Introduction

Safe water, sanitation, and hygiene (WASH) have remained as a major global concern over the recent years. WASH is a composite measurement, mostly determined by the availability of water quality, sanitation, and hygiene among the tribal community residing in Jawadhi hills, Tamilnadu: An observational study from Southern India.

Keywords: Determinants, hygiene, sanitation (WASH), water, water quality
of safe drinking water, safely managed sanitation facility, and provision for basic hand-washing facilities. Inadequate access to such facilities can directly contribute to diarrheal illnesses, helminthic infections, eye infections, skin infection, pneumonia, and childhood malnutrition.

The present situation of lack of WASH indices across the globe is worrisome. Every one out of four people in the world lack access to safe drinking water, while only two out of four people use safely managed sanitation services. The value varies widely across different geographic or economic regions. Such variations are glaringly visible in the Asian and African countries. Regional variations also exist within a country. For instance, while more than 90% of the urban population in India use safe water, the proportion comes down to 50% for the rural population. Such prominent disparities exist in the availability of safe sanitation facilities as well. The World Bank data shows that almost 40% of people in the country currently practice open defecation—the rate being 50% in rural areas. This is far from the target set in the Sustainable Development Goals (SDG) for open defecation by 2030. This alone causes an estimated economic loss of 53.8 billion USD in a year in the country.

While the indicators related to WASH are improving gradually, there is not much known about the tribal regions in India. The tribal population contributes to more than 8% of India's total population and is traditionally less developed than the non-tribal population due to various reasons like geographic barriers, and sociopolitical conditions. Notably, the prevalence of communicable diseases is reportedly high in various tribal populations. This could be attributed to the poor WASH conditions in such areas. With this background, our study aimed to assess the water, sanitation, and hygiene (WASH) practices of tribal people, examine the drinking water quality at the principal source and at households, and to identify the household-level determinants of WASH practices and drinking water quality.

Subjects and Methods

Study design: A community-based cross-sectional study.

Study period: The study was conducted between August 2015 and September 2015.

Study Setting: The study was conducted in the hamlets (small villages) of the tribal area of Jawadhi hills, spread over the Vellore and Tiruvannamalai districts of Tamil Nadu, one of the southern states in India. Jawadhi hills, mostly having forest areas, consist of 12 panchayats and 229 hamlets and is characterized by a low population density, poor literacy rate (Overall 48%), and poor health indicators. The majority (98%) of the permanent residents of this area belong to the indigenous tribal community called “Malayalee” tribes and mostly live on the natural resources available in this area.

Sample size and Selection of participants: The sample size was calculated to be 150 households, considering the prevalence of poor water and sanitation practices as $P = 50\%$, with a design effect of 1.5, a relative precision of 20%, and an alpha error of 5%.

A two-stage cluster sampling was done in the “Veerapanur” panchayat (purposively selected) which has 20 hamlets. Six hamlets were selected [Figure 1] randomly from the list. In each hamlet, 25 households were selected by systematic random sampling. A total of 150 households were included in the study.

Participants: Adults who were primarily responsible for water collection and storage in a household were chosen as respondents.

Data collection: A structured, pilot-tested, interviewer-administered questionnaire in the local vernacular was administered to the participants by the investigators after obtaining the informed consent. Household-level sociodemographic data and information pertaining to WASH were collected from the participants. A field worker trained in collecting water samples accompanied the study team for water sample collection. Drinking water samples were collected from 10 randomly selected households from each hamlet. One sample from each selected household was collected in sterile containers and transported to the Wellcome Trust Research Laboratory in CMC Vellore in ice-packed boxes at 2–8°C with an average transport time of two hours from the point of collection. Water quality was assessed in terms of pH, total dissolved solids (TDS) (using standardized instruments), chlorides, nitrates (using standardized kits), and fecal coliform counts after incubating in MacConkey agar medium (for a maximum period of 48 hours).

Definition of the outcome and the predictor variables

WASH score: We formulated a WASH score based on the reported practice of water handling, sanitation, and hygiene of the interviewer. The score was used as an indicator of the overall hygiene and sanitation practices prevalent in a household. Components of the scoring system are described in Table 1.
Minimum and maximum possible WASH scores for a household were 0 and 8, respectively. For convenience, we took the median score as a cut-off, details of which have been provided in the results section.

**Drinking water quality:** WHO defines safely managed drinking water as water which is accessible within the premises, is available when needed and is free of contamination. However, for the present study, we considered only the bacteriological quality for assessing drinking water quality at the household level. For analysis purpose, a fecal coliform count of ≤10 colony-forming units (CFU) per 100 ml was considered as acceptable.

**Predictor variables:** Source to household network distance was estimated by measuring the approximate shortest path distance between the two points. The socioeconomic scale (SES) was measured by the updated “BG Prasad scale” for the year 2014.[13] The scale is based on per capita income in Indian Rupee (INR) per month of a household. The type of house was categorized based on the type of roof, walls, and floor. A house with concrete roof, wall, and floor was considered as “pukka” house, whereas a house with all the walls and floor made up of mud and thatched roof was considered as “Kuccha” house. A house consists of features of both “pukka” and “kutchha” house was considered as “mixed” house. A respondent was considered “literate” if he/she reported that they could read and write and understand at least one language.

**Ethics Committee clearance:** The study was approved by the institutional review board where the study was conducted. (Ref- 11407[Retro] dated 27/06/2018) Informed consent was obtained from all the study participants.

**Results:** A total of 150 households were selected for the study from six hamlets. All those who were approached gave consent to participate. Table 2 summarizes the household characteristics of the participants. Most of the respondents were female (77.3%; n = 116), young to middle-aged (IQR 25–46 years), and illiterate (74.7%). Majority of the households belonged to poor socioeconomic background.

For drinking water, most of the households (88%; n = 132) depended on public sources like government-supplied public

### Table 1: Components of WASH Score

| Components of the score | Items under each component | Score |
|-------------------------|-----------------------------|-------|
| **Drinking water**      | Method of water purification |       |
|                         | Present                     | 1     |
|                         | None                        | 0     |
|                         | Covering of stored drinking water |       |
|                         | Present                     | 1     |
|                         | No covering                 | 0     |
|                         | Drawing water using a dipper/separate allocated vessel/can with tap |       |
|                         | Present                     | 1     |
|                         | None                        | 0     |
| **Sanitation**          | Type of latrine used        |       |
|                         | Improved [WHO-UNICEF [MP][1]] | 1     |
|                         | Unimproved/Open field defecation | 0     |
| **Hygiene**             | Washing hands               |       |
|                         | After toilet                | 0.25  |
|                         | Before preparing food       | 0.25  |
|                         | Before feeding children     | 0.25  |
|                         | Before eating               | 0.25  |
|                         | Usage of soap               |       |
|                         | Never                       | 0     |
|                         | Sometimes                   | 1     |
|                         | Always                      | 2     |
|                         | Bathing frequency           |       |
|                         | Bathing once daily or more  | 1     |
|                         | Bathing less frequently     | 0     |
| **Total maximum score** |                             | 8     |
taps, borewells and tubewells, with a few exceptions (12%; n = 18) who relied on sources within their household premises. [Table 3]

**Household characteristics related to WASH:** Distance between the households and the principal source of drinking water significantly varied (p < 0.05; Kruskal–Wallis test) across the clusters. [Figure 2a]. The estimated median distance was 50 meters (IQR 10 to 100 meter). The households used 20 litres of water for all purposes on average (IQR 14–30 litres); however, we did not get a significant variation (p > 0.05, Kruskal–Wallis test) across the clusters [Figure 2b]. Most of the households stored drinking water in traditional wide-mouthed metal or plastic containers (97.3%), without purification (57.3%) prior to drinking, and withdrew water with the help of a vessel by dipping their hand inside (98.6%) [Table 3]. Open-air defecation remained almost a universal practice in this area.

**WASH score:** The mean household WASH score was 4.17 (SD 1.0) with 68.7% (n = 103) households having poor WASH scores (<4). Figure 3 depicts the variation in the mean WASH score across the hamlets; however, it was not statistically significant (p > 0.05; Kruskal–Wallis test).

**Predictors of poor WASH score:** The multivariate model finds poor income (<1000 INR/capita/month) as a strong predictor for poor WASH score. [Table 4] We found people living in “pukka” or “semi-pukka” houses a weak predictor for poor WASH score than people living in “kutcha” houses (p = 0.06). Variables like “age of the respondent > 30 years” (OR-0.81; 95% CI: 0.4-1.63), “illiterate respondent” (OR-1.02; 95% CI: 0.46-2.24), and “more than 4 household members” (OR-0.83; 95% CI: 0.43-1.67) did not show any association in univariate analysis.

**Water quality analysis:** We analysed selected physical, chemical, and bacteriological parameters of the drinking water [Table 5]. The bacteriological parameter was unacceptable in most of the samples. The sampled drinking water sources were four (40%) overhead tanks, two hand pumps (20%), bore wells (20%), and dug wells (20%) each. Of these, one overhead tank and one bore well showed nil coliform.

At the household level, low per capita income is strongly associated with poor water quality in terms of coliform load [Table 6]. Variables like “age of the respondent > 30 years” (OR-0.73; 95% CI: 0.17–3.1), “illiterate respondent” (OR-1.0; 95% CI: 0.23–4.31), “more than 4 household members” (OR 0.84; 95% CI: 0.23–3.02), “highest education in the family” (OR 0.86; 95% CI: 0.16–4.66), and “household with poor WASH

### Table 3: Summary characteristics of WASH (n=150)

| Drinking water characteristics | Frequency (%) |
|------------------------------|---------------|
| Source of drinking water      |               |
| Piped water within premises   | 18 (12.0)     |
| Borewell/Tubewell             | 78 (52)       |
| Public tap                    | 53 (35.3)     |
| Surface water                 | 1 (0.7)       |
| Storage                       |               |
| Metal pots                    | 131 (87.3)    |
| Plastic vessels               | 15 (10.0)     |
| Earthen pots                  | 4 (2.7)       |
| Water stored in covered containers |       |
| Yes                           | 144 (96.0)    |
| No                            | 6 (4.0)       |
| Purification at household level|               |
| Occasional boiling            | 39 (26.0)     |
| Filtration                    | 25 (16.7)     |
| None                          | 86 (57.3)     |
| Drawing water from storage container |       |
| Tumbler/ Dedicated vessel*    | 148 (98.6)    |
| Can with tap                  | 1 (0.7)       |
| Other                         | 1 (0.7)       |
| Sanitation                    |               |
| Defecation practice           |               |
| Open field                    | 149 (99.3)    |
| Latrine                       | 1 (0.7)       |
| Hygiene                       |               |
| Hand wash after toilet        |               |
| Yes                           | 146 (97.3)    |
| No                            | 4 (2.7)       |
| Hand wash before food preparation |       |
| Yes                           | 142 (94.7)    |
| No                            | 8 (5.3)       |
| Hand wash before eating       |               |
| Yes                           | 147 (98.0)    |
| No                            | 3 (2.0)       |
| Frequency of bathing          |               |
| >Once a day                   | 9 (6.0)       |
| Once a day                    | 68 (45.3)     |
| Thrice a week                 | 61 (40.7)     |
| Less than thrice a week       | 12 (8.0)      |
| Usage of soap                 |               |
| Never                         | 11 (7.3)      |
| Sometimes                     | 80 (53.3)     |
| Always                        | 59 (39.3)     |

*Reported using a smaller vessel/tumbler to draw water from storage vessel
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Discussion and Conclusions

This study provides comprehensive findings on water quality, sanitation, and hygiene among the vulnerable tribal population known for its geographical and socioeconomic barriers. Roughly two-thirds of this population showed poor knowledge and practice as indicated by the overall WASH score. Sanitation, a component of the WASH score, was identified as the major problem. Open defecation was almost a universal practice in this area. However, the other components had a mixed response of poor practice and an acceptable practice.

Almost half of the drinking water sources are directly under the government service; however, water supply from these sources are mostly inadequate and infrequent. Anecdotal evidence states that this district goes dry during the summer season, and therefore, the quantity and frequency of water supply varies in different seasons.[13,14] Studies from other parts of the country reported similar variation.[15‑17] Infrequent water supply would compel the local population to store water for longer duration which eventually leads to high bacterial load in the drinking water. In addition to such administrative factors, unavailability of provisions for proper water handling, hand hygiene, and sanitation facility due to poor socioeconomic status could have influenced the WASH score. None of the households had a safely managed drinking water source as defined by JMP, 2017.[1] The World bank data for 2015 showed that 49% of the rural population in India used safely managed drinking water source. Hence, our study shows that tribal areas are worse off than the rural households in this aspect. Surprisingly, the present finding is far from the 2017 report of Tamil Nadu state government,[18] which states that more than 99% of the households in Vellore district have safe drinking water source from an improved source, while the figure is 93% according to NFHS-4.[19] Nevertheless,

| Table 4: Univariate and multivariate analysis for assessing determinants for poor WASH status |
|---------------------------------------------------------------|
| Variables | Frequency (%) in poor WASH group | Unadjusted OR (95% CI) | Adjusted OR (95% CI) | P |
|---------------------------------------------------------------|
| Type of house |                                              |                        |                        |    |
| Pukka/semi pukka | 65 (74.7) | 1.9 (1.0‑3.9) | 1.94 (0.95‑3.98) | 0.06 |
| Kuccha | 38 (60.3) | | | |
| Highest education in the household |                                              |                        |                        |    |
| Completed 12th standard | 87 (71.3) | 1.9 (0.8‑4.3) | 0.95 (0.37‑2.42) | 0.92 |
| Below 12th standard | 16 (57.1) | | | |
| Occupation of head of the household |                                              |                        |                        |    |
| Mostly field work | 98 (71.0) | 3.43 (1.03‑11.47) | 0.9 (0.22‑3.7) | 0.88 |
| Others | 5 (41.7) | | | |
| Per capita income in INR |                                              |                        |                        |    |
| Low (≤1000) | 89 (72.4) | 2.4 (1.04‑5.7) | 2.43 (1.02‑5.79) | 0.04 |
| High (>1000) | 14 (51.9) | | | |

Figure 2: a: Cluster-wise distribution of principal water source to household distance. b: Cluster-wise distribution of per capita water use for all purposes

Figure 3: Distribution of WASH score in different study hamlets

score (<4)” (OR 1.21; 95% CI: 0.31–4.69) did not show any significant association in univariate analysis.
in our study, nearly half the households get drinking water from a piped source which is substantially better than what was reported[20] in the nearby district where only 2% of the tribal population were getting drinking water from the piped water source.

The microbiological analysis of the drinking water was undoubtedly alarming as none of the samples from the households had an acceptable bacteriological quality. In addition to our finding of high contamination in the source samples, the other possible reasons behind high coliform count at the household level include long “source to household distance,” “improper storage,” “infrequent water purification,” the common “practice of open defecation,” and “poor hygiene practice” as evident from our findings. Studies of other low- and middle-income countries also reported a high fecal coliform count in drinking water.[21] It was reported that high contamination could be due to improper transport, storage, and handling of water from source, environmental, and behavioral factors.[22‑24] We expect the microbiological quality to vary in different seasons. The present study was done in the winter season; and therefore, we can expect even higher coliform count during summer and monsoon season.[25]

Our study has multi-level implications. First, it is one of the very few studies in India that has identified the WASH standard and drinking water quality in an indigenous tribal population that was at stake. Besides identifying the base-line WASH standard and drinking water quality, which may be associated with various diarrheal and non-diarrheal communicable diseases[26‑29]; the study also unveiled other potential risks for the study population like wage loss due to time spent in fetching water and various social hazards for women and children who fetch water.[30,31] Therefore, the present study unfolds the opportunity to develop further research questions in this area including identifying the efficacy of various strategies to improve the WASH and drinking water standards. Additionally, the primary care physicians working in the tribal or hard-to-reach areas must be aware of the role of poor WASH practices while treating health conditions that may be related to it. Repeated context-specific but scientifically valid health education by the primary care physicians may improve the condition.

Table 5: Water quality at the sources and households

| Parameters | Source (n=10) | Household (n=60) |
|------------|--------------|-----------------|
| Physical  | Within acceptable limits (%) | Not acceptable (%) | Within acceptable limits (%) | Not acceptable (%) |
| pH        | 6.5-8.5 | 10 (100) | 0 (0) | 60 (100) | 0 (0) |
| TDS       | <600 ppm | 4 (40) | 6 (60) | 20 (33.3) | 40 (66.7) |
| Chemical  |  |  |  |  |  |
| Nitrates  | <50 ppm | 10 (100) | 0 (0) | 60 (100) | 0 (0) |
| Free chloride | 0 (0) | 10 (100) | 0 (0) | 60 (100) | 0 (0) |
| Bacteriological |  |  |  |  |  |
| Fecal coliform | ≤10 CFU/100 ml | 5 (50) | 5 (50) | 12 (20) | 48 (80) |

*1 metre=3.28 feet

Table 6: Univariate and multivariate analyses of drinking water quality (Fecal coliform ≥10 per 100 ml) at the household level (n=60)

| Variables                          | Frequency (%) of households with high fecal coliform (≥10 per 100 ml) | Unadjusted OR (95% CI) | Adjusted OR (95% CI) | P |
|-----------------------------------|------------------------------------------------------------------------|------------------------|----------------------|---|
| Type of house                     |                                                                        |                        |                      |   |
| Pukka/semi pukka                  | 31 (75.6)                                                              | 0.36 (0.07-1.86)       | 2.03 (0.5-8.23)      | 0.3 |
| Kuccha                            | 17 (89.5)                                                              |                        |                      |   |
| Per capita income per month (INR) |                                                                        |                        |                      |   |
| Low (≤1000)                       | 41 (85.4)                                                              | 4.18 (1.03-16.96)      | 5.07 (1.08-23.74)    | 0.03 |
| High (>1000)                      | 7 (58.3)                                                               |                        |                      |   |
| Distance of drinking water source from household |                                                                        |                        |                      |   |
| ≥100 metres*                      | 8 (100)                                                                | 1.3 (1.12-1.51)        | 0.3 (0.05-1.8)       | 0.19 |
| <100 metres                       | 40 (76.9)                                                              |                        |                      |   |
| Type of storage container         |                                                                        |                        |                      |   |
| Earthen or plastic                | 8 (100)                                                                | 1.3 (1.12-1.51)        |                      |   |
| Metal                             | 40 (76.9)                                                              |                        |                      |   |
| Method of purification            |                                                                        |                        |                      |   |
| None                              | 32 (88.9)                                                              | 4.0 (1.05-15.3)        | 1.04 (0.25-4.31)     | 0.95 |
| Any method                        | 16 (66.7)                                                              |                        |                      |   |
| Covering of storage container     |                                                                        |                        |                      |   |
| No                                | 2 (100)                                                                | 1.26 (1.11-1.44)       |                      |   |
| Yes                               | 46 (79.3)                                                              |                        |                      |   |

[1]Parts per million. For analysis purpose, 10 CFU was taken as a cut-off as per the flexibility prescribed by WHO for developing countries.
Therefore, the key findings of our study include water quality, sanitation, and hygiene practices in this tribal area are substantially poor which is often associated with the low per capita income; household members, especially the women, are forced to spend considerable time to fetch drinking water from distant places; drinking water at the household level is almost universally infected with coliforms.

Findings from our study indicate that much work is needed to improve the water quality, sanitation, and hygiene. The findings are particularly valuable for developing nations where systematic water quality monitoring is lacking mainly because of resource constraints. Besides improving the supervision and monitoring of the existing systems, we strongly recommend adopting culturally acceptable educational models to change WASH-related behavior at the household level. These models should incorporate cost-effective strategies like regularizing household-level water treatment and improving water storage facilities to improve water quality. Such models can be implemented by local health agencies, educational institutions, and nonprofit organizations along with the general administration.

Limitation: We could not assess the water quality for all households due to lack of resources. A higher number of water samples might have detected the determinants precisely. The WASH score was devised by our team and is not validated yet.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients understand that their names and initials for their images and other clinical information to be reported in consent forms. In the form, the patients have given their consent for reducing environmental health exposure risks. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Key messages
• WASH parameters are substantially poor in the tribal area.
• Poor WASH score is uniformly distributed across the tribal clusters.
• High proportion of water samples are contaminated with fecal coliforms.
• Nearly, all tribal populations go for open defecation.
• Finding suggests existence of administrative failure in implementing programs.

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Conflicts of interest
There are no conflicts of interest.

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