A cross-sectional study of enteric disease risks associated with water quality and sanitation in Hyderabad City

J. C. Mohanty, T. E. Ford, J. J. Harrington and V. Lakshmipathy

ABSTRACT

This paper describes a cross-sectional, questionnaire-based study to estimate enteric disease risks from drinking water and poor sanitary conditions in Hyderabad City, India. Community incidence rates of enteric diseases potentially transmitted through water (acute gastrointestinal infections, typhoid, hepatitis A) obtained from questionnaire administration were found to be approximately 200-fold greater than estimates based on hospital incidence data. Community incidence rates were therefore used for comparison with a range of socio-economic and drinking water system parameters. The incidence of these diseases was found to be significantly higher in areas where sewage overflows were frequent and where sewage could accumulate around the home, where utensils were cleaned on the street, where water distribution pipelines leaked and where no residual chlorine was maintained. Surprisingly, socio-economic factors such as education and income were not strongly associated with waterborne diseases.

Regression modelling also supported an association between health outcome and the following independent variables: rate of sewage overflow, % of cast iron pipe (as a measure of less leakage potential) and % samples without residual chlorine. The strength of the relationships suggests that improvement in sewage collection systems and water disinfection, and repair of water distribution system leakage should result in significant reduction in enteric diseases. This study provides a simple epidemiological approach to identify preliminary linkages between water quality and disease that can be used to affect policy decisions.

Key words | distribution system, enteric disease incidence, surveillance

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INTRODUCTION

It has been estimated that about 50% of the world's population suffers from diseases associated with water (WHO 1996). Diarrhoeal diseases caused over 3 million deaths in 1995, with 80% among children under age five, predominantly affecting the developing world. Only a fraction of waterborne disease outbreaks are recognized, investigated and reported. Even in developed countries an aetiological agent is identified in only about half of the outbreaks (Andersson & Stenstrom 1986; Craun 1990). A critical aspect of poor water quality in most cities in developing countries is the intermittent water supply. The distribution systems remain without pressure for most of the day, allowing cross-contamination with wastewater. In these cities, sanitation practices are poor and the sewerage systems are either not in place or inadequately developed, causing surface sewage overflows in many areas. The role of water in promoting basic hygiene and sanitation through provision of safe drinking water, in food preparation, in washing practices and in wastewater collection has been stressed by many authors (e.g. Esrey *et al*. 1990; Wibowo & Tisdell 1993; VanDerslice & Briscoe 1995; WHO 1996).

Although the factors responsible for the problem of waterborne disease are largely known, assessment of the quantitative relationships between drinking water quality and human health risk is in its infancy. This is primarily because surveillance systems are inadequate to estimate incidence of waterborne disease; quantification of infective pathogens in drinking water is virtually impossible using currently available technologies, and there are multiple routes of transmission for many of the pathogens of concern (water, food, person to person, etc.) (Ford & Colwell 1996; Ford 1999). This situation complicates planning for improvement in water supply and distribution systems because, while the needs are great, the resources available to meet these needs are scarce. Planners must decide whether to invest in source water protection, water treatment, water distribution system upgrade, monitoring programmes or wastewater collection and treatment systems. In addition, any funds committed to address drinking water quality issues are not available to address other pressing health and social issues. In general, policy decisions rely on surveillance data alone, usually hospital incidence rates, which dramatically underestimate true incidence of disease. This is particularly true for diarrhoeal diseases, which are self-limiting, seldom reported due to relatively mild symptoms, yet can be significant in economic terms (lost productivity, etc.) (Morris & Levin 1995; Bennett *et al*. 1997; Ford 1999).

The work presented here represents a modest first step towards addressing this dilemma. The paper presents a cross-sectional study designed to: (i) estimate the levels of enteric disease risk posed by poor drinking water and sanitation in Hyderabad City, India (Figure 1), and (ii) explore the relationships between the levels of health risks and both indicators of water quality and socio-economic variables.

Figure 1 | Map of India, showing the location of Hyderabad.

METHODS

Study site

This study was undertaken in the Municipal Corporation of Hyderabad (MCH) area where the Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB) supplies water directly to the consumers. The population of Hyderabad was estimated at over 4.3 million in the 1991 census and the MCH area is thought to serve approximately 3 million people. The HMWSSB supplies about 600 million litres of water per day from its four surface reservoirs to the MCH area and to the surrounding municipalities. Reservoirs are sited to the west and north of the city and, according to the HMWSSB, the source water quality is good. Conventional water treatment includes flocculation/sedimentation, rapid sand filtration and chlorination. To attempt to maintain a residual, the HMWSSB adds on average 4 ppm chlorine at the treatment plants. Residual chlorine is monitored in treatment plant effluent water on a daily basis. The HMWSSB also tests presence/absence of residual chlorine in many more locations in the distribution system (nominal detection limit ~0.1 ppm). Depending on exigencies this number is increased in different water supply zones.

The treatment plants have the capacity to supply water for only 2 out of 24 hours. Bacteriological examination (total and faecal coliforms), conducted by the HMWSSB of about 400 water samples per month at distribution sites where no residual chlorine is detected, shows that the treated water rapidly deteriorates in microbiological quality as it passes through the distribution system.

The first phase of Hyderabad's water supply system was established about 100 years ago. Most parts of the system in the old city (south of the Musi River and the adjoining northern part of the river) are 60–70 years old and the main and feeder service pipelines in this area are badly corroded. Different categories of pipe materials have been used at different times depending on government policies. The most commonly used pipe materials are: cast iron, reinforced cement concrete, asbestos cement and galvanized iron. Of these categories, cast iron pipes appear to have lasted longest and do not leak for many years if properly laid. Other categories such as reinforced cement concrete and asbestos cement pipes develop cracks under traffic loads. Pipelines are laid only 1 m below the ground surface. Individual pipe connections are mostly fabricated from galvanized iron and develop holes 10–12 years after installation. As a result, water losses from leakage have been estimated to be about 30% with a residual pressure head of 10 m, supplied for only 2 hours per day (HMWSSB).

The city's sewerage system was designed for a population of 0.5 million in 1931, covering an area of 105 km^2. Very limited improvement has taken place since then. As a result, about 500 sewage overflows occur daily in the MCH area. The HMWSSB provides direct water supply and collects sewage from consumers in the MCH area. It supplies bulk water to the surrounding municipalities and *Grama Panchayats* (local self-governing units). It is not responsible for collection of sewage in these areas. The sewage overflows are a source of faecal contamination of water and thereby can be a major source of exposure to microbial pathogens. Intermittent water supply leaves the system without pressure for about 22 hours a day, which facilitates the intrusion of sewage, wastewater and other contaminants into the system.

The topography of the city is highly undulating, with maximum and minimum elevations of 610 m and 480 m above MSL, respectively. The Musi River, flowing from west to east, divides the city in two and acts as the major drainage channel (it carries only sewage during the dry season, from November through March). The topography of the city affects the flow of sewage, which tends to accumulate in low-lying areas such as city lakes, in addition to the Musi River.

Study design and methodology

Health risks of drinking water were compared across water supply distribution zones in the MCH area. Information was gathered on community incidence of enteric diseases, exposure and socio-economic variables from household surveys and on system variables from the HMWSSB.

Household survey

A household survey was conducted from 30 November to 20 December 1996, in order to estimate the community incidence rate of enteric diseases (acute gastrointestinal infections (AGI), typhoid and hepatitis A). The survey was conducted by 30 trained technical assistants, who obtained informed consent of household participants prior to administering the questionnaire. The survey covered 3,573 households (population 24,278) in 18 of Hyderabad's 20 water supply distribution zones. The head of the family or a responsible member was interviewed in each household and asked to provide information on all household members. The questionnaire for the survey was pre-tested in the city, and revised before the final version was printed.

The technical assistants were advised to start with a random number from one end of each zone, and to select every 200th house thereafter along the lane or road. If the house selected did not have a water service connection, did not obtain drinking water from a public stand post (water hydrant) or from a water tanker being supplied by the HMWSSB (same source of treated water), then they were instructed to locate the nearest house using drinking water from any of the sources mentioned above. More than 99% of the households in the MCH get drinking water from the HMWSSB.

The questionnaire was designed to obtain information on three categories:

i. Community incidence data on health outcomes, including: acute gastrointestinal infections (AGI), dysentery, cholera, typhoid and hepatitis A during the previous one month (to minimize recall bias). Details of hospital, clinic or private physician diagnosis and treatment were obtained, in addition to undiagnosed diarrhoeal events (AGI) (Table 1). A copy of the full questionnaire can be obtained from the corresponding author.
ii. Exposure indicators, including: storage of drinking water, home treatment of drinking water, cleaning practices for utensils, cleaning agents for utensils, personal cleaning habits such as hand washing after toilet use and before eating food, food storage practices, dealing with spoiled food (i.e. removing damaged portions before consumption), outside eating habits (work cafeterias, etc.), laundry practices, children's play areas, and the status of sewage in the vicinity of the household.
iii. Socio-economic determinants influencing the behaviour and attitudes of the household members. First, receiving an education, which was categorized in this analysis as primary school and above vs. uneducated. Second, income level, which was categorized as monthly income ≤1,000 rupees, >1,000 to ≤3,000 rupees and >3,000 rupees (3,000 rupees per month (~US$60) is considered necessary to meet the basic needs for the average household studied in Hyderabad).

Hospital data

Hospital incidence data were obtained from the HMWSSB, the MCH and the Institute of Preventive Medicine. Each collects daily details of cases admitted in the Fever Hospital (Hospital of the Institute of Tropical Diseases), the Golconda Hospital and the Niloufer Hospital as part of their surveillance programme for drinking water-borne diseases. Among the three hospitals, the Fever Hospital accounts for the majority of cases. This public hospital, established during British rule, is the oldest in the city, and it is acclaimed as one of the best for treatment of tropical diseases. Its clientele (the majority from lower and middle income families) extend all over the city. The Niloufer Hospital, another public institution, is exclusively for children below 12 years and caters mostly to the needs of central Hyderabad. The Golkonda Hospital (also a public hospital) mainly treats patients from the Shaikpet zone and part of the Asifnagar zone.

System variable details

The HMWSSB has seven administrative divisions in the city, which provide water supply and wastewater collection services.

Data were collected from divisions covering 20 water supply distribution zones on:

- number of sewage overflows;
- number of reported leaks in the water supply distribution system;
- points of supplementary chlorination;
- number of samples tested for residual chlorine and numbers without residual chlorine;
- percentage of cast iron and other types of water feeder and distribution pipes;
- number of water supply connections;
- population of each zone.

Data analysis

In order to investigate relationships between all these variables, a multiple linear regression analysis was conducted using Microsoft Excel Version 7.0. The dependent variable, i.e. the health outcome, was expressed as the community rate (determined from the household survey) of enteric disease (AGI, typhoid and hepatitis A) per 1,000 population as reported in the different water distribution zones. The independent variables, systemic, community exposure and socio-economic are listed in Table 2.

Regression models were then constructed with the apparently relevant explanatory variables to examine the combination of variables that most closely reflect an association with health outcome. To select the appropriate models, a stepwise addition of explanatory variables was made and the appropriateness of model fit examined at each stage. Regression diagnostics were also performed on the models (Belsey *et al.* 1980).

Table 1 | Extract from the questionnaire administered for health risk analysis of drinking water in Hyderabad, describing information on disease status (a copy of the full questionnaire can be obtained from the corresponding author)

Information requested included: type of house, location, water source, storage, use patterns, home treatment, sewerage status, hygienic status and toilet habits, scope for contamination, eating habits, food storage habits, family profile, education, occupation, income and history of waterborne disease. The following enteric disease information was requested for each family member:

History of waterborne disease in the family

	Previous one month[1]			Hospitals				
Diseases	**FT**	**RSP**	**ROP**	**OSM**	**FVR**	**NFR**	**GOVT**	**PVT**
Gastro-enteritis								
Typhoid								
Hepatitis A								
Dysentery[2]								
Cholera[2]								

Was any family member subjected to the following tests:

(1) Stool examination for microscopic study?	Positive?	Negative?
(2) Culture and sensitivity test for stools?	Positive?	Negative?
(3) Liver function tests?	Positive?	Negative?
(4) Is there a polio-affected child in the household?	Yes	No
(5) Is there a practice of soap washing of hands before eating?	Yes	No
(6) Is there a practice of soap washing of hands after using WC?	Yes	No
(7) Were there any fatalities due to any of the diseases mentioned?	Yes	No
7.1 adult males	7.2 adult females	
7.3 male children	7.4 female children	
7.5 male infants	7.6 female infants	

Source of treatment

1. Govt hospital	Name of hospital:
2. Private nursing home	Name of nursing home:
3. Private doctor/consultant	
4. Mode of treatment:	4.1 in-patient 4.2 out-patient 4.3 self-treatment 4.4 any other
5. Duration of treatment:	
6. Treatment expenses:	

FT=first time; RSP=repeat same person; ROP=repeat other person; OSM=Osmania; FVR=Fever; NFR=Niloufer; GOVT=other government; PVT=private.

[1]Information was also requested for time periods extending back for the previous 12 months, however, only information for the past month is included in the analysis to minimize recall bias.

[2]Neither of these diseases was diagnosed during the recall period.

Table 2 | Descriptive statistics of system, exposure and socio-economic variables. A number of zones shared minimum % in this table. For reasons of space, only the zone with the highest or lowest incidence of disease is listed (depending on variable), the number of other zones sharing minimum % is listed in the final column

Variables	Mean %	SD %	Max %	Min %	Max zone	Min zone
Systemic						
Samples without residual chlorine	4.39	3.86	14.18	0.18	Chanchalguda	Adikmet
Daily no. of sewage overflows (SO)	26.80	14.95	77	10	Red Hills	Prakash Nagar
Rate SO (per 1,000 population)	0.186	0.06	0.291	0.098	Red Hills	Asifnagar
Daily no. of leakages	9.05	6.61	25	2	Chilkalguda	Misriganj
Cast iron pipes	40.50	12.76	60	20	Misriganj + 1 other	Chandrayangutta + 2 others
Storage of water						
Earthen vessels	15.1	6.62	34.37	5.48	Miralam	Hussain Sagar
Plastic vessels	10.97	7.11	24.87	0.49	Chandrayangutta	Aliabad
Metal vessels	73.91	8.40	86.83	62.43	Misriganj	Chand rayangutta
Home treatment						
Total	62.64	17.46	85.64	29.91	Misriganj	Adikmet
Candle filter	22.73	11.26	45.56	7.43	Chandrayangutta	Misriganj
Zero B filter	1.25	1.70	6.24	0	Red Hills	Shaikpet + 4
Aquaguard filter	0.93	1.07	3.16	0	Chilkalguda	Asifnagar + 6
Boiling water	4.30	6.89	29.25	0	Jubilee Hills	Riyasatnagar + 2
Utensil cleaning						
Kitchen	55.17	14.39	80	23.86	Prakash Nagar	Miralam
Backyard	40.40	15.40	76.14	15.56	Miralam	Praka sh Nagar
Street	4.42	6.69	28.96	0	Asmangadh	Adikmet + 3
Cleaning agent						
Detergent	70.85	14.58	90.08	41.01	Chanchalguda	Riyasatnagar
Ash	26.51	15.38	57.55	3.47	Riyasatnagar	Asmangadh
Mud	2.64	2.48	9.65	0	Asmangadh	Adikmet + 2
Storage of food						
Refrigerator	24.80	9.54	43.51	12.15	Narayanguda	Adikmet
In dishes	43.92	15.14	71.64	17.69	Shaikpet	Jubilee Hills

Table 2 | *Continued*

Variables	Mean %	SD %	Max %	Min %	Max zone	Min zone
General hygiene						
Use damaged food	9.96	10.01	28.57	0	Asmangadh	Prakash Nagar
Eating out	43.17	14.03	70.99	21.25	Chanchalguda	Chand rayangutta
No hand washing after defecation	7.22	9.69	38.53	0	Marredpally	Aliabad + 2
External laundry	11.06	6.71	28.27	1.25	Banjara Hills	Chandrayangutta
Children’s play areas: street	42.29	19.72	78.63	8.89	Chanchalguda	Prakash Nagar
Sewage in vicinity of house	31.94	13.70	64.09	17.16	Asmangadh	Shaikpet
Socioeconomic						
Uneducated	23.20	9.60	48.30	11.20	Asmangadh	Jubilee Hills
Monthly income: ≤Rs 1,000	13.24	5.91	23.33	2.22	Hussain Sagar	Prakash Nagar
Monthly income: ≤Rs 3,000	48.91	13.76	88.06	28.97	Shaikpet	Adikmet

RESULTS

The mean and standard deviation of data on incidence of disease, on system parameters, on exposure parameters and on socio-economic variables were estimated by zone, in order to make a preliminary comparison.

Incidence of disease

A total of 903 cases of AGI, typhoid and hepatitis A were reported during the household survey. The mean incidence rate (IR) was calculated as 37.39 cases per 1,000 population (SD 19.26). The maximum incidence rate of 92.33 and the minimum incidence rate of 12.05 cases were reported from the Asmangadh and Prakash Nagar zones, respectively. Figure 2 shows a breakdown of cases of Hepatitis A, typhoid, AGI and the total of these three, by zone.

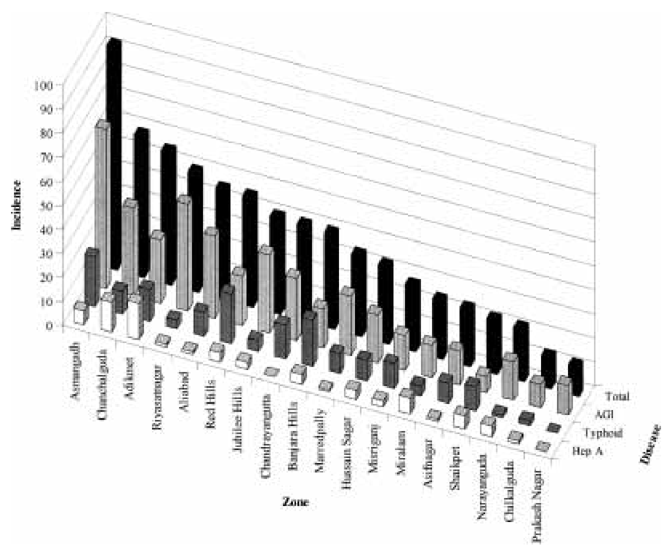

Figure 2 | Enteric diseases potentially transmitted by water in Hyderabad by zone (community rates from questionnaire survey for past month per 1,000 population). AGI=undiagnosed acute gastrointestinal infections.

 Journal of Water Supply: Research and Technology—AQUA | 51.5 | 2002

Table 3 | Hospital incidence data (IR) of AGI, typhoid and hepatitis A per 1,000 population in Hyderabad (average of 1992–1995 data)

	AGI		Typhoid		Hepatitis A	
Month	Average	IR	Average	IR	Average	IR
Jan	392	0.13	92	0.03	22	0.01
Feb	498	0.16	95	0.03	29	0.01
Mar	778	1.26	139	0.05	24	0.01
Apr	811	0.27	133	0.04	38	0.01
May	1,222	0.40	146	0.05	44	0.01
Jun	1,121	0.37	166	0.06	39	0.01
Jul	1,245	0.41	194	0.06	40	0.01
Aug	948	0.31	191	0.06	41	0.01
Sep	619	0.20	138	0.05	42	0.01
Oct	556	0.18	154	0.05	29	0.01
Nov	410	0.14	135	0.04	23	0.01
Dec	331	0.11	124	0.04	26	0.01
Total[1]	8,931	2.95	1,707	0.56	397	0.12

[1]Total number of enteric diseases (AGI+typhoid+Hepatitis A)=11,035; the average monthly total for the November–December time period=524.5; this monthly rate is therefore equivalent to 4.75% of the annual rate.

The mean incidence rate of AGI was 24.04 cases per 1,000 population (SD 14.63). The maximum IR of 65.95 cases was again from the Asmangadh zone, while the minimum IR of 6.61 was reported from the Shaikpet zone. Typhoid cases recorded a mean IR of 9.33 cases per 1,000 population (SD 6.34) with the maximum IR of 20.81 from the Red Hills zone and the minimum IR of 0 from the Prakash Nagar zone. The mean IR of hepatitis A in the city was 4.03 cases per 1,000 population (SD 4.11). The Adikmet zone accounted for the maximum IR of 15.12 cases, and the Chandrayangutta and the Prakash Nagar zones reported no cases during the survey period.

The hospital-reported IRs for AGI, typhoid and hepatitis A averaged for a one month period during November–December (average of 1992–1995 data) are 0.13, 0.04 and 0.01, respectively, per 1,000 population (Table 3). Thus, AGI, typhoid and hepatitis A hospital incidence rates are 185, 233 and 403-fold smaller, respectively, than household survey data (community incidence rates).

Systemic, exposure and socio-economic variables

Considerable variation was found between zones in systemic, exposure and socio-economic variables (Table 2).

In terms of systemic variables, a total of 49,494 water samples were tested for residual chlorine during 1996; 2,705 samples tested negative, representing 5.47% of

Table 4 | Regression models[1] for health risks of drinking water (community rates from questionnaire survey for past month per 1,000 population)

	Model 1			Model 2			Model 3		
R^2	0.52			0.68			0.72		
Adjusted R^2	0.42			0.59			0.60		
Variables	Coefficient	T Stat	P-value	Coefficient	T Stat	P-value	Coefficient	T Stat	P-value
Rate of sewage overflow	123.45	2.25	0.04	64.91	1.26	0.23	73.56	1.43	0.18
% without residual chlorine	2.16	2.42	0.03	0.88	0.99	0.34	0.46	0.48	0.64
% of cast iron pipe	– 0.65	– 2.41	0.03	– 0.47	– 1.95	0.07	– 0.42	– 1.77	0.10
% with dirty or moderate sewage				0.74	2.58	0.02	0.63	2.14	0.05
% cleaning utensils on road							0.65	1.14	0.28

[1]Regression models are constructed to assess the association between apparently relevant independent variables and the dependent variable (in this case, the health outcome expressed as the questionnaire-derived rate of enteric disease incidence for each zone). Independent variables are added in a stepwise fashion to the model and the model is examined at each stage for appropriateness of fit.

samples tested. On average, 181 leaks were reported daily in the distribution system. However, there are also many underground leaks that are not visible. In the Red Hills and Misriganj zones, cast iron pipes constitute about 60% of all the pipes and in Chandrayangutta, Jubilee Hills and Banjara Hills, cast iron pipes form about 20% of the total.

The zone with the highest enteric disease incidence (the Asmangadh zone) had the second highest number of water samples without residual chlorine (12.35%), and maximum risk factors such as sewage in the vicinity of the home, using mud as a cleaning agent and number without education. In contrast, the Prakash Nagar zone with the minimum enteric disease incidence had minimum risk factors such as number of sewage overflows, utensil cleaning in the backyard, use of damaged food and children playing in the street.

Regression analysis

In order to investigate the contribution of systemic variables to enteric disease incidence, data were aggregated at the zonal level. Thus, the total number of observations was 18. The regression output from the multiple linear regression analysis using all variables gave an R^2 value of 0.97; however, none of the independent variables was significantly correlated with the dependent variable (enteric disease incidence), which was not unexpected due to the low degrees of freedom (16). Before exploring the potential usefulness of the regression analysis further, the correlation matrix of all the variables was examined. The incidence rate of disease had high correlation coefficients with % of houses with moderate and dirty sewage status (no wastewater collection or other sanitary facilities) ($r = 0.75$), % of households cleaning utensils on the street ($r = 0.52$), rate of sewage overflow ($r = 0.44$), % of cast iron pipe ($r = -0.41$) and % of samples without residual chlorine ($r = 0.34$). Percentage of households cleaning utensils on the street is also highly correlated with % of water samples without residual chlorine ($r = 0.52$), reflecting the socio-economic status of zones at end-of-pipe locations.

The results of the regression model building exercise are shown in Table 4. Of the three models, all explanatory variables have significant p-values (probability of association with health outcome) only in model 1. The three variables in this model are all systemic variables with significant policy implications for the HMWSSB. However, the measure of appropriateness of fit of the model (R^2 and adjusted R^2) is comparatively smaller than for the other two models. An R^2 of 0.52 is still reasonable given the noise in the data. Between correlated explanatory variables, systemic variables were given preference in the model building exercise.

Regression diagnostics identified three borderline observations (with respect to predicted values) (Belsey *et al*. 1980): (i) the Red Hills (highest rate of sewage overflow; one of the two zones with highest % of cast iron pipes); (ii) the Chanchalaguda zone (second highest rate of disease and highest % of samples without residual chlorine), and (iii) the Asmangadh zone (highest rate of disease; second highest % without residual chlorine; second lowest % of cast iron pipes). However, as these observations were close to the cut-off values and not too extreme, these three zones were retained in the model.

Socio-economic variables

Education and economic status might be expected to affect health status, as the more educated, higher income communities have greater access to medical facilities and information to improve hygiene. Although there is a negative correlation between the level of education and enteric diseases, it is not significant ($r = -0.12$, p-value 0.32). However, a significant inverse relationship appears between education and other behavioural attributes, including % of households without home treatment ($r = -0.69$, p-value 0.001), % cleaning utensils on the street ($r = -0.42$, p-value 0.04) and % using mud as a cleaning agent for utensils ($r = -0.5$, p-value 0.02).

Although a higher percentage of families with monthly incomes of 1,000 rupees or less reported one or more incidences of enteric disease, the correlation was also not significant ($r = 0.13$, p-value 0.31). However, this group of households is positively correlated with the % of households cleaning utensils on roads ($r = 0.38$, p-value 0.06), % of households using mud as a cleaning agent for utensils ($r = 0.46$, p-value 0.03), % of households with no home treatment of water ($r = 0.36$, p-value 0.07), % of households not washing hands with soap after defecation ($r = 0.38$, p-value 0.06) and % of households eating spoiled food after removing the damaged portion ($r = 0.16$, p-value 0.27).

DISCUSSION

Incidence of disease

The hospital surveillance data appear to considerably underestimate the actual number of enteric diseases. This is probably not an isolated phenomenon for Hyderabad city. It is likely to be true for other Indian cities. For example, in Ahmedabad city, reported incidence rates per 1,000 people for AGI, cholera and typhoid were 2.25, 0.021 and 0.169, respectively (based on 1994 hospital incidence data, USAID 1995). Monthly averages for AGI disorders and typhoid were calculated as 0.19 and 0.014. Compared with this, the November–December reported cases in Hyderabad are 0.13 and 0.04, respectively, indicating that similar patterns of hospital incidence rates are prevalent in both the cities. Since the present study revealed a large difference between the hospital incidence rate and the community incidence rate in Hyderabad, a similar picture may emerge in Ahmedabad if an epidemiological survey is conducted.

From the hospital incidence data, the average monthly rate during the November–December period accounts for 4.75% of annual cases (Table 3). The present study estimated an incidence rate of 37.39 per 1,000 population for the same period. On extrapolation, the annual community incidence rate of enteric disease in the city is calculated as 787 per 1,000 population; and the total estimated number of cases per annum is about 2.36 million. These estimates, though they appear high, are lower than the 927 diarrhoeal cases per 1,000 population for India as reported in *Global Health Statistics* (Murray & Lopez 1996).

The reason for large discrepancies between hospital incidence data and community incidence is not difficult to understand. First, it is common practice for people in Hyderabad to go to the hospitals only if symptoms appear relatively serious. They either manage to treat themselves or consult a local private practitioner and buy drugs from the medical shops. Second, the figures here are from only three public hospitals, whereas in total there are about 150 private hospitals, nursing homes (refers to small private hospitals in the Indian context) and clinics, as well as about 70 public health service institutions and 1,200

Journal of Water Supply: Research and Technology—AQUA | 51.5 | 2002

private medical practitioners. The pattern of utilization of health services in the urban sector of Andhra Pradesh was examined in the 42nd round of the 'National Sample Survey' conducted between July 1986 and June 1987. This survey estimated that public hospitals accounted for about 38% of hospitalized cases, while 62% of hospitalized cases were in private hospitals (55%), charitable institutions (4%) and nursing homes (3%) (Govt of India 1989). This suggests that two-thirds of the hospitalized cases are not included in hospital incidence rates.

Systemic variables

The HMWSSB tries to maintain 1–2 ppm residual chlorine at the tap. Absence of residual chlorine greatly increases the risk of exposure of individuals to pathogens and therefore to increased health risks. In an effort to maintain this residual, the HMWSSB adds on average 4 ppm chlorine at the treatment plants and in the distribution system as the primary and supplementary disinfection agent. This is much higher than the residual prescribed (0.2 ppm) in the water manual prepared by the Central Public Health Environmental Engineering Organization, Ministry of Urban Affairs, Government of India. In addition, the HMWSSB uses more than 10 ppm chlorine in certain stretches, suggesting that the intrusion of sewage and other organic contaminants into the distribution system might be consuming the chlorine, given the many locations with no chlorine residual. [It should be noted that with high endemic disease risks, disinfection of drinking water should not be compromised through poorly defined health risks from disinfection by-products (Ford and Colwell 1996).]

Sewage overflow is an important factor for health risk due to drinking water. Sewage contamination of drinking water, utensils, clothes and playground soil greatly enhances the health risks for the concerned population. The percentage of leaks is an indication of the extent to which the water supply feeder and service pipelines have deteriorated in a zone. Higher leakage in the system increases the probability of contamination in the system, thereby enhancing exposure of the population to microbial pathogens. The environmental health study of Bangkok (USAID & USEPA 1990) also observed that low water pressures and even negative pressure from suction pumps at residences in some localities might be allowing sufficient infiltration of external water (mostly contaminated) into the distribution system.

A study by Wibowo and Tisdell (1993) in Central Java, Indonesia, provided evidence that safe water and sanitation are critical for improving health status. They suggested, however, that in the event of budget constraints, investment in safe drinking water should take priority over sanitation. From the work reported here, it could be argued that improvements in water supply alone will have little effect if sewage is still accumulating in and around the home. However, further studies are needed to fully evaluate these factors. Another study by VanDerslice and Briscoe (1995) in the Philippines demonstrated that water quality, household sanitation and community sanitation have strong, consistent and statistically significant effects on diarrhoea in infants. Water and Sanitation for Health (WASH) Technical Report No. 66 (Esrey *et al.* 1990) reviewed the literature on the health benefits from improvements in water supply and sanitation and found a median reduction of 20% in diarrhoeal morbidity and mortality (seven studies).

The results of the regression analysis should be accepted with a word of caution. The regression model suggests an association between the dependent variable (health outcome) and the explanatory variables (the rate of sewage overflow, % of water samples without residual chlorine and % of cast iron pipes), but not any cause and effect relationship. Results from future cross-sectional and longitudinal (diary-based) studies are necessary to strengthen these associations and eventually provide data for quantification of risks.

Exposure scenarios

In general, zones with an incidence rate of disease higher than the mean have more than one high exposure scenario (i.e. unsanitary conditions where sewage accumulates around the house, cleaning utensils on the street, children playing on street, cleaning utensils with mud, minimum use of home treatment of water, not refrigerating food, etc.), whereas zones with incidence of disease lower than the mean did not. All of these are expected to contribute to the increased incidence of enteric disease.

It cannot be assumed that households using any form of point-of-use filtration and treatment are drinking bacteriologically safe water. The National Environmental Engineering Research Institute, Nagpur, India, conducted a laboratory study to test the performance of the four most popular advertised water filters in terms of turbidity and coliform bacteria removal (Kulkarni *et al.* 1980). The two tap attachable filters (Type A, cotton wad held on a coarse sintered crucible; Type B, microporous bed held on a porous Buchner type funnel) were shown to be unreliable for producing bacteriologically safe drinking water and inefficient in turbidity removal. The two candle type filters (two-layer gravity filters with an outer porous layer of calcium and an inner layer of coal) were good at turbidity removal, but not satisfactory for bacterial elimination. However, tests on tap attachable ultraviolet purifiers (such as Aquaguard) supported the manufacturers' claims of production of 100% bacteria free water (Chaudhuri & Sattar 1990). Thus, out of a mean of 37.76% of households by zone with any form of point-of-use treatment, only a mean of 5.23% of households are probably drinking bacteriologically safe water (i.e. use ultraviolet purifier or boil water).

Good hygiene, such as hand washing with soap or other cleaning agents before eating and after using the toilet, reduces bacterial contamination. Specifically, in Hyderabad, the common practice is not to use toilet paper after defecation, but to clean by hand and water. Unless the hands are then thoroughly washed with soap, the chance of faecal contamination is very high. On average, 7.22% of households (SD 9.69) do not wash their hands after defecation, with a maximum of 38.53% in the Marredpally zone. In Asifnagar, Aliabad and Adikmet zones, all the surveyed households responded that they washed their hands after defecation. The small percentage of respondent households admitting to not washing hands is thought to be an underestimate, as people tend to be evasive when answering this specific question (interviewer's subjective observation).

Surprisingly, socio-economic variables such as income and education level are not highly correlated with the incidence of disease, suggesting that factors other than socio-economic status are important in pathogen exposure. They are, however, correlated with behavioural risk factors such as cleaning utensils on the street, and thus should be considered in developing overall strategies for risk reduction.

CONCLUSIONS

This study demonstrated that the community incidence rates of enteric diseases in Hyderabad are much higher (by a factor of ~200) than hospital incidence rates. A sizeable population utilizes the health services from sources other than the three major government hospitals. As policy decisions are based on the government hospital surveillance data, these decisions may dramatically underestimate the importance of water and sanitation in enteric disease burden. More accurate assessment of the more severe enteric disease prevalence could be obtained through data collection from the non-governmental institutions and medical practitioners. However, population surveys are the only approach to begin to estimate percentage of unreported disease. These numbers may then assist in evaluating the true human health and economic costs of poor water and sanitation, supporting policy initiatives for future infrastructure improvement.

The multiple linear regression analysis showed that disinfection, rate of sewage overflow and percentage of cast iron pipes (surrogate for leakage in the water supply distribution system) are significant predictors of enteric disease incidence. The sewage status around the households was highly correlated ($r = 0.75$) with the community incidence rate of disease. Therefore, the government should launch community education programmes to induce households to maintain sanitary and hygienic surroundings, and should prioritize the implementation of sewage collection systems in underserved areas of the city. In addition, the preliminary information presented in this paper suggests that repair of water distribution system leakage and improvement in water disinfection should result in significant reduction in enteric diseases.

This study represents one of the few attempts to link infectious disease epidemiologically with a municipal water supply in a developing country. Sophisticated approaches to pathogen-specific monitoring are unavailable, and only crude estimates of water quality can be obtained from within the distribution system. This study provides a simple epidemiological approach based on administration of an extensive questionnaire to obtain community incidence of disease and information on basic hygiene and sanitation. The preliminary linkages between water quality and disease can be used to affect policy decisions to improve water delivery and wastewater collection systems, and to develop more effective surveillance.

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