Microbial Safety Associations in Point of Use Drinking Water of Salyan, Nepal

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Abstract: - Drinking water access is increasing but its safety remains a major health concern. Point of Use (PoU) safety of drinking water is important as diarrheal disease is still a major cause of morbidity and mortality especially among under five year's children. Range of factors influences microbial safety of drinking water. Understanding probable factors associated to PoU microbial safety can aid in reducing health vulnerability. A cross-sectional study of 400 households at Salyan district, Nepal was conducted. Household survey, Spot observations, Physical parameters, and Microbial contamination (*E. coli*), of PoU drinking water were assessed. Physical parameters were within the limit value of National Drinking Water Quality Standards (NDWQS), 2005. Microbial contamination (*E. coli*) was laboratory confirmed in 191 (50.5%) PoU samples. Uncovered storage vessels possessed twice much as odds risk (OR=2.24; CI=1.208-4.166) of contamination than that of covered ones. Households with water in the dwelling had odds of 52% (OR=0.520; CI=0.332-0.814) greater risk of contamination. Technical and Behavioral factors were evidenced to be associated with microbial contamination in study sample. Access of drinking water alone didn't possessed microbial safety; rather unsafe access increased the risk of contamination. The study indicates that, if water is from safe distribution point and stored in a covered vessel which is easily cleanable, PoU drinking water shall be microbiologically safe.

Key-words: - Point of Use, Microbial, Drinking water, fecal contamination, Factors

1 Introduction

Nepal's access to improved drinking water is increasing i.e. 66% in 1990 which have reached to 92% in 2015 [1]. The access alone may not always ensure safety at the household level [2,3]. Risk of microbiological contamination in drinking water increases at home [3–6]. Every year 10,500 children under five years of age die in Nepal because of waterborne diseases majorly diarrhea [7].

Escherichia coli (*E. coli*) as an indicator of fecal pollution, is a well-established practice for assessing drinking water quality [8]. Studies have identified different factors to be associated with fecal contamination at Point of Use (PoU) drinking water [3,9]. Nepal's Water Sanitation and Hygiene (WASH) interventions majorly focus to raise coverage with limited focus on drinking water quality [10]. Unsafe supply multiplies health vulnerability rather than serving to its purpose. Water quality test results are normally not available on time, which would have allowed managing and preventing effects due to unsafe water. Thus, understanding susceptible factors associated with microbial water safety at PoU may aid to plan interventions for reducing health vulnerability due to unsafe water.

2 Materials and Methods

Cross-sectional study was done in 400 randomly selected households from highly diarrheal disease vulnerable district – Salyan [11]. A simple prevalence formula:

$$N=4(PQ)/L^2,$$

was used for sample size calculation, assuming 50% prevalence of associated factors at the confidence interval of 95%, and 5% allowable error. Women above 18 years providing consent

to participate were considered as target respondent. Women were purposively preferred as they are the ones being involved in daily household chores, having good knowledge of household related water, sanitation, and hygiene practices [12]. Six various factors – i. Social (Respondent's Education, Main income source, Family type), ii. Technical (Practicality to clean storage vessel, Drinking water treatment method, neck size of storage vessel), iii. Accessibility (Drinking water dependent point, Water accessibility in dwelling, round the clock water availability, Sanitation facility, Sanitation facility status, Hand washing facility for sanitation), iv. Knowledge & Attitude (Participated in WASH awareness prior one week, Water filter in household, Water purifier in household, Stock soap in household), v. Behavioral (Storage of drinking water, Treatment of water prior drinking, Cleans water storage vessel, Exclusive vessel for drinking, Storage of remaining food, Use for hand washing, Hand washing in all critical times), and vi. Environmental factors (Stagnant water around premises, Considerably clean household, Dustbin in household, Clean sanitation facility, Cleaning materials in sanitation, Soap in sanitation, Water for sanitation, Soap in kitchen) were considered to assess probable microbial safety associations. Those variables which are contextually assumed to effect microbial quality are assessed under each of aforementioned factors. Biases may occur if the unobserved factors associated with E. coli contamination in PoU drinking water are also associated with the exposure factors under the study.

PoU samples from each sampled household were collected in sterile vials and transported (transportation time -less than 6hours using ice box) to onsite laboratory for microbial analysis following American Public Health Associations 1998 guidelines [13]. Wag-tech field test kit was used following membrane filtration method with M. Lauryl sulphate for enumeration of *E. coli*. The result of test parameters were then compared with National Drinking Water Quality Standards (NDWQS) 2005 [14], and further graded as per WHO 1993, Bacteriological risk grading [8].

3 Results

3.1.Household's Characteristics

Majority of respondents were just literate (43.80%) with nuclear family (68.80%) relying on agriculture (54.80%). Communal tap was the main (85.50%) distribution point of drinking water, which was available round the clock for 60.50% houses. Only 30% had access of water within household premises. Almost all (99.30%) had sanitation facility of which 5.30% were shared. Hand washing facility either inside or outside sanitation facility was observed in 69.30% of households.

On observation, 86.50% of water storage vessels were covered and almost all (97.50%) were moderately wide necked *(Eg. Gagri*). Most (68.80%) of the vessels were easily cleanable - being wide necked and light weighted. Almost all (91.80%) reported to clean storage vessel on regular basis. Similarly, 376 (94%) of kitchens kept their remaining food in covered utensils, but only 80 (20.50%) kitchens were observed to have soap for hand washing. Practice of water treatment prior drinking was reported by 44.50 %, but not all treatment methods were safe for microbial safety (Table 1). About 40.20% of households didn't have exclusive vessel for drinking water.

Some 37% of the respondents did participate in any WASH awareness program prior one week of survey. Presence of water filter (20%), water purifier (5.30%), and stock soap (55.80%) in households were considered as positive attitude of households towards safe WASH. Almost all (96.30%) reported of using soap & water for hand washing but only 26 (6.50%) respondents reported to wash hands during all critical times.

Most (96.20%) of the household's premises were free from stagnant water. There were no visible human or animal excreta in 86.50% households and hence considered as clean households. Dustbin was observed in 93 (23.30%) houses. Among those with owned sanitation facility, 96.22% reported to clean sanitation facility regularly, 87.15% of facilities were observed with cleansing materials. Soap inside or outside sanitation was observed in 276 (69.52%) facilities, similarly water was available in 265 (66.75%) facilities.

3.2. PoU Microbial safety

Total 378 PoU water samples were analyzed for interpretation of microbial safety, 22 were discarded as the incubation result were smudged. Physical parameters of water samples were within NDWQS, 2005 limit value. Average water temperature was 27.48°C (SD=2.588) with average pH 8.08 (SD = 0.360). Fecal contamination was laboratory confirmed in 191 (50.50%) PoU samples. As per WHO 1993 bacteriological risk grading, 8.5% of the household were at very high risk (101-1000cfu/100ml), 14.3% in high risk (11-100cfu/100ml), 27.8% (1-10cfu/100ml) in low risk and, 49.5% with no risk (0cfu/100ml) of contamination.

3.3. Factors Associated with PoU Microbial Safety

Aforementioned six factors were assessed for associations with E. coli contamination. Factors like Behavioural, Knowledge, Technical, and Accessibility are evidenced to be associated with fecal contamination in study sample. Significant difference was observed among those households who cover their remaining foods and drinking water with lid (Table 2). Those households where drinking water is stored uncovered have 2 times higher odds (OR=2.244; CI=1.208-4.166) for *E. coli* contamination. Significantly low (39.60%) contamination was evidenced in those households where respondents were knowledgeable about WASH issues- being recently participated in WASH awareness program. Those with no recent knowledge on WASH had 2 times higher odds (OR=2.017; CI= 1.318-3.086) for water contamination. Practicality of cleaning water storage vessel was also evidenced to be significantly associated for *E. coli* contamination (Table 2).

Light weighted storage units with wide neck for easy rolling of hands or brush to clean was considered as easily cleanable storage vessels. Moderately narrow and narrow necked with some weight were considered as not cleanable. Those vessels which were easily cleanable were comparatively less contaminated (45.90%), against its counterpart (61.60%). The odds of contamination was 89% higher (OR=1.894; CI=1.207-2.973) for non cleanable vessels.

Significant difference in *E. coli* contamination was observed as per distribution point of drinking water. Access to improved facility without quality concerns is evidenced to be of higher contamination risk. It was evidenced that most (80.60%) of the piped water into dwelling are contaminated. Lowest contamination was seen in communal taps (46.70%). Further analysis was made to learn if access to water at dwelling has any effect on contamination. Those households with water access within household premises was grouped as - HHs with water in dwelling, and those depending on communal taps and other distribution points beyond household premises was categorized as its counterpart. Significant difference in *E. coli* contamination was evidenced as households with water access in dwelling had odds of 52% (OR=0.520; CI=0.332-0.814) higher odds of *E. coli* contamination in drinking water.

None of the assumed social and environmental factors showed any significant association with PoU microbial water safety.

Table 1: Descriptive of variables considered for microbial safety

Factors	Variables	N=400 (100%)	Factors	Variables	N=400 (100%)
Social	**Respondent Education**		**Accessibility**	**Drinking water dependent point**	
	UG or PG	2 (0.50%)		Communal tap	340 (85.00%)
	Certificate level	3 (0.80%)		Improved tap in dwelling	31 (7.75%)
	High school level	22 (5.50%)		Other un-improved point	29 (7.25%)
	Secondary level	69 (17.30%)		**Water accessibility in HH compound**	
	Primary level	74 (18.50%)		Yes	120 (30.00%)
	Literate	175 (43.80)		No	280 (70.00%)
	Illiterate	55 (13.80)		**Round the clock water availability**	
	Main income source			Yes	242 (60.50%)
	Agriculture	219 (54.80%)		No	158 (39.50%)
	Service	55 (13.80)		**Sanitation facility**	
	Business	20 (5.0%)		Yes	397 (99.30%)
	Remittance	90 (22.50%)		No	3 (0.70%)
	Others	16 (4.0%)		**Sanitation Facility Status (n=397)**	
	Family type			Shared sanitation	21 (5.30%)
	Nuclear	275 (68.80%)		Owned Sanitation	379 (94.7%)
	Joint	125 (31.30%)		H**and washing facility for Sanitation**	

Technical	**Practicality to Clean Storage Vessel**			Yes	277 (69.30%)
	Easily cleanable	278 (69.50%)		No	120 (30.70%)
	Not cleanable	122 (30.50%)	**Knowledge & Attitude**	**Participated in WASH awareness program prior one week**	
	Drinking Water Treatment Method (n=178)			Yes	148 (37.00%)
	Boiling	44 (24.70%)		No	252 (63.00%)
	Strain through cloth	72 (40.40%)		**Water filter in household**	
	Use filter	60 (33.70%)		Yes	80 (20.00%)
	SODIS	1 (0.60%)		No	320 (80.00%)
	Using medicine	1 (0.60%)		**Water purifier in household**	
	Boiling	44 (24.70%)		Yes	21 (5.30%)
	Neck Size of drinking water storage vessel			No	379 (94.7%)
	Wide neck vessel	10 (2.50%)		**Stock soap in household**	
	Moderately wide neck vessel	390 (97.50%)		Yes	223 (55.80%)
				No	177 (44.20%)

Factors	Variables	N=400 (100%)	Factors	Variables	N=400 (100%)
Behavioral	**Storage of drinking water**		**Environmental**	**Stagnant water around household premises**	
	Covered vessel	346 (86.50%)		Yes	15 (3.80%)
	Uncovered vessel	54 (13.50%)		No	385 (96.2%)
	Treatment of water prior drinking			**Considerably clean household**	
	Yes	178 (44.50%)		Yes	346 (86.50%)
	No	222 (55.50%)		No	54 (13.50%)
	Cleans water storage vessel			**Dustbin in household**	
	Yes	367 (91.80%)		Yes	93 (23.30%)
	No	33 (8.20%)		No	307 (76.70%)
	Exclusive vessel for drinking purpose			**Clean Sanitation Facility (n=397)**	
	Yes	239 (59.80%)		Yes	382 (96.22%)
	No	161 (40.2%)		No	18 (3.78%)
	Storage of remaining food			**Cleaning materials in Sanitation (n=397)**	
	Covered Utensil	376 (94.00%)		Yes	346 (87.15%)
	Uncovered Utensil	24 (6.00%)		No	51 (12.85%)
	Use for hand washing			**Soap in Sanitation Facility (n=397)**	
	Soap & Water	385 (96.30%)		Yes	276 (69.52%)
	Others	15 (3.7%)		No	121 (30.47%)
	Hand washing in all critical times			**Water for Sanitation (n=397)**	
	Yes	26 (6.50%)		Yes	265 (66.75%)
	No	374 (93.50%)		No	132 (33.25%)
				Soap in Kitchen	
				Yes	82 (20.50%)
				No	318 (79.50%)

Table 2: Associated factors and Microbial Safety

Factors	Associated Variables	Fecal contamination		Total	P-value	Odds-Ratio (OR)	Confidence Interval (CI)
		- ve n=187 (49.5%)	+ve n=191 (50.5%)	N=378 (100%)			
Behavioral	**Storage of remaining food**						
	Covered utensil	184 (51.4%)	174 (48.6%)	358 (100%)	0.002**	5.992	1.726-20.806
	Uncovered utensil	3 (15%)	17(85.6%)	20 (100%)			
	Storage of drinking water						
	Covered vessel	170 (52.1%)	156 (47.9%)	326 (100%)	0.009*	2.244	1.208-4.166
	Uncovered vessel	17 (32.7%)	35 (67.3%)	52 (100%)			
Knowledge	**Participated in WASH awareness program prior one week**						
	Participated	84 (60.4%)	55 (39.6%)	139 (100%)	0.001*	2.017	1.318-3.086
	Not participated	103 (43.1%)	136 (56.9%)	239 (100%)			
Technical	**Practicality to Clean Storage Vessel**						
	Easily cleanable	144 (54.10%)	122 (45.90%)	266 (100%)	0.005*	1.894	1.207-2.973
	Not cleanable	43 (38.40%)	69 (61.60%)	112 (100%)			
Accessibility	**Water in household compound**						
	Water access in dwelling	44 (38.3%)	71 (61.7%)	115 (100%)	0.004*	0.52	0.332-0.814
	No water access in dwelling	143 (54.4%)	120 (45.6%)	263 (100%)			
	Drinking water dependent point						
	Improved tap in dwelling	6 (19.4%)	25 (80.6%)	31 (100%)			
	Communal tap	170 (53.3%)	149 (46.7%)	319 (100%)	0.001*	-	-
	Other unimproved point	11 (39.3%)	17 (60.7%)	28 (100%)			

* = Pearson Chi-square &** = Fisher's Exact

4 Discussions

E. coli contamination was high in PoU drinking water. Our study data is consistent to other studies [3,4,15], stating that access to water alone does not assure that it is free from contamination. Unsafe access to water within household premises rather increased the risk of contamination. Access just in dwelling without in-house plumbing may have resulted in high contamination as single distribution point was considered for overall water related activities. Similar to other findings [16], perceiving that the water within dwelling is clean and does not need to be treated at home is particularly troubling safety of drinking water. The above findings materialize the theory of reasoned action. Reasoned action predicts that behavioral intent is created by two factors: our attitudes and our subjective norms. Subjective norms are basically perceived social pressure to perform or not to perform the behavior. Here in study findings, almost all households perceived that their drinking water is clean, limiting drinking water treatment practice as they did not believe that it was necessary, since they had consumed such water without any issue. The result highlights the problem of incapacity to reliably provide quality water. This overstress health risk as residents tend to use contaminated water assuming that it is clean or safe for consumption. Also, the presence of structure regardless to its reliability may give an impression that the water need has been met and no further intervention is required.

Water treatment practice was limited, ineffective treatment method was noticeable in number of households. Though few reported boiling, study findings showed that even boiled water were not likely to be free from contamination. One study states, even among those households who could describe correct practice of boiling water were not associated with improved water quality [17]. The reason behind this may be inappropriate boiling procedure, and/or improper handling after boiling, and/ or improper storage.

Behavioral practices like covered water vessels, food vessels, were protective against contamination. It is to be noted that practice of covering vessels with unsafe materials like jute sack, slate, wooden planks etc existed in the study sample which was considered as uncovered due to inappropriate use. Partially covered were also treated same. This observation of hygienic behavior is supported by studies which found that covered vessels reduce the contamination of *E. coli* and TTC significantly [5,16,18,19]. Mintz et al. (1995) further details safe storage vessels with: (i) an opening that is large enough to facilitate filling but too small to allow hands to enter; (ii) a size, shape, weight and durability that renders it suitable to be taken to and filled at the pump to eliminate transfers to another vessel; and (iii) a spigot or tap for access without inserting cups or other utensils [20].

An intervention study in Zimbabwe found that homes where traditional drinking water containers are replaced with covered, narrow mouthed urns with a tap outlet have significantly less contamination than the control group [21]. This observation is supported by intervention studies, which have found that covered vessels reduce fecal and total coliform counts in stored water by 50% [21,22]. The safe storage of water is particularly important because even if water is disinfected, unsafe storage will lead to its contamination [23].In our study sample, the vessels characteristics like opening and size, shape, weight, and durability of sampled household were similar as defined by Mintz et al (1995) except for presence of spigot or tap. In addition to those characteristics, lid of storage vessel, and practicality to clean storage vessel showed importance in maintaining water quality. Neck size of storage vessel failed to yield statistical significance is sampled households. It is to be noted that, although almost all reported to clean storage vessels but only those which were comparatively observed practicable to clean - considering its weight and size, were free from contamination. Households with contaminated water did not show any significance with presence of sanitation facility, hand washing facility in sanitation, treatment practice of water, agent used for hand washing, and assumed environmental factors. Nevertheless, high PoU contamination indicates that uninterrupted water supply alone is not effective unless quality aspect is considered which has the biggest health impact. The

provision of an improved supply is not enough as long as prolonged home storage of drinking water is required [5].

5 Conclusions

Behavioral, Technical, and Knowledge factors were associated with microbial safety of drinking water at PoU. Accessibility showed associations differently, if quality aspect were not considered it imposes higher microbial risk through various probable modes. The study indicates that, if water is from improved distribution point and stored in a covered vessel which is easily cleanable, PoU drinking water is considerably safe.

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Author Contributions:
For this project, Mr. Manish was the concept builder . Shweta and Manish went to collect data. Subodh was responsible for analysis and Prativa was responsible for manuscript preparation. Editing and review was done by all the authors and co-authors

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