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Cholera outbreak investigation, Bhadola, Delhi, India, April–May 2018

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Background: In the Gangetic plains of India, including Delhi, cholera is endemic. On 10 May 2018, staff at the north Delhi district surveillance unit identified a laboratory-confirmed cholera outbreak when five people tested positive for *Vibrio cholerae* O1 Ogawa serotype in Bhadola. We investigated to identify risk factors and recommend prevention measures.

Methods: We defined a case as ≥3 loose stools within 24 h in a Bhadola resident during 1 April–29 May 2018. We searched for cases house-to-house. In a 1 : 1 unmatched case control study, a control was defined as an absence of loose stools in a Bhadola resident during 1 April–29 May 2018. We selected cases and controls randomly. We tested stool samples for *Vibrio cholerae* by culture. We tested drinking water for fecal contamination. Using multivariable logistic regression we calculated adjusted ORs (aORs) with 95% CIs.

Results: We identified 129 cases; the median age was 14.5 y, 52% were females, 27% were hospitalized and there were no deaths. Symptoms were abdominal pain (54%), vomiting (44%) and fever (29%). Among 90 cases and controls, the odds of illness were higher for drinking untreated municipal water (aOR=2.3; 95% CI 1.0 to 6.2) and not knowing about diarrhea transmission (aOR=4.9; 95% CI 1.0 to 21.1). Of 12 stool samples, 6 (50%) tested positive for *Vibrio cholerae* O1 Ogawa serotype. Of 15 water samples, 8 (53%) showed growth of fecal coliforms.

Conclusions: This laboratory-confirmed cholera outbreak associated with drinking untreated municipal water and lack of knowledge of diarrhea transmission triggered public health action in Bhadola, Delhi.

Keywords: Delhi, outbreak, untreated water, *Vibrio cholerae* 01

Introduction

In India, an estimated 22 000 cholera cases occur annually.[1] Cholera has emerged and spread from the endemic Gangetic plains, including Delhi, to different parts of India.[2–5] In 2017 there were 31 cholera outbreaks with 7 deaths in the country.[6] In the same year, in Delhi, 99 laboratory-confirmed cholera cases were reported.[6] Cholera outbreaks have been reported from Delhi repeatedly.[7–12]

The Integrated Disease Surveillance Programme (IDSP) leads the surveillance of diarrhea and cholera, among other diseases, nationwide.[6] The IDSP also manages detection, investigation and response to outbreaks. Various programs in the country systematically address known risk factors such as contaminated water or food, inadequate water supply, poor hygiene and limited access to sanitation to prevent diarrheal diseases.[13,14]

The North Delhi district surveillance unit of the IDSP identified a laboratory-confirmed cholera outbreak when, within a span of 2 wk (13–26 April 2018), five people in Bhadola tested positive for *Vibrio cholerae* O1 Ogawa serotype at the microbiology laboratory of the Maharishi Valmiki Infectious Diseases Hospital (MVIDH). Bhadola is an urban colony in North Delhi, with a population of 7208 people residing in 2419 households. On 10 May 2018, the district surveillance unit alerted the central unit of the IDSP. We investigated to describe the epidemiology and identify risk factors for illness, and to provide evidence-based recommendations for control of the outbreak in Bhadola, north Delhi.

Methods

Outbreak confirmation

We retrieved cholera data from the laboratory forms of the IDSP available at MVIDH for the weeks corresponding to the months of April and May in 2015, 2016, 2017 and 2018. We counted the number of culture-confirmed *Vibrio cholera* cases reported in Bhadola during the previous 3 y and compared this total with the number of cases reported in 2018 to confirm the outbreak.

Case search

We defined a suspected case as an acute onset of ≥3 loose stools within 24 h in a Bhadola resident during 1 April–29 May 2018. We defined a laboratory-confirmed case as a suspected case whose stool sample tested positive for *Vibrio cholerae* by culture. We searched for suspected cases house-to-house in Bhadola. We established passive surveillance at government and private health facilities and laboratories that serve Bhadola to report suspected or laboratory-confirmed cholera cases until 29 May 2018 to include 10 d after 5 d of incubation of the last reported case.

Case control study

We conducted a 1:1 unmatched case control study to identify risk factors. A control was defined as an absence of loose stools in a Bhadola resident during 1 April–29 May 2018. All cases meeting the suspect case definition were eligible for the case control study. To ensure higher sensitivity in the outbreak setting, we expanded the standard WHO case definition, which excludes children aged <2 y, to include all age groups. A sample size of 90 (cases=45; controls=45) was calculated considering alpha at 5%, power at 80%, exposure among controls at 50%, exposure among cases at 80% and OR=3.0. We selected cases and controls randomly from the house number list prepared during the house-to-house search. We used the Stat Trek random number generator[15] to select random house numbers. If no eligible case or control subject was found in the selected house, we added one to the selected random number and searched for the study subject in the next house number.

Data collection

We used a semistructured questionnaire to collect data for sociodemographic factors, drinking water sources (municipal water supply, private water pipeline, filtered water bottle, borewell), treatment of drinking water (boil, chlorinate, reverse osmosis [RO], any other filtration, other), handwashing with soap after defecation and before eating (no, sometimes, always). With the permission of the respondent we checked the following: drinking water storage container (covered, uncovered), mouth of drinking water storage container (narrow: if hand could not pass through the mouth of the container; or else wide), drinking water retrieval (short or no handle, long handle, tap attached to vessel, other), soap available in toilet and kitchen (yes, no), toilet in the house (yes, no) and type of sewage in the house (uncovered, covered).

We interviewed parents or guardians if a case or control was aged <15 y. We performed an indepth interview with the index case and inquired about illness onset, symptoms, treatment and risk factors.

Data processing

We dichotomized responses to analyze exposures related to drinking water source (municipal water supply vs others), treatment of drinking water (no vs boil or chlorinate or RO or any other filtration), hand hygiene (handwashing with soap after defecation: no or sometimes vs always; handwashing with soap before eating – yes or no; soap available in kitchen – yes or no; soap available in toilet – yes or no). We also created two composite variables: untreated municipal water (yes or no) and poor hand hygiene (yes or no). We combined responses for drinking water sources and treatment of drinking water to create a new variable, 'untreated municipal water (yes or no)'; if a respondent consumed the municipal supply water and did not treat drinking water at home then responses were coded as yes, or else no. We created another new variable, 'poor hand hygiene (yes or no)' by combining responses for handwashing with soap after defecation, handwashing with soap before eating, soap available in toilet and soap available in kitchen.

Data analysis

We calculated proportions and attack rates. Continuous variables were dichotomized at median and if categorical variables had cell counts <5 they were dichotomized. We performed χ^2 tests and tested statistical significance at $p<0.05$. We performed logistic regression analysis and calculated ORs with 95% CIs. Risk factors that were significant at $p<0.05$ were further analyzed in the multivariate model and we calculated adjusted ORs (aOR) with 95% CI. We analyzed data in EpiInfo 7.2 (CDC, Atlanta, GA, USA).

Laboratory investigation

We transported stools samples from active cases (those who had symptoms at the time of data collection and who did not report a history of antibiotic use) in Cary Blair medium to MVIDH, Delhi, within 8 h of collection. We tested stool samples for enteric pathogens—*Vibrio cholerae*, *Salmonella* and *Shigella* sp.—by culture. Isolation and identification of enteric pathogens were performed using standard procedures.[15]

Environmental investigation

We collected drinking water samples from household taps in sterile autoclaved containers for bacteriological examination (fecal coliforms) by most probable number (MPN) presumptive test[16] at MVIDH, Delhi. We assessed drinking water supply and sewage system.

Table 1. Description of cases, *Vibrio cholerae* outbreak, Bhadola, Delhi, India, 1 April–29 May 2018 (N=129)

	N	%
Cases		
Suspected	123	95
Laboratory-confirmed	6	5
Median age (range)	14.5 y (5 d–80 y)	
Female	67	52
Hospitalized	35	27
Died	0	0
Median duration of illness (range)	3 (1–30) d	
Symptoms		
>3 loose stools in 24 h	129	100
Abdominal pain	70	54
Vomiting	57	44
Fever	37	29
Attack rate (cases/population)	129/7208	1.8

Results

Outbreak confirmation

During April–May 2015, 2016 and 2017, from the MVIDH laboratory forms, no cholera cases were reported from Bhadola. Thus the observed cholera cases in 2018 constituted an outbreak.

Descriptive epidemiology

We identified 129 suspected cases, of which 6 (5%) were laboratory-confirmed for *Vibrio cholerae*. Median age was 14.5 y (range: 5 d–80 y), 13 (10%) were aged <1 y and 44 (34%) were aged <5 y. There were 67 (52%) females. Of 129 cases, 35 (27%) were hospitalized and there were no deaths. Common symptoms were abdominal pain (70; 54%) and vomiting (57; 44%). The attack rate was 1.8% (129/7280) (Table 1). Eleven (8%) households had more than one case. The epidemic curve shows multiple peaks indicating a propagated outbreak (Figure 1).

The index case was an adult male who had >3 loose stools within 24 h for 3 d (3–5 April 2018) without any other symptoms. He sought treatment from a private doctor and recovered after 3 d of illness. He did not report traveling, meeting or caring for an individual with diarrhea in the month prior to illness. In addition, he did not report any similar illness among his family members. His drinking water source was municipal water and he did not treat drinking water at home. Drinking water was stored in a wide-mouth container and drawn by a utensil without handle. His house had a toilet; soap was available in the toilet as well as in the kitchen.

Case control study

We selected 45 of 129 eligible cases randomly. The characteristics of cases and controls are given in appendix 1. An equal number of controls were enrolled. Cases and controls were not different with respect to sociodemographic characteristics, except for age ≤25 y and not Hindu (p<0.05) (Table 2). We also found statistically significant associations between illness and drinking untreated municipal water, poor hand hygiene and no knowledge of diarrhea transmission (p<0.05) (Table 2). On bi-variate analysis, illness was associated with untreated municipal water (OR=3.0; 95% CI 1.2 to 7.1), poor hand hygiene (OR=9.5; 95% CI 1.1 to 79.6), age ≤25 y (OR=2.4; 95% CI 1.0 to 5.8) and no knowledge of diarrhea transmission (OR=6.1; 95% CI 1.2 to 29.8) (Table 3). In the adjusted model, illness was associated with untreated municipal water (aOR=2.3; 95% CI 1.0 to 6.2) and lack of knowledge of diarrhea transmission (aOR=4.9; 95% CI 1.0 to 21.1) (Table 3).

Laboratory investigation

During a house-to-house search, 30 of 129 cases had diarrhea. Of these, 13 had not taken any antibiotics. We collected stool samples from 13 (43%) and tested 12 (1 sample was discarded due to insufficient quantity). Of 12 stool samples from active cases, 6 (50%) tested positive for *Vibrio cholerae* O1 Ogawa serotype by direct and enrichment plating on thiosulfate citrate bile salts sucrose (TCBS) agar. The typical colonies appearing on TCBS agar were confirmed by the standard biochemical and serological procedures[15] with commercial antisera kits containing polyvalent and monovalent antisera. All tested negative for *Salmonella* and *Shigella* using standard laboratory techniques.[15,17]

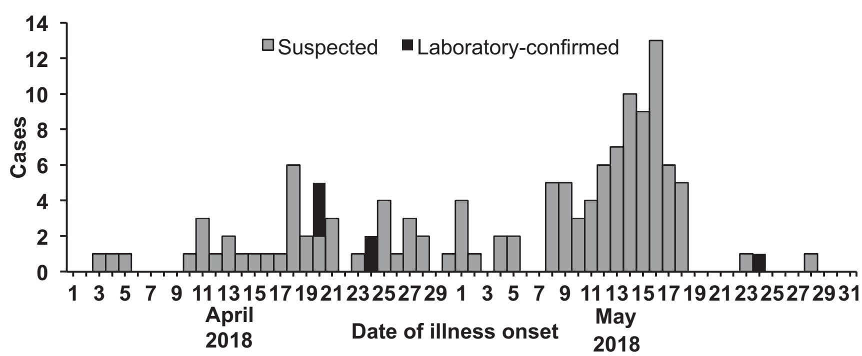

Figure 1. Suspected and laboratory confirmed cholera cases by date of illness onset, *Vibrio cholerae* outbreak, Bhadola, Delhi, India, 1 April–29 May 2018 (N=129).

Table 2. Univariate analysis of risk factors for illness, *Vibrio cholerae* outbreak, Bhadola, Delhi, India, 1 April–29 May 2018 (N=90)

	Cases, n=45 (%)	Controls, n=45 (%)	Total, N=90 (%)	p-value	OR	95% CI
Drinking water						
Untreated municipal water[a]	31 (69%)	19 (42%)	50 (56%)	**0.010**	**3.03**	**1.27 to 7.19**
Storage container - uncovered	1 (2%)	1 (2%)	2 (2%)	0.753	1.00	0.06 to 16.49
Storage container - wide mouth	19 (42%)	22 (49%)	41 (46%)	0.336	0.76	0.33 to 1.75
Retrieval - short or no handle	38 (84%)	34 (76%)	71 (80%)	0.215	1.75	0.61 to 5.04
Hand hygiene and sanitation						
Poor hand hygiene[b]	44 (98%)	37 (82%)	81 (90%)	**0.015**	**9.51**	**1.13 to 79.60**
No toilet in house[c]	0	0	0	0.752	1.00	0.06 to 16.49
Sewage in house - uncovered	1 (2%)	0	1 (1%)	0.752	1.00	0.06 to 16.49
Sociodemographics						
Age ≤25 y	29 (64%)	19 (42%)	48 (53%)	**0.028**	**2.48**	**1.06 to 5.80**
Gender - female	29 (64%)	21 (47%)	50 (55%)	0.069	2.07	0.88 to 4.82
Religion - not Hindu	1 (2%)	7 (16%)	8 (9%)	**0.029**	**0.12**	0.01 to 1.04
Caste - scheduled/non-scheduled	30 (67%)	25 (56%)	55 (61%)	0.194	1.60	0.68 to 3.75
Literacy - illiterate	10 (23%)	9 (20%)	19 (21%)	0.478	1.14	0.41 to 3.14
Monthly income ≤10 000 rupees	22 (59%)	21 (60%)	43 (60%)	0.577	1.09	0.47 to 2.50
Occupation - unemployed	8 (18%)	7 (15%)	15 (17%)	0.413	1.17	0.38 to 3.56
Family has below poverty line card	2 (4%)	1 (2%)	3 (3%)	0.500	2.04	0.17 to 23.40
Diarrhea transmission knowledge						
No knowledge	10 (22%)	2 (4%)	12 (13%)	**0.013**	**6.14**	**1.26 to 29.89**
Knowledge source - not health worker[d]	26 (74%)	31 (72%)	57 (73%)	0.517	0.61	0.26 to 1.46

Univariate analysis shows drinking untreated water, poor hand hygiene, age <=25 yrs, non- hindu, and no knowledge of diarrhoea transmission was statistically significant ($p<0.05$).
[a]Municipal supply water that was not treated (boiled, chlorinated, reverse osmosis filtration or any other filtration) at home before drinking.
[b]Did not wash hands with soap after defecation or before eating or did not have soap available in toilet or kitchen.
[c]One added to each cell.
[d]Among those who knew about diarrhea transmission (n=78).

Table 3. Multivariate analysis of risk factors for illness, *Vibrio cholerae* outbreak, Bhadola, Delhi, India, 1 April–29 May 2018 (N=90)

	OR	95% CI	aOR	95% CI
Untreated municipal water	**3.03**	**1.27 to 7.19**	**2.38**	**1.01 to 6.22**
Poor hand hygiene	**9.51**	**1.13 to 79.60**	7.84	0.87 to 70.06
Age ≤25 y	**2.48**	**1.06 to 5.80**	2.24	0.87 to 5.72
Religion - not Hindu	0.12	0.14 to 1.04	–	–
No knowledge regarding diarrhea transmission	**6.14**	**1.26 to 29.89**	**4.97**	**1.01 to 21.10**

All variable in the table were included in the multivariate analysis. Drinking untreated municipal water and no knowledge of diarrhea transmission was statistically significant at $p<0.05$.

Environmental investigation

In Bhadola, most houses have toilets attached to the sewage system and the municipal corporation supplies drinking water. Of 15 water samples collected from household taps, 8 (53%) tested positive for fecal coliforms with an MPN index of >50/100 ml. The municipal corporation supplies piped drinking water for only 2 h each day. We found that the drinking water pipeline was breached at three sites and was also exposed to sewage water since it overlapped uncovered sewage. The municipal corporation of North Delhi maintains the sewage system. The electricity supply is intermittent and is provided by the state electricity board.

Discussion

This was a laboratory-confirmed *Vibrio cholerae* O1 Ogawa serotype outbreak associated with consumption of untreated municipal water and lack of knowledge about diarrhea transmission in Bhadola, Delhi. Breaches in the water pipeline may have been the likely mode of contamination of piped municipal water.

The epidemiology of this outbreak in Bhadola is similar to other cholera outbreaks in Delhi[7–11] and in India.[12,18–24] In our investigation, we identified consumption of untreated municipal water as a risk factor for the outbreak. The municipal water may have been contaminated following breaches in the water supply pipeline. A lack of prompt repair explains the propagated course of the outbreak. Urban areas in developing countries receiving piped water systems are vulnerable to cholera outbreaks due to breaks in quality system maintenance.[23,24] Chlorination of drinking water[18,22,25–28] and repair of drinking water pipelines[18,21,25–28] have been prioritized during cholera outbreaks in the past.

Health education for diarrhea prevention has proven to be an effective intervention.[25] In our investigation, lack of knowledge concerning diarrhea transmission was a significant risk factor for illness. Previous studies have indicated that water treatment at home or at the point of use can reduce diarrhea by 35%.[29–32] However, knowledge of consistent and correct use of filters or flocculent disinfectants at home or at the point of use[32,33] determines the effectiveness of this intervention. A regular supply of piped water and electricity are also critical for the functioning of water filters at home.

In urban colonies, intermittent availability of water, electricity, multiple administrative (health, sanitation, water departments) authorities, low socioeconomic status and a low level of awareness, among other factors, pose complex challenges.[18,33,34]

We informed the district administration about the contamination of drinking water supplied by the municipal corporation and leaks in the drinking water pipeline. Based on the recommendations, the administrators made arrangements for alternative safe drinking water to be supplied to the community by water tankers. The repair of the breached pipeline was initiated. We recommended that the municipality office regularly monitor water quality (biochemical and microbiological) at the point of distribution as well as at the point of use (random houses). We also recommended weekly checks of drinking water pipelines for leakages. In the interim, we advised community members to use alternative sources of safe drinking water and to chlorinate or filter water before consumption.

We also supported the local public health department to conduct refresher training for all nine frontline health workers about diarrhea prevention and control, collection and transportation of stool samples, distribution of oral rehydration solution and chlorine, reporting of suspected cases to the IDSP and patient referral. We assisted in preparing a health worker training chart to hold diarrhea prevention sessions in the community once a month and preferably once every week before the monsoon season, since diarrhea and cholera outbreaks are more common during the monsoon season in India.[5,35] We performed a health education session (risk factors for diarrhea, prevention of drinking water contamination and handwashing) in the local school; subsequently, we requested that school staff hold similar sessions more frequently.

Our investigation had some limitations. We used a sensitive case definition for our case control study, which may reflect the burden of acute diarrheal disease in the community rather than cholera. We did not use standardized water and sanitation survey questions, therefore some of our results lack external validity and need to be interpreted with caution. There may have been some recall bias but we attempted to minimize this by limiting the recall period to 15 d. Although the local administration provided safe drinking water during the outbreak, it was challenging to ensure continued availability. In India, water boards are outside the purview of public health departments but both need to work closely to ensure monitoring of chlorination at pumping stations, in distribution networks and at households, as well as periodic inspection of water pipelines for breaches. These measures are possible through more capital investment and better management of water and sanitation services in urban India.

Cholera continues to be a major public health challenge in resource-constrained countries like India. Timely detection of this outbreak and a rapid response resulted in its control and curtailed its spread. Multiple factors related to safe water supply, water quality monitoring, access to sanitation facilities and lack of knowledge regarding diarrhea prevention are linked to cholera outbreaks in low and middle income countries. Evidence generated from such investigations provide a case for increasing investment in safe water and sanitation. Sustained education campaigns by health workers on boiling or chlorinating drinking water and handwashing will reiterate the role of safe drinking water and hand hygiene to prevent diarrheal diseases. This will be a critical step for India towards meeting global sustainable development goals for health and sanitation.

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Ethical approval: This outbreak investigation was carried out as part of an emergency public health response with prior approval from the National Centre for Disease Control, Delhi, India, hence was exempted from ethical review.

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Appendix 1.

Table A1. Characterstics of cases and controls, Vibrio cholerae outbreak, Bhadola, Delhi, India, 1 April29 May 2018 (N90)

	Cases, n=45 (%)	Controls, n=45 (%)	Total, N=90 (%)
Drinking water source			
Municipal supply	41 (91%)	33 (73%)	74 (82%)
Private water pipeline	0	1 (3%)	1 (1%)
Filtered water bottle	4 (9%)	11 (25%)	15 (17%)
Other	0	0	0
Drinking water treatment at home			
None	31 (69%)	19 (42%)	50 (56%)
Boil	4 (9%)	3 (7%)	7 (8%)
Chlorinate	0	0	0
Reverse osmosis/any other filter	10 (22%)	23 (51%)	33 (37%)
Drinking water treatment at home – municipal water (n=74)			
None	31 (73%)	19 (58%)	49 (66%)
Boil	4 (10%)	3 (9%)	7 (9%)
Reverse osmosis/any other filter	6 (17%)	11 (33%)	18 (24%)
Handwashing with soap after defecation			
No	0	0	0
Sometimes	0	0	0
Always	45 (100%)	45 (100%)	45 (100%)
Handwashing with soap before eating			
No	1 (2%)	0	1 (1%)
Sometimes	24 (56%)	14 (31%)	38 (42%)
Always	20 (44%)	31 (69%)	51 (57%)
Drinking water retrieval			
Short or no handle	18 (40%)	12 (27%)	30 (33%)
Long handle	7 (16%)	11 (24%)	18 (20%)
Tap attached to vessel	19 (42%)	21 (47%)	40 (44%)
Soap available in kitchen			
No	42 (93%)	34 (75%)	76 (84%)
Yes	3 (7%)	11 (25%)	14 (16%)
Soap available in toilet			
No	3 (7%)	0	3 (3%)
Yes	42 (93%)	45 (100%)	87 (97%)
Median age (range)	17 y (4 mo–80 y)	28 (2–58) y	25 y (4 mo–80 y)
Religion			
Hindu	44 (98%)	38 (84%)	82 (91%)
Muslim	1 (2%)	4 (9%)	5 (6%)
Sikh	0	3 (7%)	3 (3%)
Caste			
Scheduled	30 (67%)	25 (56%)	55 (61%)
Non-scheduled	15 (33%)	20 (44%)	35 (39%)
Education of respondent/mother			
Graduate or above	2 (4%)	4 (9%)	6 (7%)
Intermediate or post-high school	7 (16%)	6 (13%)	13 (15%)
High school	2 (4%)	10 (22%)	12 (13%)
Middle school	14 (32%)	9 (20%)	23 (26%)
Primary school	8 (18%)	5 (11%)	13 (15%)
Literate	1 (2%)	2 (4%)	3 (3%)
Illiterate	10 (23%)	9 (20%)	19 (21%)
Median monthly income in rupees (range)	10 000 (5000–17 000)	10 000 (6000–17 000)	10 000 (5000–17 000)
Occupation of respondent/household head			
Laborer or vendor	20 (44)	23 (51)	43 (48)
Other occupation	17 (38)	15 (33)	32 (35)
Unemployed	8 (18)	7 (15)	15 (17)

Table A1. continued

	Cases, n=45 (%)	Controls, n=45 (%)	Total, N=90 (%)
Diarrhea transmission knowledge and source			
Drinking contaminated water	17 (38%)	21 (47%)	38 (42%)
Eating contaminated food	14 (31%)	14 (31%)	28 (31%)
Not washing hands before eating	2 (4%)	4 (9%)	6 (7%)
Not washing hands after defecation	1 (2%)	2 (4%)	3 (3%)
Eating stale food	1 (2%)	2 (4%)	3 (3%)
None of the above	10 (22%)	2 (4%)	12 (13%)
Diarrhea transmission knowledge sources among those who had knowledge (n=78)			
Health worker	9 (20%)	12 (27%)	21 (23%)
Family/Friend	7 (15%)	9 (20%)	16 (18%)
School	4 (9%)	10 (22%)	14 (15%)
TV/radio	5 (11%)	3 (7%)	8 (9%)
Other	10 (28%)	9 (21%)	19 (24%)