

Original Research Article

Water quality at the source and incidence of water borne diseases in rural households of South India

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ABSTRACT

Background: The relation of water quality indicators and water borne diseases (WBD) is not properly studied in tropical countries like India. Most of the studies done were cross sectional which reported only point prevalence. This tends to under-estimate and is not adequate to explain the relation. In this context to assess the incidence of water born diseases in relation to household drinking water quality, a longitudinal prospective study was conducted.

Methods: The study was conducted in a South Indian state, in a rural area among the members of 300 households by weekly data collection for one year. Water samples were collected and analysis was done thrice corresponding to the climate. Bacterial quality indicators - Total coliform count (TCC), Faecal coliform count (FCC) and *E. coli* were estimated. The data were processed and analyzed.

Results: From 300 households, total 1459 persons were enrolled. During the 12 months period, 72 episodes of WBDs were recorded with incidence rate of 49/1000 person years. Proportional morbidity due to WBD was 11.9%. The WBD reported were ADD, dysentery and hepatitis A. Up to 30% water sources contained *E. coli* in summer and winter samples and more than 60% in rainy samples. Faecal coliform count was >10 MPN/100 ml in all the seasons in more than 60% water sources

Conclusions: Most of the main water source wells were contaminated. Contamination was more in rainy season. Incidence of WBD has no correlation with water quality indicators in all the seasons ($p \geq 0.05$).

Keywords: Drinking water quality, Bacteriological indicators, Water borne diseases, South India

INTRODUCTION

Access to safe drinking water has long been a central aim of public health and international development policy and water has a profound effect on human health both as a means to reduce disease and as a medium through which disease-causing agents may be transmitted.^{1,2} The provision of water was one of the eight essential components of primary health care at Alma-Ata, in 1978.¹

Millennium Development Goals (MDG), declared to halving the proportion of people without sustainable access to safe drinking-water and basic sanitation, by 2015.^{1,3} The proposed Sustainable Development goals (SDG) declared in goal 6 to achieve universal and equitable access to safe and affordable drinking-water for all by 2030.⁴

The World Health Organization (WHO) Joint Monitoring Committee (JMC) classified household water sources as

improved and unimproved.^{2,5} “Use of an improved source” was adopted as an indicator for monitoring access to safe drinking water, presuming that it will not risk health.⁶ Providing disinfected piped water, to each household is the best solution to waterborne disease, which is not available in most of the developing world due to resource constraints.⁷

A systematic review of studies assessing water source contamination published between January 1990 and August 2013 estimated that 1.8 billion people globally used a source of drinking water which suffered from faecal contamination and it was more in rural (41%, CI: 31–51%) than in urban areas (12%, CI: 8–18).⁶ A report quoting the WHO stated that more people would die from consuming unsafe drinking water and unsanitary conditions by the year 2020 than from AIDS.⁸ So water quality control is critical in reducing the potential for explosive epidemics.^{7,9}

In India, as per the latest statistics, 85% of the rural households have access to drinking water within or near to their premises and water borne diseases (WBD) account for 10% of the total burden of diseases and claim about 5 million lives.^{8,10,11} It is well recognized that failure to protect water sources and inadequate water treatment are the primary reasons for drinking water contamination with bacteria.¹² Two different studies from North India found that 32.1% and 40% samples of water were bacteriologically contaminated, and it was higher in the rainy seasons.^{8,13} In the South Indian state of Kerala majority of the population (62%) were using dug well as the drinking water source and its contamination was positively correlated with density of houses and average rain fall.¹⁴⁻¹⁷ Recently along with quality, quantity of water also got equal or greater importance with attributable risk reduction of 39% and 23% respectively.^{2,18} Studies from Ecuador and Pakistan reported no association between drinking water quality and the incidence of diarrhea.^{18,19} Most of the studies on WBD were cross sectional and reported only point prevalence, with recall bias which tends to under estimate and is not adequate to explain the relation.^{8,13,16,17}

In this context with the following objectives a longitudinal prospective study was conducted in Kerala, a state of India.

Primary objectives were to assess the incidence of water born disease and to determine the water quality at the source in the study area. Secondary objective was to study the relation between incidence of WBD with water quality at source.

METHODS

The longitudinal study was conducted in South Indian state, Kerala (Kozhikode district) extending for a period of twelve months from July 2015 to August 2016. There are 65.95 lakhs households and 50 lakhs wells enumerated

with density ranging from 120-150 wells per square kilometer.^{15,20}

Study area

Kozhikode district is located in the western coast of Kerala situated between North latitudes 11° 08' and 11° 50' and East longitudes 75° 30' and 76° 08'. According to the 2011 census, Kozhikode district has a population of 3,089,543, population density of 1,318 per square kilometer and 23,445 square kilometer area. Topographically it is divided into sandy coastal area, laterite midland area and rocky high land area. According to the topography (coastal, midland, hilly) three rural areas were selected Chemenchery, Mavoor, Pudupady.

Sample size

According to the previous study the reported household prevalence of WBD was 23%.²⁰ At 95% CI and an error of 20%, the minimum sample size calculated was 300.

Selections of households were done by multistage method. From the selected areas, 3 revenue wards were selected randomly and from each ward, the house list was collected. The first house was selected by simple random method and the consecutive houses were selected till adequate sample size of 100 in each area was attained.

The study protocol was approved by the IEC Medical College, Calicut. Data collection and drawing water samples were done after getting voluntary written informed consent from the head of the household

Data collection

The household data collection was done by 6 adequately trained women health workers (1 per 50 houses) by weekly house visits using a pre tested structured proforma prospectively for 12 months. Data on socio demographic details, housing, environment, sources of drinking water, WBD morbidity and health/sickness behavior were collected. Sanitary inspection was done using a standard check list.

Definition

Water-borne diseases are diseases caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogens.¹⁸

Diarrhea (ADD) was defined as three or more loose stools during a 24-hour period. A diarrhea episode was marked as a new episode if the person had two or more days without diarrhea. For other diseases the diagnosis was cross checked with medical records.

Water quality sampling: By sub sampling using systematic random method, 10 houses were selected in each ward (10X3=30) and from 30 drinking water sources, water

samples were collected and analysis was done thrice corresponding to the seasons (July, December, May) from Centre for Water Research Development Management (CWRDM lab) Calicut using standard Technique.

The samples drawn aseptically were transferred to 10 ml sterile bottles and properly labelled. Two samples were collected from each well after which they were transported to the laboratory in ice cold condition and subjected to bacteriological analysis on the same day. The Most Probable Number (MPN) test was used to enumerate the total number of bacteria in the well water samples. All the media used in this study were prepared and sterilized according to manufacturer's instructions. The bacteria determined included Total Coliform Count (TCC), Faecal Coliform Count (FCC) or Thermo Tolerant coliforms (TTC) and *E. coli*. Total coliform and fecal coliform counts were estimated and recorded in Most Probable Number units per 100 ml (MPN/100ml). The pH and Total Dissolved Solids (TDS) were estimated using standard methods. The criteria given by WHO and Bureau of Indian Standards (BIS) for drinking water quality were used as acceptable limits.^{1,9,10}

The meteorological data like rain fall, temperature, humidity were collected from secondary sources for 12 months.

Statistical analysis

The data analysis was performed using Statistical package of social sciences (SPSS) version 16. According to the type of data, association or correlation was tested, either by chi-square/Pearson and spearman correlation coefficient. The relation of WBD with different qualitative and quantitative variables were analyzed. The morbidity was measured as incidence rates.

RESULTS

From 300 households, total 1459 persons were enrolled as study subjects with an average family size of 4.9 members. The mean age was 30.4±20 years. The sex wise and religion wise distribution are given in Table 1.

The characteristics of water sources and hygiene practices are given in Table 2.

All the houses had water seal toilets. In 85.6% of the houses water was available around the year and in 93.45% electric motor was connected with well. The mean distance from house to water sources was 7.7±12.2 meters.

The mean distance between well and septic tank was 13.8±3.2 meters.

The seasonal wise water quality parameter results – pH, Total dissolved solids, FCC/TTC and *E. coli* are given in Table 3.

Table 1: Demographic details of the population (n=1459).

Characteristics	Number/mean	Percentage /SD
Average Family size	4.9	±2.3
Sex		
Females	746	51.1%
Age (years) (mean)	30.4	±20
Age group: children <5 years	130	8.9%
Religion		
Hindu	99	33%
Muslim	174	58%
Christians	27	9%
Education		
≥10th standard	1001	68.6%
Average Land holding –Cents	28.2	±55

Table 2: Household water sources and hygiene practices (n=300).

Item	Frequency	Percentage
Water source		
Dug well	280	93.3
Bore well	19	06.3
Public supply	1	0.3
Treatment of water before consumption		
Boiling	286	95.3
Filtering	1	0.3
No treatment	10	3.3
Storage of water in kitchen		
Metallic vessels	212	70.5
Earthen pots	30	9.8
Solid waste management		
Burning	232	77.4
Open dumping	33	11
Composing	3	09
Liquid waste management		
Soakage pit	166	55.
Drainage	18	6.1
Cultivation	59	19.7
Open /No system	57	19

During the 12 month period, 605 episodes of morbidities were reported among the cohorts of which 72 were water borne disease with an incidence of 49/1000 person years. The proportional morbidity due to WBD was 11.9%. The WBD reported were ADD, dysentery and hepatitis A. The details are given in table 4. Twenty-three episodes of WBD (34%) were among children in the age group 0-5 years (n=130, consisted 8.9% of population) with an incidence rate of 177/1000 person years.

The monthly incidence, seasonal pattern of WBD and rain fall are given in Figure 1.

Table 3: Microbiological quality of water.

Water quality indicators	Monsoon July	Winter December	Summer May
PH	6.59±0.83	7.61±0.38	7.57±0.53
Total dissolved solids (TDS) milligram/L	105.33±49.65	113.20±105.6	191.81±173.4
Mean fecal coliform count (ThermoTolerent Coliforms)	852±1130	415±903	169±342
FecalColiform>10 MPN/100ml	73%	66%	60%
E. Coli –Present	63%	27 %	31%
Height of water Column –Meters	3.9±1.2	3.5±1.5	2.4±1.1

The incidence of WBD had no correlation or relation with *E. coli* and Fecal coli count in all the seasons ($p \geq 0.05$)

though there is a negative correlation with distance from septic tank ($r = -0.118, p = 0.53$).

The distance from septic tank to the water source has got significant correlation with *E. coli* ($r = -0.37, p = 0.02$) and Fecal coli ($r = -0.43, p = 0.04$) during summer season.

Table 4: Details of reported water borne diseases (n=1459).

WBD	Frequency	Proportion %	Incidence Per 1000 /year
ADD	48	66.7	34
Dysentery	13	18.0	8.9
Hepatitis A	11	15.3	7.5
Total WBD	72	100	49

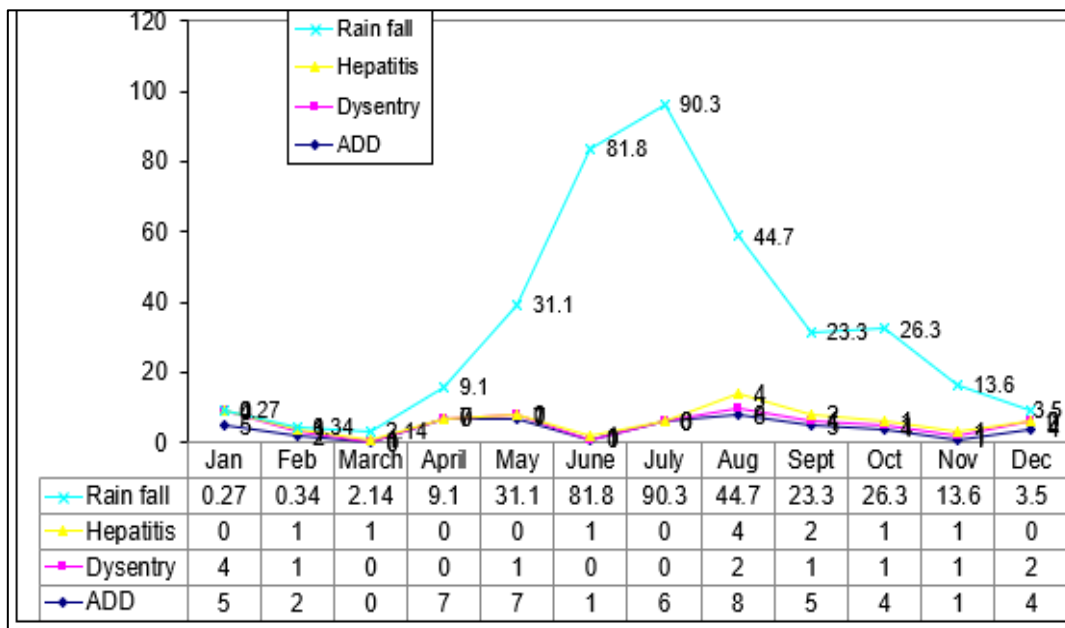


Figure 1: Monthly incidence of WBD and Rainfall in cm.

DISCUSSION

We conducted a one year longitudinal study in a selected rural area of south India among 300 houses holds with 1459 individuals by directly collecting data by weekly house visits and the water samples from the point sources were analyzed three times according to the seasonality. Among the households 93.3% had dug well as the water source and majority (83.3%) were within the premises and protected. At the state level, 62% sources are dug well. As

per the WHO- JMP 2011 criteria it can be included as improved source of water and presumed to be safer.^{1,2,9} Though the department of Health and family welfare mandated monthly disinfection of wells by chlorination using bleaching powder by health workers, majority were not practicing it. At the point of use, 95% practiced the physical method - boiling of water as treatment. For storage of water in kitchen >70% were using metallic vessels with lids. This may reduce contamination at storage and consumption points in these households (Table 2).

All the households had sanitary toilets of water seal type and zero open defecation. Due to constraints in land availability the mean distance between septic tank and water source was less (13.8 ± 3.2 meters) than as prescribed minimum distance 15 meters by WHO.

During the 12 month period of follow up the incidence of WBD was 49/1000 which was less than previously reported from the state as 84 and 78/1000 per year and showed a declining trend.^{20,21} The proportional morbidity due to WBD was 11.9% which was similar to the previous report from the country.¹¹ As given in Table 4, the WBDs mainly reported were ADD (2/3rd), Dysentery and hepatitis (Table 4). As a development paradox, being in the late phase of epidemiological transition, the state now experiences out breaks of hepatitis.²¹ As reported elsewhere compared to other age groups, the children in 0 to 5 years age have high morbidity due to WBD which was 177/1000 with a relative risk of 3.61 (95% CI 2.6- 4.7).

This area receives Southwest and Northeast monsoons during June to August and October to November respectively, where the former consists >80% of the rain. The total rainfall during the year was 3285 mm. Though there were no peaks of seasonality trends, increased number of cases were reported during summer and rainy months, possibly explained by microbial concentration and contamination of water (Figure 1).

As per the water quality parameters given by WHO and BIS, the pH and TDS values of our samples in all the seasons were within the permissible values 6.5 and 500 mg/litre (Table 3).^{1,10}

Indicator bacteria *E. coli* was found in upto 30% water sources in summer and winter samples and in more than 60% in rainy samples. Correspondingly Faecal coliform count was >10 MPN/100 ml in all the seasons in more than 60% water sources and the count was markedly increased during monsoon samples.

Cross sectional studies from north Indian states previously reported these contamination rates as 32% and 40%.^{8,13} The presence of coliform and *E. coli* in water is an indication of faecal contamination and has been associated with waterborne diseases among the consumers. But corresponding to the indicators no such out breaks were reported spatially or temporarily from the area except few sporadic incidences.

Our study identified significant correlation between the bacterial burden indicators and proximity of source of water to septic tank in summer ($r=0.43$, $p=0.02$ and $r=0.37$, $p=0.04$). A study from the district reported presence of Faecal coliforms / TTC in 68% of samples with positive correlation ($r=0.47$, $p=0.01$) with distance between the septic tank and well.²²

Both microbial indicators have got significant correlation in all the samples ($p=0.01$) which point out their common

source of origin or pathway of contamination. The increase of bacterial indicators during rainy season in our study especially in areas with sandy soil compared to laterite point out the probability of percolation of bacteria through soil layers. The density of houses, dug wells, proximity of septic tanks which cause pressure on lands along with the climatic conditions may be other environmental factors.

In our study the incidence of WBD had no relation with *E. coli* and Fecal coliform count in source water in all the seasons ($p \geq 0.05$) which point out the weak relation of household source water quality with WBDs. A similar prospective study in the southern Punjab and Pakistan where drinking water quality was monitored weekly among children younger than 5 years in 200 households, found no association between the incidence of childhood diarrhea and the number of *E. coli* in the drinking water sources.²⁰ Another study which uses chlorination as proxy indicator also reported that it has no relation with WBD.⁶

Since the literacy rate in the area was 99%, the low outcome may be attributed to the increased hygienic practices among the members like storage, boiling before consumption along with hand washing which prevent further contamination with pathogenic microbes. Meta-analysis reported that hand washing with soap at critical points (before eating, after defecating and before handling food), improved sanitation and point of use water treatment are three most effective interventions which reduce the risks by 37%, 34% and 29%.²³ Other possibilities are rather than household sources people are acquiring more infections from outside sources (work place, school etc). Supporting this, study from the state reported that those children eating out side and not washing hands have higher risk of WBD (OR=1.6, OR=2.3).²⁴ Nutritional status, immunologic status, and genetic factors of a person also play a large role in determining disease outcome. First, not all diarrhea disease pathogens are transmitted exclusively via water. They can also be transmitted by food, fomites, personal contact, and in some cases via droplets.¹⁹ From the neighboring country Myanmar, a study reported that at point of use 94% of the water samples contain faecal coliforms and the prevalence of ADD among children were 156/1000, less than our study.²⁵ As reported by many studies from developing countries our study also found that the relation between water quality at the source and WBD was lower than sanitation and treatment at point of use.^{5,6,7,19}

WHO criteria for safe water accessibility include improved water, equated it as safe.^{1,19} There is substantial evidence to demonstrate that improved sources of drinking water can contain *E. coli*. In a systematic review of microbial drinking water quality, many improved sources including piped water were found to be contaminated with *E. coli*.^{6,24} This has implications in the use of international targets for safe drinking-water access. The selection of indicators and parameters for water quality assessment and analysis should be country and possibly region specific and may also be specific to certain sources of water.^{1,2} Guidelines

for Drinking-Water Quality recommend that faecal indicator bacteria, preferably *E. coli* or alternatively thermo tolerant coliform (TTC), should not be detectable in any 100 ml drinking water sample.^{1,6,9} In tropical regions, where diarrheal disease poses the biggest health burden, the indicator organisms have been found to naturally occur, bringing into question their utility as indicators of fecal contamination.^{6,19} In tropical climate, the proportion of *E coli* is less in faecal coliforms; therefore they are not useful as an indicator of faecal pathogens and no public health significance.^{1,18} It has been argued that the WHO Guideline value of zero faecal coliforms is too restrictive for untreated water sources in rural communities as it is not feasible in practice. Therefore, it is of primary importance that water users are guaranteed a minimum level of achievable standards.^{5,18} Our data suggest that such a restrictive standard also lacks adequate justification on epidemiological grounds.

The majority of the previous studies were cross-sectional and do not provide information on temporal variability in water quality and the outcome. Since our study was longitudinal, seasonal temporal effects on variability of WBD, water quality was studied as well as recalls bias was reduced.

We have noticed few limitations for our study. Since the WBD data was collected weekly from households minor episodes from other members of the family may not be passed to the informant so there may be chances of under reporting. Due to resource constraints we did the water quality analysis by taking sub samples and could not analyze the water samples at weekly intervals.

CONCLUSION

Our study found that though majority of people are using protected dug well, as per water quality indicators, the contamination was very high which has got no association with water borne disease. We believe this finding warrants extensive consideration of the use of indicators in studies of waterborne disease. Further studies are necessary to create more precise ways of studying the role of water in the transmission of WBD.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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