Association of water, sanitation, hygiene and food practices with enteric fever in a paediatric cohort in North India

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ABSTRACT
Background Our aim was to assess the association of water, sanitation and hygiene (WASH) and food practices with culture-confirmed enteric fever in children <15 years of age.

Methods We followed a cohort of 6000 children from an urban low socioeconomic neighbourhood in South Delhi for 2 years to estimate burden of culture-confirmed enteric fever. Risk ratios (RRs) were estimated to study the association between WASH practices and enteric fever. We assessed the microbiological quality of drinking water and conducted geospatial analysis to evaluate the distribution of enteric fever cases around households with contaminated drinking water.

Results A total of 5916 children in 3123 households completed survey. Piped water (82%) was the major source of household drinking water. One-third (32%) of the households treated water before consumption. Almost all households had sanitary toilets (99.9%) and 16% used shared toilets. Consumption of food from street vendors and unnamed ice creams more than once a week was observed in children from 12.7% and 38.4% households, respectively. Eighty culture-confirmed enteric fever cases were reported. The risk of enteric fever was 71% higher in children belonging to households having food from outside once a week or more (RR 1.71, 95% CI 1.00 to 2.94). The RR for enteric fever in children living in households with contaminated drinking water was 0.75 (95% CI 0.45 to 1.26). We found that 14.8% of the households had presence of coliforms or Escherichia coli in their household drinking water. The odds of having a case of enteric fever within a 5 and 25 m buffer zone around households with contaminated drinking water were 4.07 (95% CI 0.81 to 20.5) and 1.44 (95% CI 0.69 to 3.00), respectively.

Conclusion In addition to WASH practices, optimal food hygiene may have a role in urban low socioeconomic population to control enteric fever.

INTRODUCTION

Low-income and middle-income countries have high burden of enteric fever, with South Asia and sub-Saharan African countries accounting for majority of the cases.1

ESTIMATES FROM A META-ANALYSIS SHOWED THAT THE POPULATION-BASED POOLED INCIDENCE OF TYPHOID AND PARATYPHOID IN INDIA WAS 377 (178–801) AND 105 (74–148) PER 100,000 PERSON YEARS, RESPECTIVELY, WITH HIGHEST INCIDENCE AMONG CHILDREN AGED 2–4 YEARS.2 IN AN EARLIER COHORT IN DELHI, THE INCIDENCE RATE OF TYPHOID PER 1000 PERSON-YEARS WAS 27.3 AMONG UNDER-5 CHILDREN, 11.7 IN 5–19-YEAR OLDS, AND 1.1 AMONG PARTICIPANTS AGED 19 AND 40 YEARS.3

Risk of enteric fever seems to be higher in populations with poor accessibility to safe water and sanitation facilities.4 A recent systematic review on the association between water, sanitation and hygiene (WASH) factors and typhoid fever revealed that improved water source (OR 0.73, 95% CI 0.56 to 0.95),
treated water (OR 0.59, 95% CI 0.45 to 0.75), availability of household latrine (OR 0.87, 95% CI 0.68 to 1.11) and good hygiene (OR 0.52, 95% CI 0.40 to 0.67) were associated with lower risk of typhoid fever, while open defecation (OR 0.99, 95% CI 0.84 to 1.18) and unsafe waste management (OR 1.56, 95% CI 1.25 to 1.95) were associated with higher risk of typhoid.

In India, less than 50% of the population has access to safely managed drinking water. However, there is an improvement in the availability of basic sanitation (from 38% in 2014 to 95% in 2019) following implementation of Swachh Bharat Mission (2014). The studies on the association of WASH and enteric fever from Indian settings included in the review by Brockett et al were published in the early 2000s. Also, there was a lot of heterogeneity in the burden of enteric fever across different states ranging from 215 per 100 000 PY in Kolkata to 980 per 100 000 PY in New Delhi. Multiple initiatives during these years have affected the WASH and food hygiene practices as well as immunisation schedules across different states in the country. Contrary to the speculations of a lower burden, our recent study reported a high burden of enteric fever, that is, 703.7 (95% CI 560.5 to 874.7) per 100 000 PY.

In the present scenario, with improved access to water and sanitation, the role of WASH practices towards disease burden of enteric fever remains to be reasserted. Using the data from our paediatric longitudinal cohort in Delhi, we aimed to estimate the association between WASH and food practices with culture-confirmed enteric fever. As an exploratory exercise, we also aimed to study the spatial distribution of enteric fever cases and contaminated drinking water in the community by using geographical information system (GIS).

**METHODS**

**Study design**

This study was part of the ‘Surveillance of Enteric Fever in India (SEFI)’ paediatric cohort, conducted for estimation of enteric fever burden in children across four sites in India. The protocol of the SEFI study has been published previously. The North Indian site comprised adjoining blocks of Sangam Vihar, a low-income urban neighbourhood in the south district of New Delhi.

**Data collection**

We conducted a door-to-door household survey to identify eligible children aged 6 months–14 completed years. Six thousand eligible children who consented to participation were enrolled and followed up weekly for 24 months from enrolment or until the child attained the age of 15 years (whichever was earlier). We conducted geotagging of all enrolled participants and households. In the event of fever, our team made daily contacts until the end of the fever episode. Blood culture was performed if fever lasted for three or more consecutive days. WASH and food hygiene practices were assessed using a structured interview schedule that was administered during home visit in the study households. The WASH questionnaire was based on a modified version of the WHO document on core questions on drinking water and sanitation for household surveys. Information related to food practices was obtained for the eldest enrolled child in the household.

To estimate the prevalence of microbiologically safe drinking water consumption among households in the study area, we conducted a subsurvey in 108 households selected by simple random sampling in December 2019. The sample size for this exercise was calculated assuming that 50% of households in the community would have access to microbially safe drinking water with a relative allowable error of 20%. We collected drinking water samples (1.5 L) from the drinking water storage point in these households to test for the most probable number of coliform per 100 mL, pH and total dissolved solids. The laboratory tests were conducted in TÜVs (Technischer Überwachungsverein) (TUV SUD), Gurgaon, Haryana, India. Presence of coliforms in drinking water was labelled as contaminated drinking water.

**Data management**

Data were collected on tablets with built-in GIS using Android application package ‘EntericFev’, developed in-house by the SEFI team and stored in a secured Amazon cloud-based server. Data were monitored using a dashboard-based system; weekly reports were generated and reviewed. Quality checks were conducted by a central independent team of experts.

**Data variables and analysis**

Data were analysed by Stata V.16 software. Mean and median were calculated for continuous variables, while proportions were calculated for categorical variables. We conducted a child-based analysis to study the association between WASH practices and enteric fever. To account for the design effects of household clustering, when more than one child were included in the cohort from a household, we used Stata’s robust variance estimator (cluster) option. Improved source of drinking water was defined as use of piped water system or bottled water. Adequate water treatment was defined as treatment of water by boiling, bleach/chlorine or filtration. Safe drinking water in a household was defined as presence of improved source of drinking water along with practice of adequate water treatment. An improved toilet facility included flush toilets and pit latrines. Safe sanitation was defined as improved toilet facility with no sharing of toilets. Consumption of cooked foods, along with rare consumption of outside food (consumption of food from street vendors and/or unnamed ice creams less than once a week), was labelled as good food practices. Univariable analysis was done to see the association between WASH and food practices with incidence of enteric fever. Based on the directed acyclic graph (DAG) conceptual model (dagitty.net), age, education, family size and receiving typhoid vaccine were
identified as the potential confounders. We included the covariates in our final multivariable model which were either suggested by the conceptual DAG model or significant at p<0.25 in univariable analysis (figure 1). The cases of typhoid and paratyphoid along with the households with contaminated drinking water were plotted using ArcGIS V.10.8 on a Google Earth base map of July 2021 for the study area20 (figure 2). We estimated Moran’s index to assess clustering of enteric fever cases in the area.21 We conducted a buffer analysis to estimate the odds of a case of enteric fever within a coverage area of 5, 10 and 25 m radius around the study households with and without contaminated drinking water.22

Patient and public involvement statement
Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research.

Table 1  Baseline characteristics of the study population (N=5916)

| Characteristic                                      | n* (%)          |
|----------------------------------------------------|-----------------|
| Total number of households                         | 3123            |
| Female gender                                      | 2896/5916 (48.9)|
| Age group (years)                                  |                 |
| <5                                                  | 1850/5916 (31.3)|
| 5–10                                               | 2469/5916 (41.7)|
| >10                                                | 1597/5916 (27.0)|
| Nuclear family                                      | 4301/5916 (72.7)|
| Family size: mean (SD) (N=5916)                    | 5.7 (2.2)       |
| Highest education in family as years of schooling   |                 |
| Illiterate                                          | 66/5916 (1.1)   |
| <5                                                  | 114/5916 (1.9)  |
| >5                                                  | 5736/5916 (97)  |
| Pucca house†                                        | 5862/5916 (99.1)|
| Proportion of children living in overcrowded households (>2.5 persons per living room) | 4233/5916 (70.6) |
| Separate kitchen available                          | 3770/5916 (63.7)|
| Monthly income in Indian national rupees: median (IQR) (n=5916) | 10 000 (8000–15 000) |
| Received typhoid vaccine                            | 820/6000 (13.7) |
| Type of typhoid vaccine received                    |                 |
| Polysaccharide                                      | 778/820 (94.9)  |
| Conjugate/unclear                                   | 42/820 (5.1)    |
| Vaccine received at a government facility           | 782/820 (95.4)  |

*Figures indicate n (%), unless indicated otherwise. †Pucca house is a term that refers to housing in South Asia built of substantial material such as stone, brick, cement, concrete or timber.

RESULTS
A total of 6000 children <15 years were enrolled; 31% were <5 years; 42% were between 5 years and 10 years; and 27% were between 10 years and 15 years of age. Around half of them were male (51%). Three-fourth (73%) of the children belonged to nuclear families, and 70.6% belonged to overcrowded households. The median monthly income was Rs 10 000 (IQR 8000–15 000). In this paediatric cohort, 13.7% had been vaccinated against typhoid, of which 95% received a polysaccharide vaccine, mostly from a government health facility (table 1).

The survey on demographic characteristics and WASH and food practices was completed in 3123 households with 5916 children. Piped water from the Delhi municipal corporation (82%) and bottled water (10%) were the major sources of household drinking water; around one-third (32%) of the households treated water before consumption. The most common method of purification was filtration (94%). Almost all the households
had sanitary toilets, of which 21% had flush systems. Sharing of toilets with other families was observed in 16% of the households. Among children >3 years of age, 90% (4387/4903) were using toilets; 4% (194/4903) were disposing off stools in the garbage, while in 1.1% (55/4903), the stools were disposed-off in the drain/ditch. Consumption of uncooked food without washing was observed in 1.9% of the households. Consumption of food from street vendors and unnamed ice creams from street vendors more than once a week was noted in participants in 12.7% and 38.4% of households, respectively. (table 2)

A total of 80 children had culture-confirmed enteric fever; 68 had *Salmonella typhi* and 10 had *S. paratyphi*; and two children had coinfection. No enteric fever-associated deaths were observed. Spatial autocorrelation analysis suggested a clustering pattern for the typhoid fever cases in the study area (Moran’s Index 0.48, z-score 2.5, p=0.012); no clustering was suggestive for paratyphoid fever cases (Moran’s Index 0.16, z-score 0.28, p=0.778).

The risk of enteric fever was 1.71 times higher in children belonging to households eating food from outside once a week or more (adjusted risk ratio (RR) 1.71, 95% CI 1.00 to 2.94). The risk of enteric fever was 25% lower in children living in households with availability of safe drinking water (adjusted RR 0.75, 95% CI 0.45 to 1.26); however, the association was not statistically significant. The risk of enteric fever was 1.32 times higher in children living in households sharing toilets (adjusted RR 1.32, 95% CI 0.76 to 2.30; table 3).

We found that 16/108 (14.8%, 95% CI 8.7% to 22.9%) of the households had presence of coliforms in their household drinking water; all the 16 households had a coliform count of >100/100mL of drinking water. The median total dissolved solids in drinking water was 130 mg/L (IQR 65–151) and the mean (SD) pH was 7.2 (0.5). Buffer analysis revealed that the odds of having a case of enteric fever in the surrounding radius of 5, 10 and 25 m in households with contaminated drinking water against households without contaminated drinking water were 4.07 (95% CI 0.81 to 20.5), 1.74 (95% CI 0.54 to 5.67) and 1.44 (95% CI 0.69 to 3.00), respectively (table 4).

### DISCUSSION

This study reports the association between WASH practices and incidence of enteric fever in children up to 15 years of age. Our findings suggest that consumption of safe drinking water and safe sanitation practices were associated with a lower risk of enteric fever, while sharing of toilets and eating food from outside were associated with a higher risk of enteric fever. However, the precision for some of these associations was wide and the association is non-significant. Nearly 15% of the households had presence of *E. coli* or coliforms in their household drinking water. Geospatial analysis revealed higher odds of a case of enteric fever in surrounding zones of households with contaminated drinking water as compared with those without contaminated drinking water.

In the present study, the possibility of selection bias was low, as all children from geographically contiguous areas in the study site were offered participation. Though the

| Table 2  | WASH and food practices (N=5916) |
|----------|---------------------------------|
| **WASH parameter** | **n (%)** |
| **Drinking water-related practices** | |
| Source of drinking water | |
| Piped water from Municipality | 4845 (81.9) |
| Bottled water | 605 (10.2) |
| Public tap/standpipe | 226 (3.8) |
| Others* | 240 (0.4) |
| Households treating water before consumption | 1917 (32.4) |
| Methods of water treatment (N=1917) | |
| Filtration† | 1809 (30.6) |
| Boiling | 92 (1.5) |
| Others ‡ | 16 (0.3) |
| Improved source of drinking water | 5158 (87.2) |
| Adequate water treatment | 1907 (32.2) |
| Safe drinking water | 1733 (29.3) |
| **Sanitation practices** | |
| Type of toilet facility used | |
| Pit latrines | 4695 (79.3) |
| Flush type toilet | 1220 (20.6) |
| Composting toilet | 1 (0.1) |
| Children living in households with shared toilets | 942 (15.9) |
| Child stool disposal practices | |
| Child used toilet/latrine | 5046 (85.3) |
| Discarded into toilet/drain | 505 (8.5) |
| Others§ | 363 (6.2) |
| Safe sanitation | 4965 (83.9) |
| **Food practices** | |
| Practice of consumption of uncooked food without washing | 111 (1.9) |
| Consuming ice cream (stick ice/unnamed ice creams from street vendors) once a week or more | 2275 (38.4) |
| Eating foods from outside once a week or more | 752 (12.7) |
| Eating uncooked food once a week or more | 4117 (69.6) |
| Good food practices | 1188 (20.0) |

*Others included tanker trucks and tube well.†1166 (19.7%) used a candle filter, while 643 (10.9%) used an electric water purifier.‡Others included straining through cloth and storage.§Others included throwing into a garbage and left in the open.

WASH, water, sanitation and hygiene.
collection of data related to WASH was not recorded from all the households with eligible children, we could capture this information for 98.5% of the households. Water sampling and testing were done by trained manpower as per standardised guidelines. Active weekly contacts and incentivisation in the form of phone recharge were done to ensure reporting of fever episodes and to reduce loss to follow-up rates. Blood culture sensitivity is 60% to

| Table 3 | Unadjusted and adjusted relative risk for association between WASH parameters and enteric fever |
|---------|--------------------------------------------------------------------------------------------------|
| **WASH practices** | **No enteric fever N=5836, n (%)** | **Enteric fever N=80, n (%)** | **Unadjusted RR (95% CI)** | **P value** | **Adjusted* RR (95% CI)** | **P value** |
| Water | Improved source of drinking water† | 5087 (87.2) | 71 (88.8) | 1.16 (0.58 to 2.31) | 0.674 | 1.15 (0.58 to 2.30) | 0.686 |
| | Adequate water treatment‡ | 1886 (32.2) | 21 (26.3) | 0.75 (0.46 to 1.23) | 0.261 | 0.75 (0.45 to 1.23) | 0.254 |
| | Safe drinking water§ | 1714 (29.4) | 19 (23.8) | 0.75 (0.45 to 1.25) | 0.275 | 0.75 (0.45 to 1.26) | 0.273 |
| Sanitation | Toilet sharing | 926 (15.9) | 16 (20.0) | 1.32 (0.77 to 2.27) | 0.317 | 1.32 (0.76 to 2.30) | 0.322 |
| | Safe sanitation¶ | 4901 (84.0) | 64 (80.0) | 0.77 (0.44 to 1.32) | 0.337 | 0.77 (0.44 to 1.33) | 0.342 |
| Food practices | Consumption of ice creams once a week or more | 2247 (37.9) | 28 (35.0) | 0.88 (0.56 to 1.39) | 0.589 | 0.86 (0.55 to 1.36) | 0.527 |
| | Eating food from outside once a week or more | 736 (12.4) | 16 (20.0) | 1.74 (1.01 to 3.00) | 0.044 | 1.71 (1.00 to 2.94) | 0.053 |
| | Consumption of uncooked food once a week or more | 4063 (68.6) | 54 (67.5) | 0.95 (0.60 to 1.51) | 0.828 | 0.90 (0.56 to 1.43) | 0.654 |
| | Good food practices** | 1171 (20.1) | 17 (21.3) | 1.07 (0.63 to 1.83) | 0.614 | 1.08 (0.64 to 1.85) | 0.613 |

*Adjusted for age, education, family size and typhoid vaccine received. 
†Improved source of drinking water was defined as use of piped water system or bottled water. 
‡Adequate water treatment was defined as treatment of water by boiling, bleach/chlorine or filtration. 
§Safe drinking water in a household was defined as presence of improved source of drinking water and practice of adequate water treatment. 
¶Safe sanitation was defined as improved toilet facility with no sharing of toilets. More than 99% of the study subjects belonged to households with an improved toilet facility. 
**No consumption of uncooked food, no consumption of food from outside and no consumption of unnamed ice creams once a week or more.

| Table 4 | Odds of enteric fever within a buffer area of 5, 10 and 25 m radius around the study households with and without contaminated drinking water |
|---------|--------------------------------------------------------------------------------------------------|
| **Buffer zone (m)** | **Population** | **Total enrolled** | **Enteric fever positive** | **Enteric fever negative** | **OR (95% CI)** |
| 5 | Children living in the buffer zone around HHs with contaminated drinking water | 101 | 3 | 98 | 4.07 (0.81 to 20.5) |
| | Children living in the buffer zone around HHs without contaminated drinking water | 402 | 3 | 399 | |
| 10 | Children living in the buffer zone around HHs with contaminated drinking water | 160 | 4 | 156 | 1.74 (0.54 to 5.67) |
| | Children living in the buffer zone around HHs without contaminated drinking water | 695 | 10 | 685 | |
| 25 | Children living in the buffer zone around HHs with contaminated drinking water | 619 | 11 | 608 | 1.44 (0.69 to 3.00) |
| | Children living in the buffer zone around HHs without contaminated drinking water | 1783 | 22 | 1761 | |

HH, household.
detect enteric fever, and therefore there is a possibility of some degree of underdetection of cases. We believe that unequal distribution of the undetected cases among the exposed and unexposed groups is unlikely, but the small number of cases may be a reason for less power and the observed wide CIs. As ascertainment of exposure related to food practices was history based, we cannot completely rule out the chances of misclassification bias. The possibility of recall bias is also very less in this study as most of the information was related to the routine practices of the household members. The estimates for association were adjusted for confounding factors and were conceptualised based on the DAG model. Given the overall low risk of bias, we believe that our findings are valid for the study sample.

Previous estimates suggested that WASH and food practices are associated with enteric fever. A systematic review by Brockett et al reported that an improved water source (16 studies; OR 0.73, 95% CI 0.56 to 0.95) and treatment of water before consumption (9 studies; OR 0.59, 95% CI 0.45 to 0.75) are associated with significantly lower odds of typhoid fever. Similar to our findings, it was reported that food and drink consumed outside the home (39 studies) was significantly associated with higher odds of typhoid (OR 1.6, 95% CI 1.4 to 1.8). The study also reported that that ice cream consumption was significantly associated with higher odds of typhoid (10 studies; OR 1.5, 95% CI 1.2 to 1.9, \( I^2=31\% \)). Another study from Kolkata, India, used prospective data from a large cohort to evaluate whether baseline WASH variables predicted typhoid risk in an urban slum area. The analysis reported association with flush toilet (HR=0.30, 95% CI 0.1 to 0.95, p=0.041); source of drinking water from a private tap, well or pump (HR=0.31, 95% CI 0.14 to 0.71; p=0.005); and water treatment by filter or boiling for daily use (HR=0.45, 95% CI 0.18 to 1.1; p=0.081). Our study findings substantiate reports from previous studies, and therefore it seems that WASH and food hygiene practices are associated with incidence of enteric fever in children in urban low-income neighbourhoods in Delhi.

Our study has certain limitations. As this study was limited to children up to 15 years of age, we cannot comment on the association among adults. We did not include hand hygiene as a risk factor in the present study. It is likely that hand hygiene plays a role in disease transmission among children, and we may have missed this association in the present study. Also, since the study was done in a low socioeconomic neighbourhood of Delhi, it may not be generalisable to other settings.

Our findings suggest that beyond the WASH factors, poor food hygiene practices are associated with enteric fever in children in low-income urban settings in North India. Even though there has been an improvement in WASH parameters over the past few decades, there is a need to focus on improving food hygiene and eating-out practices. Encouragement and involvement of communities to undertake appropriate food hygiene behaviour is a necessary strategy for prevention of enteric infection.

The findings also suggest that apart from WASH factors, there may be several other factors that affect the transmission dynamics for, for example, sociodemographic profile and typhoid vaccine coverage. In our population, the vaccination coverage for typhoid vaccine was 13.1%. This highlights the need for strategies to accelerate vaccination coverage beyond improving WASH-related factors.

A holistic approach targeted at improving access to safe drinking water and sanitation facilities, education for better food hygiene health practices, disease surveillance and vaccination coverage together may help achieve the goal of disease elimination.

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Patient consent for publication Consent obtained from parent(s)/guardian(s)

Ethics approval This study involves human participants and was approved by Approval was obtained from the CHRDS Ethics Review Committee, Delhi. Written informed consent was obtained from the parents and assent was obtained from children >7 years of age, before the interview. The study was registered prospectively in the Clinical Trial Registry of India (CTR/2017/09/000719). Participants gave informed consent to participate in the study before taking part.

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