

A large cholera outbreak in Kano City, Nigeria: the importance of hand washing with soap and the danger of street-vended water

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ABSTRACT

The aim of this study was to identify the risk factors for cholera during an outbreak in Nigeria. Cases were defined as recent onset of acute diarrhoea with dehydration in a patient hospitalised at the Infectious Diseases Hospital in Kano City. Meningitis patients admitted concurrently at the same hospital were recruited as unmatched controls. Data were collected on age, sex, place of residence, hygienic practices, and on food and water consumption. A total of 5600 cholera cases and 340 cholera deaths were reported between December 1995 and May 1996 (attack rate=86.3 per 100,000 population) in the state of Kano. Compared to the 77 controls, the 102 cases were more likely to have drunk street-vended water (age-adjusted odds ratio (AAOR)=3.2; 95% confidence interval (CI): 1.4–7.1) and less likely to have drunk tap water in their homes (AAOR=0.2; 95% CI: 0.1–0.7) or to have washed hands with soap prior to eating food (AAOR=0.2; 95% CI: 0.1–0.6). While no data suggested that the municipal water supply was contaminated, safe water systems and hand hygiene practices might have prevented a high proportion of cases if implemented early during this outbreak.

Key words | case control studies, cholera, disease outbreaks, hand hygiene, waterborne diseases

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INTRODUCTION

In developing countries, cholera often occurs as rapidly progressive, large-scale outbreaks (Swerdlow & Isaacson 1994; Swerdlow *et al.* 1997). These large-scale outbreaks cause a high burden of disease and rapidly overwhelm curative health care services, particularly during complex humanitarian emergencies or in settings where public health systems have broken down (Swerdlow & Isaacson 1994). In addition to this health-related toll, large-scale cholera outbreaks cause great economic loss as inappropriate external restrictions may lead to disruptions in trade and travel. Thus, identifying interventions that would be effective in preventing or limiting the spread of these outbreaks would have substantial public health and economic impact.

Effective prevention measures against cholera outbreaks require the identification of the predominant

sources of infections and implementation of targeted interventions. However, two problems limit the feasibility of this approach. First, many cholera outbreaks are not investigated using epidemiological methods that allow identification of risk factors for illness (Tauxe *et al.* 1995). Second, during many outbreaks, the cholera vibrio is transmitted through many routes that cannot all be identified. The high concentrations of pathogens in the stools of infected individuals and the high faecal output cause high levels of environmental contamination that exposes other persons to infection. These outbreaks are often not caused by a single common source but rather by the ingestion of various types of food and beverages that become contaminated through various unidentified breaks in hygienic practices (Swerdlow & Isaacson 1994; Tauxe *et al.* 1995). Thus, estimating the proportion of cases

that could be prevented through implementation of selected improved hygienic practices might be a better approach than attempting to identify outbreak-specific vehicles.

In February and March 1996, northern Nigeria faced a meningitis outbreak of unprecedented magnitude. This outbreak, during which 109,580 cases were reported (Mohammed *et al.* 2000), overwhelmed the curative healthcare system and prompted a major intervention from the Nigerian Ministry of Health with the assistance of non-governmental organizations, including *Médecins Sans Frontières (MSF)*. Emergency preventive and curative public health measures were implemented. In the midst of this outbreak, the state of Kano (1996 population: 4,931,789) was struck by another large-scale outbreak of severe diarrhoea that was soon confirmed to be cholera, as two stool samples examined at the French National Reference Centre for Vibrios and Cholera (Institut Pasteur, Paris, France) grew *Vibrio cholerae* serogroup O1, serotype Inaba. The presence in Kano State of a team of epidemiologists provided an opportunity to investigate this outbreak and to examine potential risk factors for illness.

METHODS

Public health surveillance

The passive public health surveillance system that had been stimulated for the meningitis emergency was adapted to also monitor the cholera outbreak. A case of cholera was defined as acute watery diarrhoea of rapid onset provoking severe dehydration in a patient in Kano State since 1 December 1995. District health officials reported cases on line listings that collected information regarding date of birth, district of residence, gender, and occurrence of death. Line listing reports were sent to the State Ministry of Health in Kano City where they were computerized. There, software produced an automated analysis of the incidence according to time, place, and demographic characteristics (EPISURV software, Epicconcept, Paris, France). Maps representing district-specific incidence rates were drawn using EPIMAP (CDC, Atlanta, GA, USA).

Case-control study

To investigate potential risk factors for illness that would point towards modes of transmission during this outbreak, an unmatched case-control study was carried out in the Kano City Infectious Diseases Hospital during 16–17 March 1996. Because the Kano City Infectious Diseases Hospital was the primary reference centre in the Kano City Metropolitan area for both meningitis and cholera, it provided a unique opportunity to rapidly conduct a case-control study through the recruitment of hospital-based meningitis patients as control subjects. For the purpose of the study, a case was defined as an admission at the Infectious Diseases Hospital of a patient presenting with acute watery diarrhoea of rapid onset provoking severe dehydration, since 15 March 1996. This case definition is considered highly predictive of confirmed cholera infection in an epidemic setting (Vugia *et al.* 1994). Controls were defined as referrals to the same hospital for the treatment of meningitis. Because the two diseases were of equivalent severity and because the Infectious Diseases Hospital was the primary reference centre for both diseases, catchment areas and therefore secondary study bases were assumed to be equivalent (Wacholder *et al.* 1992a, b). Sample size was set to 72 cases and 72 controls in order to identify an odds ratio of 3 (for a risk factor on which intervention would have a significant impact), assuming 20% prevalence of exposure among controls, with an alpha risk of 5% and 80% power. Case patients and control subjects were asked their age, gender, place of residence, and selected exposures in the 5 days preceding disease onset. Examined exposures included hand-washing practices and potential exposures to contaminated food and water identified through an initial rapid pilot study conducted through open interviews of a convenience sample of 20 case patients hospitalised for the management of cholera. Healthcare workers responsible for admission of patients were trained for data collection and interviewed patients on admission to the hospital. Patients admitted unconscious, and those unable to reliably answer questions, were not recruited. Univariate and adjusted odds ratios were calculated with exact methods. Quantitative variables were compared using the Kruskal-Wallis, non-parametric test.

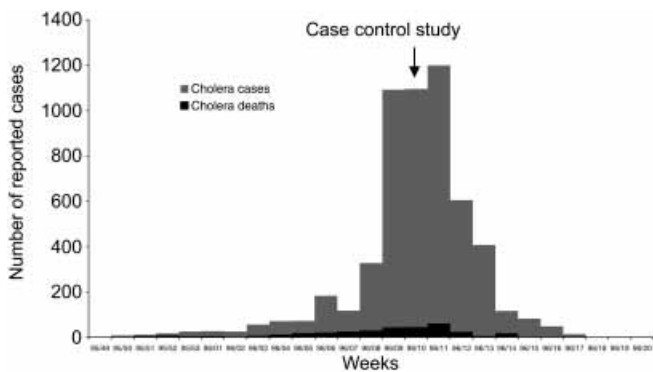


Figure 1 | Number of cholera cases and cholera deaths reported each week in Kano State, Nigeria, 1995–1996.

Proportions across more than two groups were compared using the Chi square test. Finally, a logistic regression model was progressively built, starting with the variables that were significantly associated with the outcome in univariate analysis and continuing with progressive attempts to include additional variables. Effect modification was checked between significant risk factors and age and gender through attempts to include interaction terms. All statistical analyses were conducted with the EPI-INFO software (Atlanta, GA, USA) apart from the logistics regression that was conducted using EGRET (SERC, Seattle, WA, USA). Attributable fraction for exposures thought to be causally associated with cholera was calculated using standard formulae (Rothenberg & Hahn 1996).

RESULTS

Descriptive epidemiology

A total of 5,600 cholera cases and 340 deaths from cholera were reported from the State of Kano to the Ministry of Health between the 49th week of 1995 and the 20th week of 1996 (1996 population: 4,931,789, incidence: 86 cases per 100,000 population, case-fatality ratio: 6.1%). The weekly number of reported cases peaked during the 12th week of 1996 and then decreased to reach pre-epidemic levels during the 19th week of 1996 (Figure 1). Age, place of residence, and outcome information were only avail-

Table 1 | Attack rate of cholera by age group, Kano State, Nigeria, 49th week of 1995–10th week of 1996

Age group	Cases	Population	Attack rate per 100,000
0–4 years	459	1,120,963	40.9
5–14 years	348	1,846,289	18.8
15–29 years	430	184,189	23.3
30 years and over	399	1,780,348	22.4

able from the 49th week of 1995 to the 10th week of 1996. The incidence was highest among children under 5 years of age and did not vary substantially across older age groups (Table 1). Within the State of Kano, the incidence was highest in the Kano City metropolitan area, the State capital (Figure 2).

Analytical epidemiology

A total of 179 participants (102 case patients and 77 control subjects) were included in the case-control study during the 24-hr data collection period. The median age of all study participants was 20 years (quartiles 10–30), and 64 (36%) of the 176 participants for whom gender information was available were female. While case patients were

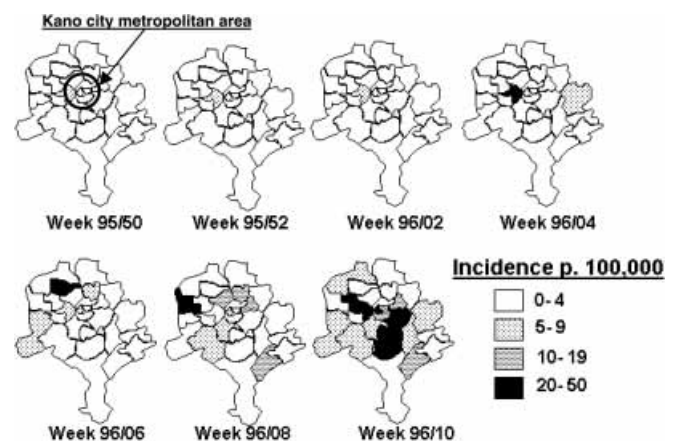


Figure 2 | Cumulated incidence of cholera for selected weeks by Local Government Areas (districts), Kano State, Nigeria, 1995–1996.

Table 2 | Selected exposures in the 5 days preceding illness among cholera case patients and meningitis control subjects, cholera outbreak in Kano State, Nigeria, 15–17 March 1996

Potential exposures	Cases #/total	Controls #/total	Odds ratio (95% CI)	Age-adjusted odds ratio (95% CI)
Drinking water sold by street vendors	55/99	18/73	3.8 (1.9–7.9)	3.2 (1.4–7.1)
Drinking tap water at home	66/101	63/74	0.3 (0.1–0.7)	0.2 (0.1–0.7)
Drinking bottled water	10/92	19/66	0.3 (0.1–0.7)	0.1 (0.1–0.5)
Drinking water from a well	51/97	38/67	0.85 (0.43–1.7)	0.98 (0.44–2.1)
Drinking local drinks sold by street vendors	63/96	47/74	1.1 (0.5–2.2)	1 (0.5–2)
Eating cold food leftovers (rice or ‘tuwo’)	79/98	68/73	0.3 (0.1–0.9)	0.5 (0.2–1.2)
Eating ‘alefu’	71/96	59/69	0.48 (0.19–1.1)	0.51 (0.17–1.4)
Eating fried fish	48/98	39/58	0.47 (0.22–0.97)	0.78 (0.33–1.8)
Eating salad	76/96	44/64	1.7 (0.8–3.8)	1.5 (0.6–3.9)
Eating food sold by street vendors	61/99	49/67	0.6 (0.3–1.2)	0.6 (0.2–1.3)
No hand washing before meals	6/102	3/77	1.5 (0.32–9.8)	1.0 (0.14–8.6)
No hand washing with soap before meals	44/100	16/74	2.8 (1.4–6.0)	4.0 (1.8–9.8)

older than control subjects (median 25 years versus 14, $p = 0.0001$), the case and control groups were similar with respect to the proportion of females (36%) and the district of residence ($p = 0.45$, global chi square test, data not shown). The rest of the analysis was stratified by age using nine groups (0–3, 4–6, 7–9, 10–14, 15–19, 20–29, 30–39, 40–54 and 55+) because (1) case patients were older than control subjects and (2) examination of stratum-specific measures of association did not suggest that age was an effect modifier for the exposures examined.

Compared to control subjects, case patients were more likely to have drunk water sold by street vendors (age-adjusted odds ratio (AAOR): 3.2, 95% CI: 1.4–7.1), and to have failed to wash hands with soap before meals (AAOR: 4.0, 95% CI: 1.8–9.8) Table 2. In addition, compared with control subjects, case patients were less likely to have drunk water from a tap located within their household or to have drunk bottled mineral water. Other

exposures, including the failure to wash hands with water before meals, were not associated with being a case patient (Table 2). The strength of the association between drinking water sold by street vendors and cholera did not vary according to the place of residence (Woolf’s test to test for effect modification: 2.1; $p = 0.5$), and was not confounded by the association between failure to wash hands with soap before meals and illness. Similarly, the association between failure to wash hands with soap before meals and cholera was not confounded by the association between drinking water sold by street vendors and illness. In multivariate analysis, factors significantly associated with illness after adjustment for age included drinking water sold by street vendors (adjusted odds ratio (AOR): 4.1, 95% CI: 1.7–9.5) and failure to wash hands with soap before meals (AOR: 1.9, 95% CI: 1.1–3.3). Drinking bottled water was associated with a lower risk of illness (AOR: 0.25, 95% CI: 0.01–0.71).

To better measure the association between the source of water supply and illness, a restricted analysis was conducted among 63 study participants who reported drinking water from only one type of source during the 5 days that preceded the onset of illness. For the purpose of this analysis, the one study participant who reported drinking only bottled water was analysed with the group of study participants reporting drinking only tap water from a source located within their household. When this group of participants was used as a baseline, compared with control subjects, case patients were more likely to have drunk only well water (29.4% versus 12.5%, odds ratio (OR): 2.9, 95% CI: 0.62–18) and to have drunk water sold by street vendors (17.2% versus 0%, OR undefined, $p = 0.06$, Fisher exact test). No significant effect modification was detected.

The attributable fraction associated with drinking water sold by water vendors was 37% and the attributable fraction associated with the failure to wash hands with soaps before meals was 33%. Overall, 75 (75.0%) of the 100 case patients for whom information was available reported either exposure for an overall attributable fraction of 61.5%.

DISCUSSION

This cholera outbreak caused substantial death, disease, and economic loss. In addition, it created major concern as it occurred at a time when pilgrims were heading to Mecca. However, a rapid epidemiological investigation was possible and yielded useful results that suggested that drinking water sold by water vendors and failure to wash hands with soap before meals were independently associated with illness. In addition, as an ongoing rumour attributed the outbreak to the municipal water supply system, the epidemiological information that ruled out this hypothesis was most useful to local public health officials. Given the complex situation in Kano State, a large-scale intervention to increase access to safe water and improve hand hygiene practices was not undertaken. However, health officials communicated the results of the investigation to the public through a radio address which may have affected people's practices. Although no epidemiological



Figure 3 | Water vendor in a street of Kano City, March 1996 (photo: Dr Denis Coulombier).

information was available to determine what prompted the decrease of incidence in the weeks that followed the case-control study, this phenomenon most probably reflected the natural course of this rapidly progressing outbreak.

During this outbreak, drinking water sold in the streets by water vendors was associated with illness. Consumption of street-vended water has been associated with cholera during previous outbreaks in Latin America (Ries *et al.* 1992; Weber *et al.* 1994; Tauxe *et al.* 1995). Water contaminated during storage has also been associated with the spread of cholera in India (Deb *et al.* 1982, 1986) and in Peru (Swerdlow *et al.* 1992). In South Africa, treatment of water with bleach or by boiling protected against illness from cholera (Sinclair *et al.* 1982). Because municipal water supply is not available for all households, water vendors can be observed at all times in large numbers in the streets of Kano City (Figure 3). Discussion with selected informants suggested that their activity had not changed before or during the outbreak. Water vendors filled 20-litre, narrow-mouthed, covered plastic vessels with water taken from public stand pipes, pushed two-wheeled street carts that accommodated 16 such vessels through the streets, and sold water to households. While the source of contamination of the water sold by water vendors may have varied and could not be determined, the epidemiological evidence suggested that the municipal water system was not contaminated and that the

contamination occurred after the water had left the pipe. Stages at which the water may have been contaminated included water collection at the standpipe, water transferring from the vendor's vessels to the purchaser's containers, and unhygienic manipulations of domestic water containers within households, such as placing hands in water containers (Swerdlow *et al.* 1997). Stored water usually has a higher level of bacterial contamination than source waters (Han *et al.* 1989; Swerdlow *et al.* 1992; Dunne *et al.* 2001). Contamination of stored water can be prevented by safe water systems that include (1) point-of-use treatment of water using sodium hypochlorite, (2) safe water storage in plastic containers with a narrow mouth, lid, and a spigot to prevent re-contamination, and (3) behavioural change (Mintz *et al.* 1995). Interventions aimed at the introduction of safe water systems in developing countries indicated that these (1) can be made available at low cost (less than 4 dollars per year and per family; Reiff *et al.* 1996); (2) are acceptable to users (Quick *et al.* 1996, 1997; Macy & Quick 1998; Luby *et al.* 2001a); (3) are successful in achieving a substantial decrease in the level of faecal contamination of stored water (Quick *et al.* 1996, 1997, 1999; Luby 2001a) or street-vended beverages (Sobel *et al.* 1998); (4) are effective in achieving a decrease in the incidence of endemic diarrhoeal diseases (Semenza *et al.* 1998; Quick *et al.* 1999); and (5) may be used for the provision of safe oral rehydration solutions in healthcare settings during a cholera outbreak (Daniels *et al.* 1999). During this outbreak, the fraction of cholera attributable to water sold by water vendors suggests that in such a setting, additional chlorination at the time of collection might have prevented illness. As vendors are already selling water, they might be appropriate salesmen for low cost hypochlorite.

The results of the case-control study also indicated that persons who washed hands with soap before meals were at lower risk of illness from cholera. While hand washing with water alone, which was not protective, is a common practice in West Africa, hand washing with soap is more rare. Epidemiological evidence from Guinea-Bissau (Shaffer *et al.* 1988), Guinea (St Louis *et al.* 1990), Ecuador (Weber *et al.* 1994), and El Salvador (Quick *et al.* 1995) suggests that hand washing with soap may be associated with a lower risk of cholera during

outbreaks. Soap is effective in reducing hand contamination whether or not contaminated or chlorinated water is used for hand washing (Luby *et al.* 2001b). In addition, interventions aimed at increasing the use of soap in households were effective in achieving a 67% reduction in the secondary transmission of shigella in Bangladesh (Khan 1982). Studies have also indicated that use of soap and hand washing promotion can achieve a 26 to 62% decrease in the incidence of diarrhoea in developing countries (Clemens & Stanton 1987; Han *et al.* 1988; Pinfold & Horan 1996; Shahid *et al.* 1996). During this outbreak, use of soap to wash hands before meals might have prevented illness.

This study had two main limitations. A number of confounding factors, including socio-economic status, may have led to a non-causal association between poor hand and water supply hygiene and cholera. Because we did not collect information on these factors, we are unable to estimate how this lack of data might have affected the results of our analysis. However, the associations that we identified in this study confirm results of investigations conducted in other settings where these associations fulfilled usually accepted causality criteria. In addition, hypothetical associations between socio-economic status and cholera would be most likely explained by differences in hygienic practices. Finally, while there are few data available from developing countries, in industrialized countries meningococcal meningitis is more common among ethnic groups among which there is a higher proportion of persons from a lower socio-economic status (Wenger *et al.* 1990; Wilson *et al.* 1995). This probable association between meningococcal disease and lower socio-economic status would limit the suspected confounding effect of socio-economic status on the association between hygienic practices and cholera. Second, because the control group was hospital-based rather than population-based, the estimated population prevented fraction might have been distorted. However, because *Nesseiria meningitidis* is not transmitted through ingestion of contaminated food, water, or beverages, our reference group can be assumed to be equivalent to the general population with respect to the distribution of food, water, and beverage-related exposures and this factor is unlikely to substantially affect our results.

CONCLUSION

The study design was an efficient use of public health resources in an unusual emergency situation of dual epidemics. This study, along with evidence from the epidemiology of other diarrhoeal diseases, suggests that simple water supply and hand hygiene practices, including point-of-use chlorination and safe water vessels, and hand washing with soap, might be effective in preventing the transmission of cholera in large-scale outbreaks. While the logistical and behavioural implications of the introduction of a point-of-use safe water system (CDC 2001), can restrict their use in an emergency setting, they could reduce the burden of disease and death associated with cholera in communities where they have been implemented in the framework of long-term interventions. In such long-term interventions where they have been shown to be effective in preventing diarrhoeal disease, they may reduce the magnitude of cholera outbreaks or help abort their initiation. Future large-scale cholera outbreaks should also be used to evaluate the effectiveness of emergency measures aiming at improving hand washing and water handling practices. In the meantime, efforts should be made to (1) improve the effectiveness of communication activities for improved hand hygiene practices, and (2) ensure the long term sustainability of interventions aimed at the introduction of safe water systems in communities at high risk of pathogens transmitted through the faecal-oral route.

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REFERENCES

- CDC 2001 *Safe Water System*. Available from URL: <http://www.cdc.gov/safewater/>
- Clemens, J. D. & Stanton, B. F. 1987 An educational intervention for altering water-sanitation behaviors to reduce childhood diarrhea in urban Bangladesh. I. Application of the case-control method for development of an intervention. *Am. J. Epidemiol.* **125**, 284–291.
- Daniels, N., Simons, S. L., Rodrigues, A., Gunnlaugsson, G., Forster, T. S., Wells, J. G., Hutwagner, L., Tauxe, R. V. & Mintz, E. D. 1999 First do no harm: making oral rehydration solution (ORS) safer in a cholera epidemic. *Am. J. Trop. Med. Hyg.* **60**, 1051–1055.
- Deb, B. C., Sircar, B. K., Sengupta, P. G., De, S. P., Sen, D., Saha, M. R. & Pal, S. C. 1982 Intra-familial transmission of *Vibrio cholerae* biotype El Tor in Calcutta slums. *Indian J. Med. Res.* **76**, 814–819.
- Deb, B. C., Sircar, B. K., Sengupta, P. G., De, S. P., Mondal, S. K., Gupta, D. N., Saha, N. C., Ghosh, S., Mitra, U. & Pal, S. C. 1986 Studies on interventions to prevent El Tor cholera transmission in urban slums. *Bull. WHO* **64**, 127–131.
- Dunne, E. F., Angoran-Benie, H., Kamelan-Tano, A., Sibailly, T. S., Monga, B. B., Kouadio, L., Roels, T. H., Wiktor, S. Z., Lackritz, E. M., Mintz, E. D. & Luby, S. 2001 Is drinking water in Abidjan, Cote d'Ivoire safe for infant formula? *J. AIDS* **28**, 393–398.
- Han, A. M., Hlaing, T., Kyin, M. L. & Saw, T. 1988 Hand washing intervention to reduce ascariasis in children. *Trans. R. Soc. Trop. Med. Hyg.* **82**, 153.
- Han, A. M., Oo, K. N., Midorikawa, Y. & Shwe, S. 1989 Contamination of drinking water during collection and storage. *Trop. Geograph. Med.* **41**, 138–140.
- Khan, M. U. 1982 Interruption of shigellosis by hand washing. *Trans. R. Soc. Trop. Med. Hyg.* **76**, 164–168.
- Luby, S., Agboatwalla, M., Raza, A., Sobel, J., Mintz, E., Baier, K., Rahbar, M., Qureshi, S., Hassan, R., Ghouri, F., Hoekstra, R. M. & Gangarosa, E. 2001a A low-cost pilot intervention for cleaner drinking water in Karachi, Pakistan. *Int. J. Infect. Dis.* **5**, 144–150.
- Luby, S. P., Agboatwalla, M., Raza, A., Sobel, J., Mintz, E. D., Baier, K., Hoekstra, R. M., Rahbar, M. H., Hassan, R., Qureshi, S. M. & Gangarosa, E. J. 2001b Microbiologic effectiveness of hand washing with soap in an urban squatter settlement, Karachi, Pakistan. *Epidemiol. Infect.* **127**, 237–244.
- Macy, J. T. & Quick, R. E. 1998 Evaluation of a novel water treatment and storage intervention in Nicaragua. *Pan. Am. J. Pub. Health* **3**, 135–136.
- Mintz, E. D., Reiff, F. M. & Tauxe, R. V. 1995 Safe water treatment and storage in the home: A practical new strategy to prevent waterborne disease. *J. Am. Med. Assoc.* **273**, 948–953.
- Mohammed, I., Nasidi, A., Alkali, A. S., Garbati, M. A., Ajayi-Obe, E. K., Audu, K. A., Usman, A. & Abdullahi, S. 2000 Severe epidemic of meningococcal meningitis in Nigeria, 1996. *Trans. R. Soc. Trop. Med. Hyg.* **94**, 265–270.

- Pinfold, J. V. & Horan, N. J. 1996 Measuring the effect of a hygiene behaviour intervention by indicators of behaviour and diarrhoeal disease. *Trans. R. Soc. Trop. Med. Hyg.* **90**, 366–371.
- Quick, R. E., Thompson, B. L., Zuniga, A., Dominguez, G., De Brizuela, E. L., De Palma, O., Almeida, S., Valencia, A., Ries, A. A. & Bean, N. H. 1995 Epidemic cholera in rural El Salvador: risk factors in a region covered by a cholera prevention campaign. *Epidemiol. Infect.* **114**, 249–255.
- Quick, R. E., Venczel, L. V., Gonzalez, O., Mintz, E. D., Highsmith, A. K., Espada, A., Damiani, E., Bean, N. H., De Hannover, E. H. & Tauxe, R. V. 1996 Narrow-mouthed water storage vessels and in situ chlorination in a Bolivian community: a simple method to improve drinking water quality. *Am. J. Trop. Med. Hyg.* **54**, 511–516.
- Quick, R. E., Mintz, E. & Sobel, J. 1997 A new strategy for waterborne disease transmission. 23rd Water, Engineering and Development Centre Conference. Durban, South Africa.
- Quick, R. E., Venczel, L. V., Mintz, E. D., Soletto, L., Aparicio, J., Gironaz, M., Hutwagner, L., Greene, K., Bopp, C., Maloney, K., Chavez, D., Sobsey, M. & Tauxe, R. V. 1999 Diarrhea prevention in Bolivia through point-of-use disinfection and safe storage: a promising new strategy. *Epidemiol. Infect.* **122**, 83–90.
- Reiff, F. M., Roses, M., Venczel, L., Quick, R. & Witt, V. M. 1996 Low cost safe water for the world: a practical interim solution. *J. Pub. Health Policy* **17**, 389–408.
- Ries, A. A., Vugia, D. J., Beingolea, L., Palacios, A. M., Vasquez, E., Wells, J. G., Garcia Baca, N., Swerdlow, D. L., Pollack, M. & Bean, N. H. 1992 Cholera in Piura, Peru: A modern urban epidemic. *J. Infect. Dis.* **166**, 1429–1433.
- Rothenberg, R. B. & Hahn, R. A. 1996 Measures of attribution. In: *Prevention Effectiveness; A Guide to Decision Analysis and Economic Evaluation*, C. Haddix, S. M. Teusch, P. A. Shaffer & D. O. Dunet (eds). Edited by A. Oxford: Oxford University Press.
- Semenza, J. C., Roberts, L., Henderson, A., Bogan, J. & Rubin, C. H. 1998 Water distribution system and diarrheal disease transmission: a case study in Uzbekistan. *Am. J. Trop. Med. Hyg.* **59**, 941–946.
- Shaffer, N., Mendes, P. & Costa, C. M. 1988. Epidemic of cholera in Guinea Bissau: importance of foodborne transmission, Abstract # 1459, 28th Interscience conference on Antimicrobial agents and chemotherapy.
- Shahid, N. S., Greenough 3rd, W. B., Samadi, A. R., Huq, M. I. & Rahman, N. 1996 Hand washing with soap reduces diarrhoea and spread of bacterial pathogens in a Bangladesh village. *J. Diarrhoeal Dis. Res.* **14**, 85–89.
- Sinclair, G. S., Mphahlele, M., Duvenhage, H., Nichol, R., Whitehorn, A. & Kustner, H. G. 1982 Determination of the mode of transmission of cholera in Lebowa. *S. African Med. J.* **62**, 753–755.
- Sobel, J., Mahon, B., Mendoza, C. E., Passaro, D., Cano, F., Baier, K., Racioppi, F., Hutwagner, L. & Mintz, E. 1998 Reduction of fecal contamination of street-vended beverages in Guatemala by a simple system for water purification and storage, handwashing, and beverage storage. *Am. J. Trop. Med. Hyg.* **59**, 380–387.
- St Louis, M. E., Porter, J. D., Helal, A., Drame, K., Hargrett-Bean, N., Wells, J. G. & Tauxe, R. V. 1990 Epidemic cholera in West Africa: The role of food handling and high-risk foods. *Am. J. Epidemiol.* **131**, 719–728.
- Swerdlow, D. L., Mintz, E. D., Rodriguez, M., Tejada, E., Ocampo, C., Espejo, L., Greene, K. D., Saldana, W., Seminario, L. & Tauxe, R. V. 1992 Waterborne transmission of epidemic cholera in Trujillo, Peru: Lessons for a continent at risk. *Lancet* **340**, 28–33.
- Swerdlow, D. L. & Isaacson, M. 1994 The epidemiology of cholera in Africa. In: *Vibrio cholerae and cholera: Molecular to global perspectives*, K. Wachsmuth, P. Blake & O. Olsvik (eds). American Society for Microbiology, Washington, DC.
- Swerdlow, D. L., Malenga, G., Begkoyian, G., Nyangulu, D., Toole, M., Waldman, R. J., Puh, D. N. & Tauxe, R. V. 1997 Epidemic cholera among refugees in Malawi, Africa: treatment and transmission. *Epidemiol. Infect.* **118**, 207–214.
- Tauxe, R. V., Mintz, E. D. & Quick, R. E. 1995 Epidemic cholera in the new world: translating field epidemiology into new prevention strategies. *Emerg. Infect. Dis.* **1**, 141–146.
- Vugia, D. J., Rodriguez, M., Vargas, R., Ricse, C., Ocampo, C., Llaque, R., Seminario, J. L., Greene, K. D., Tauxe, R. V. & Blake, P. A. 1994 Epidemic cholera in Trujillo, Peru 1992: Utility of a clinical case definition and shift in *Vibrio cholerae* O1 serotype. *Am. J. Trop. Med. Hyg.* **50**, 566–569.
- Wacholder, S., McLaughlin, J. K., Silverman, D. T. & Mandel, J. S. 1992a Selection of controls in case-control studies. I. Principles. *Am. J. Epidemiol.* **135**, 1019–1028.
- Wacholder, S., McLaughlin, J. K., Silverman, D. T. & Mandel, J. S. 1992b Selection of controls in case-control studies. II. Types of controls. *Am. J. Epidemiol.* **135**, 1029–1041.
- Weber, J. T., Mintz, E. D., Canizares, R., Semiglia, A., Gomez, I., Sempertegui, R., Davila, A., Greene, K. D., Puh, N. D. & Cameron, D. N. 1994 Epidemic cholera in Ecuador: multi-drug-resistance and transmission by water and seafood. *Epidemiol. Infect.* **112**, 1–11.
- Wenger, J. D., Hightower, A. W., Facklam, R. R., Gaventa, S. & Broome, C. V. 1990 Bacterial meningitis in the United States, 1986. Report of a multi-state surveillance study. *J. Infect. Dis.* **162**, 1316–1323.
- Wilson, N., Baker, M., Martin, D., Lennon, D., O'Hallahan, J., Jones, N., Wenger, J., Mansoor, O., Thomas, M. & Jefferies, C. 1995 Meningococcal disease epidemiology and control in New Zealand. *N. Zealand Med. J.* **108**, 437–442.