

Short Communication

A study on contamination risks of wells from Kollam district, southern India

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ABSTRACT

The key to provide microbiologically safe drinking-water lies in understanding the various mechanisms by which water gets contaminated. This study assessed the risk of contamination and microbiological and chemical quality of water from protected dug wells in five selected Panchayats in Kollam district, Kerala state, southern India. Sanitary inspection was conducted for 70 protected dug wells using World Health Organization established procedures for risk of contamination scoring. Microbiological and chemical analysis of water samples was done. The areas with higher incidence of hepatitis A had a higher proportion of wells with high risk of contamination scores ($p = 0.006$). High risk of contamination scores for wells were associated with higher incidence of fecal pollution (odds ratio 11.80; 95% confidence interval 1.87–74.86). The study highlighted the need to make the wells safe in this area, for control of waterborne diseases.

Key words | hepatitis A, risk of contamination scoring, sanitary inspection, sanitary well, waterborne diseases, water quality

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INTRODUCTION

Safe water is one of the most important needs in public health in developing countries in the twenty-first century. Diseases related to contamination of drinking-water constitute a major burden on human health. Each year, two million people die from waterborne diseases and billions (10^9) more suffer illness (World Health Organization [WHO] 2011). A retrospective analysis of data from low- and middle-income countries estimated that in 2012, 502,000 diarrhea deaths were caused by inadequate drinking-water and 280,000 deaths were caused by inadequate sanitation (Prüss-Ustün *et al.* 2014).

Pollution of water – both microbial and chemical – is a major problem faced by the rural population in several parts of India. Waterborne diseases cost an annual \$600 million in lost production and medical treatment in the country (United Nations Children's Fund [UNICEF] 2004).

The quality of water, whether used for drinking, domestic purposes or food production has an important impact on health. Water of poor quality can cause disease outbreaks

and it can contribute to high background rates of waterborne disease. Dangerously high concentrations of chemical hazards, such as arsenic, fluoride, iron, and phosphates originating from natural or other sources affect millions in the world (WHO 2013).

With 6.7 million wells, Kerala, the southernmost state in India had one of the highest well densities in the country (250 open wells/km²) (Planning Commission 2008). Around 80% of the population in Kerala is estimated to depend on groundwater for different uses. Kerala also has the highest coverage of individual household latrines in India. Sources of microbial contamination of groundwater include agricultural runoff, effluents from septic tanks, sewage discharges, and infiltration of dissolved animal fecal matter (Bryan *et al.* 2009). Poor well maintenance and construction, particularly of shallow dug wells can increase the risk of bacteria and other harmful microorganisms getting into the water supply (Lawrence *et al.* 2001).

Sanitary inspection, which identifies actual and potential sources of contamination of groundwater abstraction points, was proposed by the World Health Organization as part of the comprehensive and complementary risk-based assessment of drinking-water quality (WHO 1997). This proposed approach supports the operation and maintenance of water points by providing clear guidance for remedial action to protect and improve the water supply (Luby *et al.* 2008). There are limited published studies on sanitary risk of wells, done with proper random sampling techniques (Bain *et al.* 2014).

The number of people infected with waterborne diseases like hepatitis A, acute diarrheal disease and typhoid has been on the rise over the last three years in Kollam district, Kerala state, southern India. A large proportion of hepatitis A cases reported from the state are from Kollam. Huge outbreaks of hepatitis A have occurred in the district in every recent year (Directorate of Health Services 2013). The current study assessed the risk of contamination and microbiological and chemical quality of water from dug wells in five selected Panchayats in Kollam district.

METHODS

Study setting

Kollam district is situated on the south west coast of Kerala within the geographical co-ordinates of 8.54° North latitude and 76.38° East longitude. Average rainfall in the district is 2182 mm. It is hottest in March, April and May (temperature 32–33 °C). Humidity rate is 63% in January and 87% in June–July. Kollam district has a tropical humid climate with an oppressive summer and plenty of seasonal rainfall. Sandy loams are found in the coastal belts while the rest of the district has laterite soil.

The study was carried out in five purposively selected Panchayats (administrative units with around 25,000 population) in Kollam – two (Mayyanadu, Palathara) with high incidence of hepatitis A and three (Panmana, Thrikkaruva, Panayam) with low incidence of hepatitis A.

Study design

This is a cross-sectional study.

Sampling

One ward (smallest administrative unit with around 1500 population) was selected randomly from each Panchayat. Ten houses were selected using simple random sampling from each ward. In addition to that, two public wells and two wells from the rural slums in each Panchayat were selected. Thus a total of 14 protected wells were selected from each ward. On-site sanitary inspection and well water sampling were done on the selected wells.

Study period

The study was conducted in September, a dry season in between monsoons.

Sanitary inspection

The WHO established format for sanitary inspection consisting of a set of questions which have ‘yes’ or ‘no’ answers were used. The questions were structured such that ‘yes’ answers indicate that there is a reasonable risk of contamination and ‘no’ answers indicate that the particular risk appears to be negligible. Each ‘yes’ answer scored one point and each ‘no’ answer scored zero points. At the end of the inspection, the points are totaled, yielding a sanitary inspection risk score. A higher score represents a greater risk that drinking-water is contaminated by fecal pollution from the area immediately surrounding the well (Lloyd & Batram 1991; WHO 1997; Godfrey *et al.* 2006; Luby *et al.* 2008; Vaccari *et al.* 2009; Parker *et al.* 2010). Questions regarding the practice of chlorination of the wells were also asked.

Water sample testing

WHO guidelines for water quality testing were followed for sample collection procedures (WHO 1997). Water samples were collected by Junior Health Inspectors who were trained in a group of five, for a day in the field on water sample collection and sanitary inspection. All precautions were taken to ensure that there was no external contamination of the samples. Taps were sterilized for a minute using a cigarette lighter before collecting water. For wells

without taps, a stone was tied, using a string, to the bottle and the bottle was lowered down the well using a copper wire tied to the neck of the bottle. The copper wire was heated for one minute before use in each well. The bottle was immersed to at least 1 m below the water level. Two liters of water were collected in new plastic containers for chemical analysis.

Water bottles were closed and transported within two hours to an International Organization for Standardization certified laboratory with absolute precautions to avoid contamination. Water samples were processed within four hours of collection, for microbes to identify presence of *Escherichia coli* (*E. coli*). Chemical testing was done for residual chlorine, chloride, pH, total dissolved solids (TDS), iron, fluoride and phosphates.

Analysis

Contamination risk scores for wells were calculated and the wells were classified as low, medium, high or very high risk of contamination (risk of contamination score: 0–3 = low; 4–5 = medium; 6–7 = high; 8–10 = very high). Frequencies and percentages were calculated and chi square, for difference between proportions, Fischer's exact test and odds ratios (OR) with 95% confidence intervals (CI) were used to detect any associations. A *p*-value of less than 0.05 was considered as statistically significant.

RESULTS

In total, there were 70 protected dug wells studied including 10 public wells. In 35.7% of wells studied, a sanitary structure such as a septic tank or pit latrine was located within 10 m. A total of 27.1% of wells had other sources of pollution like cow dung nearby. A parapet was not available for 8.6% of wells, 42.9% of wells were not covered and 20% reported washing/bathing animals near the well. The characteristics of the wells studied are shown in Table 1.

Among the wells at Mayyanadu and Palathara (areas with high incidence of hepatitis A), seven (25%) wells belonged to the high risk/very high risk of contamination scores category as compared to one (2.4%) among wells from low incidence of hepatitis A areas (*p* = 0.006).

Table 1 | Characteristics of the wells studied (*N* = 70)

Characteristics of well	No. (%)
A sanitary structure (e.g. septic tank) within 10 m of the well	25 (35.7%)
Other sources of pollution within 10 m of the well (e.g. cow sheds, cow dung)	19 (27.1%)
Drainage faulty allowing ponding within 2 m of the well	25 (35.7%)
Platform less than 5 × 5 ft (1.52 × 1.52 m) dimension	32 (45.7%)
Pulley/bucket left with a chance for contamination	18 (25.7%)
Parapet not available	6 (8.6%)
Sealed at least 3 m from ground level	17 (24.3%)
Well without any coverings on top	30 (42.9%)
Washing clothes/bathing near well	14 (20%)
Septic tank situated at a higher level than well	4 (5.7%)

The mean risk of contamination scores at Palathara, Mayyanadu (areas with high incidence of hepatitis A) were 3.42 (SD 2.06) and 4.21 (SD 2.39) respectively while the figures were 2.07 (SD 1.07), 2.42 (SD 1.50) and 1.78 (SD 0.98) at Thrikkaruva, Panayam and Panmana respectively.

Out of 10 wells selected from rural slum areas, 2 (20%) belonged to the high risk of contamination category. One public well (10%) was at very high risk of contamination. The mean scores for household wells, public wells and wells at rural slums were 2.32 (SD 1.82), 2.9 (SD 2.18) and 3.60 (SD 2.50) respectively.

As reported by the households, 7.1% of wells were never chlorinated in the last year, 54.2% were chlorinated 1–3 times, 27.1% were chlorinated 4–6 times and 11.4% of wells 7–10 times in the last year.

E. coli were isolated in pure culture from six well water samples (8.5%). *E. coli* was isolated from one (1.9%) well with low, two (20%) wells with medium and two (28.6%) wells with high risk of contamination scores. *E. coli* was isolated from three (37.5%) wells belonging to the high/very high risk contamination score category and three (4.8%) wells belonged to the low/medium risk of contamination score category (OR 11.80; 95% CI 1.87–74.86). Four (14.3%) samples from areas with high incidence of hepatitis A and two (4.8%) well water samples from areas with low incidence of hepatitis A showed presence of *E. coli* (OR3.33; 95% CI 0.56–19.69). Three (6%) household wells,

two (20%) wells at rural slum areas and one (10%) public well showed presence of *E. coli* (Table 2).

Iron exceeded the recommended value of 0.3 g/dl in two samples (Bureau of Indian Standards 2012). pH was less than 6.5 in 9/70 (12.8%) well water samples. Residual chlorine was absent in 69/70 (98.5%) samples tested. Chloride, phosphate, fluoride and TDS were in the normal range in all samples tested.

DISCUSSION

This study assessed the risk of contamination of wells and its relation to various factors. Low risk of contamination scores for wells were associated with lesser pollution as evidenced by isolation of *E. coli*. The areas with higher incidence of hepatitis A had a higher proportion of wells with high risk of contamination scores.

The greatest risk to public health from microbes in water is associated with consumption of drinking-water that is contaminated with human and animal excreta, although other sources and routes of exposure may also be important (WHO 2011). Millennium Development Goal number 7 includes a target to halve, by 2015, the proportion of the population without sustainable access to safe drinking-water. The key to providing microbiologically safe drinking-water lies in understanding the various mechanisms by which water gets contaminated, and formulating interventions at critical points to decrease and prevent contamination of drinking-water (WHO 2011). A recent systematic review on fecal contamination of drinking-water in low- and middle-income countries reported that protected

dug wells were rarely free of fecal contamination and it is not uncommon for these sources to contain high levels of fecal indicator bacteria (Bain *et al.* 2014).

Kerala is one state where early and rapid socioeconomic development and urbanization happened. The Hepatitis A Virus (HAV) antibody sero prevalence rate reported from Kerala was less than 10% in children below 5 years old as compared to 60–80% from many other parts of the country (Mathew *et al.* 1998; Mittal 1998; Dutta *et al.* 2000). Improvement in hygienic and socio-economic conditions in the state might have resulted in a decrease in the number of natural childhood infections. An epidemic of hepatitis A in the age range of 2–75 years was reported from central Kerala in 1998 (Sebastian *et al.* 1998). In 2004, an epidemic of hepatitis A occurred in the Kottayam district of Kerala which also mainly involved young adults (Arankalle *et al.* 2006). The age group affected in the outbreaks at Kollam was also the same as in the previous two huge hepatitis A outbreaks reported from the state, adding evidence to the fact that a substantial proportion of individuals were not exposed to HAV till adulthood. These outbreaks of hepatitis A in young adults from Kerala are suggestive of a region with intermediate HAV endemicity. In such situations even mild contamination of water might lead to explosive and prolonged outbreaks.

A systematic review and meta-analysis on fecal contamination of drinking-water in low- and middle-income countries concluded that greater use should be made of techniques like sanitary inspections, to provide a complementary means of assessing safety and to help identify corrective actions to prevent water contamination (Bain *et al.* 2014). Determining contamination risk scores is a simple process which requires minimal training. This

Table 2 | Univariate analysis of factors associated with fecal contamination in well water

Characteristics of wells	Categories	Number (%) without <i>E. coli</i>	Number (%) with <i>E. coli</i>	Odds ratio (95% confidence interval)
Risk of contamination scores	High/very high	5 (62.5%)	3 (37.5%)	11.80 (1.87–74.86) ^a
	Low/medium	59 (95.2%)	3 (4.8%)	
Location by incidence of hepatitis A	High	24 (87.5%)	4 (14.3%)	3.33 (0.56–19.69)
	Low	40 (95.2%)	2 (4.8%)	
Ownership of wells	Household	47 (94%)	3 (6%)	1 (Reference)
	Public wells	9 (90%)	1 (10%)	1.74 (0.16–18.51)
	Rural slums	8 (80%)	2 (20%)	3.92 (0.56–27.31)

^a*p* < 0.05.

method of scoring is inexpensive and it produces results regarding the potential sources of contamination within a very short period of time. It could also help in the selection of appropriate remedial actions to improve well water quality. However the contamination risk score only provides information on the environment immediately surrounding the well. Groundwater contamination further away from the well is not considered.

High risk and very high risk category wells need improved construction to block contamination pathways, improved hygiene practices around the well and comprehensive management measures to protect wells from anthropogenic activities. There is need for enforcement of public laws on construction of latrines, and guidelines for well construction. Quality and frequency of well chlorination need to be ensured, as residual chlorine was not found in the majority of the samples.

The study is limited by a small sample size. The selected region and its associated conditions might have increased the apparent relationship between the risk of contamination scores and the fecal pollution levels observed in the well water samples. This study was conducted at one time of the year and hence regional and seasonal variability could not be considered.

CONCLUSION

This study assessed the risk of contamination of dug wells and its relation to various factors in Kollam district, Kerala, southern India. The areas with higher incidence of hepatitis A had a higher proportion of dug wells with high risk of contamination scores. High risk of contamination scores for wells were associated with higher incidence of fecal pollution. Sanitary inspection of wells, using risk of contamination scoring according to established WHO procedures, could be used as a simple tool to predict the presence of bacterial fecal pollution of the wells. The study highlighted the importance of making wells safe. This could be achieved through improvement of physical infrastructure of wells, regular behavior change communication for the public, enforcement of public health laws and training for health workers.

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