during the flood. If

exposure to tap water were the primary cause of the increase in symptoms, we would have expected to observe a strong relation between water consumption and gastrointestinal symptoms and would have expected to observe an enhanced effect of the active water treatment device during the flood.

There is some evidence that the increase in gastrointestinal symptoms during the flood may have been due to direct exposure to floodwater. During the flood, persons whose homes or yards were flooded were at increased risk of gastrointestinal symptoms. This finding is consistent with a recently published health survey conducted by the Centers for Disease Control and Prevention in southeastern Texas following severe flooding in 2001 (24). This door-to-door survey of 420 households found that residents of flooded households were significantly more likely to report diarrhea within 1 week of the worst flooding than residents whose households were not flooded (odds ratio = 4.7, 95 percent CI: 1.8, 12.0).

Children aged ≤12 years were at increased risk of gastrointestinal symptoms if their home had been flooded or if they had cleaned up flood-contaminated material. In general, children had higher relative risks of gastrointestinal symptoms for most types of flood exposure, which is consistent with the greater susceptibility of children to gastrointestinal pathogens (25). This finding may also be related to poorer hygiene among children following exposure to floodwater and flood-contaminated items. The association between highly credible gastrointestinal symptoms and any flood contact was even more pronounced among children under 5 years of age (IRR = 3.18, 95 percent CI: 1.79, 5.66). Because no episodes of diarrhea or severe diarrhea occurred among children who had contact with floodwater or flood-contaminated items, it seems apparent that, in children at least, these symptoms were rather mild.

Direct contact with floodwater did not entirely explain the increase in incidence observed during the flood period, probably because few subjects reported coming into contact with floodwater. In fact, the IRR for gastrointestinal symptoms during the flood period remained elevated when persons who had had any contact with floodwater (IRR = 1.45, 95 percent CI: 1.16, 1.82) and persons whose homes had been flooded (IRR = 1.36, 95 percent CI: 1.10, 1.67) were excluded from the analysis.

An outbreak of gastrointestinal illness related to norovirus (Norwalk-like virus) was reported during the flood. However, it involved few cases and was restricted to a nursing home. County health department and water officials visited the site and collected and tested samples but found no evidence of the virus or other evidence of substandard water quality (L. Katz, personal communication, Scott County Health Department, 2002).

Limitations

The results of this study were based entirely on self-reported occurrences of gastrointestinal symptoms. Such data may be susceptible to recall bias. While recall bias could have resulted in the observed increases in highly credible gastrointestinal symptoms or diarrhea, it would be unlikely to be associated with more severe outcomes, such as hospitalization for gastrointestinal symptoms. Information on some potential confounders, such as diet and socioeconomic status, was not available for analysis, although it is difficult to predict how these factors may have influenced the results. The calculations of numbers of symptoms attributable to the flood (population attributable risk calculations) assumed that the entire increased rate observed was, in fact, caused by the flood. If part or all of this increase was due to other factors, the numbers of illnesses calculated will have been overestimates.

The results observed in this study are likely to have been highly dependent on local factors related to community transmission of gastrointestinal illness. Therefore, these findings may be limited in their application and generalizability to floods experienced in other communities.

In conclusion, this study documented a measurable increase in gastrointestinal symptoms during a severe flood in the Midwest in 2001. This effect was greater among persons who were susceptible to gastrointestinal illness. During the flood, children who had direct contact with floodwater were at increased risk of gastrointestinal symptoms, as were adults whose homes or yards were flooded. There was no evidence for transmission of gastrointestinal symptoms through the public water supply during the flood. However, the rate of gastrointestinal symptoms during the flood remained elevated after persons who had contact with floodwater were excluded. This suggests that people either contracted illness through sources other than contact with floodwater or flood-contaminated items or unknowingly came into contact with floodwater or flood-contaminated items. The increase may also have been attributable, in part, to other transmission pathways, such as secondary transmission or consumption of food that had been in some way affected or contaminated by floodwater.

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