Reduction of Diarrheal Diseases Cases by the Introduction of Sand-Filtered Drinking Water in a Rural Western Hilly Area in Nepal

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ABSTRACT

A three years (June 2012 to March 2015) community intervention study aimed to see the reduction in diarrheal diseases cases (supported by JICA Partnership Program) was done in a hilly Dhital Village Development Committee (VDC) (now *Machhapuchhre Gaupalika*-6) in Kaski District, Nepal. The VDC is inhabited by 2,781 people and most of them live on subsistence agriculture. Because of insufficient and/or non-functional water supply, locals drink heavily contaminated natural spout water, harvested rain water and puddle water for drinking and were associated with high incidence of diarrheal disease cases (DDCs) as revealed from the local Community Health Clinic (CHC) record. To reduce the DDCs in the VDC, we introduced the sand filtration device (SFD) made of locally available materials were installed (n=15; nine schools and six communities sites inhabited mainly by backward people) for the filtration (purification) of drinking water. Water quality of both raw (before filtration) and filtered water was checked (sample n=51) for protozoa (by microscopy) and for coliform/ fecal coliform bacteria (by using Colilart kit and PetriFilm test). The microbes in the SFD filtered water was reduced significantly (Bacteria: by 23.1% and Protozoa: by 88.2%) compared with the microbes in raw water (however, to assure the water safety, locals were also advised to boil or expose the filtered water to sunlight). Before introduction of SFD in village, only 24.0% of households were using treated water which reached to 100.0% after SFD introduction together with various awareness programs. This finding correlated well with the reduction of overall diarrheal disease cases in the VDC (reduced from 18.4% before introducción of SFD to 4.9% after SFD introduction; x^2=21.068, p=NS). The frequency of diarrheal disease cases were significanly low among locals drinking only SFD filtered water (with or without boiling or exposing to sunlight) 3.4% compared to 15.6% among those drinking raw wáter (x^2=8.906, p=0.012). These findings indicated that the diarrheal disease in the village was associated with the contamination of drinking water, and the disease can be reduced with the introduction of locally made SFD which, in turn, contribute in the improvement of health and economic condition of locals.

Keywords: Drinking water, contamination, sand filtration, diarrheal disease, Nepal.

INTRODUCTION

Water-borne diseases both diarrheal (diarrhea and dysentery) and non-diarrheal (typhoid fever, hepatitis and others) are the major public health problems in developing and least developed countries and of these, diarrheal diseases alone is estimated to cause over 500 thousands deaths each year.[1] Globally, in the year 2015, diarrhea accounted for 9% (over 500 thousands) all deaths among children under age 5 worldwide despite availability of simple effective treatment.[2] Globally, at least 1.8 billion people use a drinking-water source contaminated with human feces[1] attributed to poor sanitation. Around 2.4 billion people who do not use improved sanitation, and 663 million who do not have access to improved water sources.[3] Reportedly, in low- and middle-income countries, 38% of health care facilities lack improved water source, 19% do not have improved sanitation and 35% lack water and soap for hand washing.[1] About 10% of burden of diseases worldwide can be prevented simply by improving the quality of drinking water, sanitation, and hygiene and water resource management and has strong economic sense: every dollar invested leads to up to eight dollars in benefits.[4] The global mobilization behind the

Millennium Development Goal (MDG) (with a deadline of 2015) aimed at improving the health and economic status/livelihood of the people has increased the global population using improved drinking water source to 91% from 76% in 1990.[5] However, the safety of drinking water is not guaranteed due to the lack of integrity of the water supply.[6]

According to census 2011, more than 80% of 26.5 million Nepalese populations live in the rural area and altogether 38% do not have access to toilet facilities and about 18% population do not have access to safe drinking water.[7] Nepal, according to UN Report-2015, was on track in meeting MDG goal with regard to improved drinking water source (to 95%).[6] However, in many places, the integrity of the water supply system is not only poorly functional but totally broken[8-11] and there is big question in water safety and sustainability.[6,12] Drinking water (piped water, natural taps or well water) is heavily contaminated with coliform and well as fecal coliform bacteria[8-11,13-15] and has not been changed over the decades.[15] Even the bottled water is contaminated with coliform/fecal coliform bacteria.[16] This has contributed in the endemicity of diarrheal disease in the country. The prevalence of diarrheal disease in under-five children is 14% with under-five mortality and infant mortality rate of 54 and 46 deaths/1000 live births, respectively.[17] Hence, diarrheal disease still poses a major health challenge and demand effective control measures.[18]

To tackle the diarrheal disease and other waterborne diseases and associated economic loss, water quality interventions (point-of-use water treatment) is very effective.[19] The various water quality interventions (treatment methods) such as coagulation and flocculation, sedimentation, different techniques of filtration, boiling and disinfection have been developed and are being used. Of them, sand filtration device (SFD) is considered to be simple and cost-effective in reducing waterborne both diarrheal and non-diarrheal diseases.[20-23] In this paper, we report the reduction of diarrheal diseases cases by the introduction of SFD in a rural western hilly village (Dhital Village Development Committee) in Kaski District, Nepal.

MATERIALS AND METHODS

Study area: This study was done in a hilly area called Dhital VDC (Kaski District) in western Nepal (Fig. 1) (June 2012 to March 2015) based on the result of preliminary survey on drinking water contamination with coliform/fecal coliform bacteria and protozoan parasites, and high frequency of diarrheal disease cases recorded at the local Community Health Center (CHC) (*Samudayik Swasthya Kendra*) and Primary Healthcare Center (PHC). According to census 2011, the VDC population is 2,781 (767 households) living on subsistence agriculture.[7] Some areas in VDC are inhabited by a cluster of lower caste people called *Dalit*. There are nine schools (two high schools and seven primary schools)

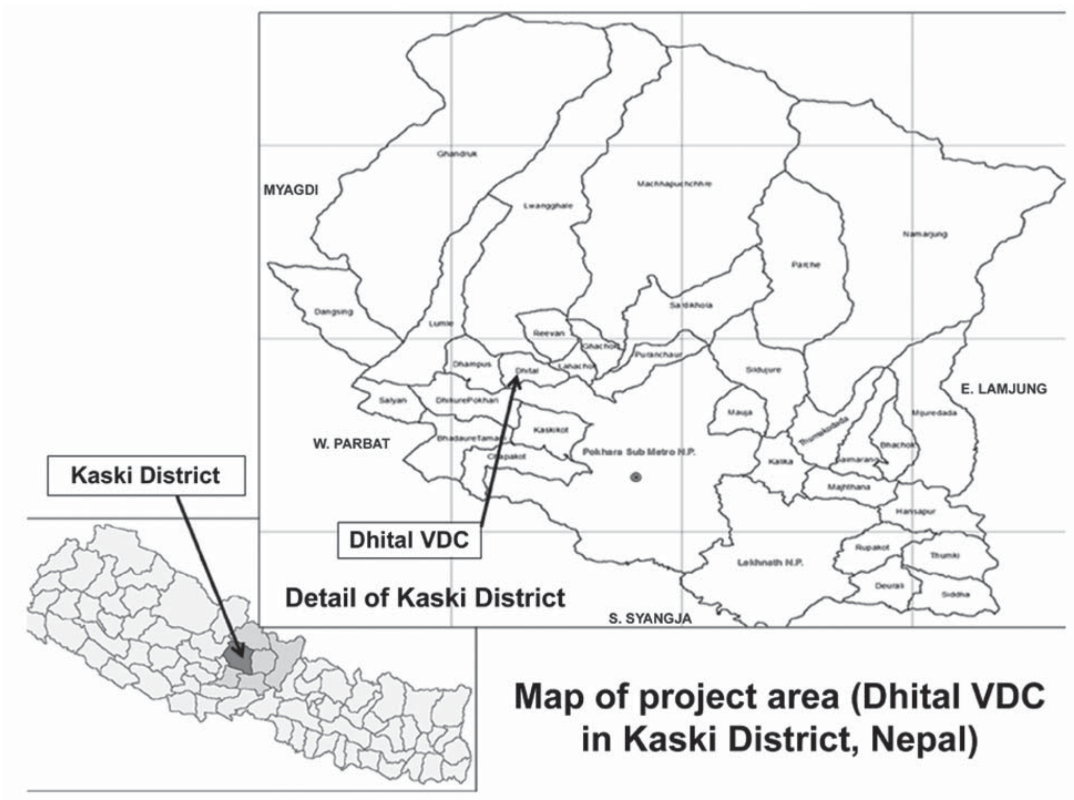

Fig. 1: Dhital VDC in Kaski District in western Nepal (total population 2,781; M = 1,252 and F = 1,530 living in 767 households)[7]

Fig. 2: Local women collecting water from sallow well (left) and a non-functional community tap water alongside the walking trail (right)

and two health care facilities (1 CHC and 1 PHC). The piped water supply system is not only sufficient but also poorly functional or broken (Fig. 2) despite a separate Water Management Committee (WMC) at VDC and locals are forced to drink contaminated natural spout or sallow well water.

Type of study: This was a community intervention study done as part of partnership project entitled "improvement of health condition and livelihood of Dhital VDC inhabitants through improvement of quality of drinking water" was developed by Kobe Tokiwa University (KTU) in Japan and National Institute of Tropical Medicine and Public Health Research (NITMPHR) in Nepal. The Kaski District Development Committee, Dhital VDC Office and other local stake holders namely Schools/School Management Committee (SMC) and local mother groups were consulted at the time of project proposal development and this work was supported by JICA Partnership Program, Government of Japan.

Filtration of water: Based on heavy contamination of water found during preliminary survey, a total of 15 SFDs were installed (nine at schools and six at community sites) using locally available materials. The SFD with concrete base consisted of three filtering units in series (Fig. 3a) with one extra unit ready to use condition (for replacement). Each filtering unit consisted of perforated bucket (at the bottom) filled with sand in it which is placed inside another bucket (slightly bigger in size) where filtered water is collected. The water filtered from upper unit goes to second unit and subsequently to third (final) unit (Fig. 3b) and then goes into the collecting tank. The VDC Office, WMC, CHC, SMC including teachers/students, and mother group of respective area were involved in the SFD establishment at school and/or community. The water filtration rate (flow speed) of all SFD units was fixed at 1.5 liters/minute or less. For household use, the SFD making technique using pet bottles (1.5L or 2.0L) (Fig. 3c) was also demonstrated to locals.

Checking of water contamination: Presence of coliform bacilli and fecal coliform bacilli (*Escherichia coli*) in raw (before filtration) and SFD filtered water was done using commercially available Colilart kit (IDEXX Laboratories, Westbrook, USA) as described and used earlier.[8-10,24] Commercial PetriFilm test system (3M, Minnesota, USA) was used for the quantitation of *E. coli*.[25] For this, upper cover was lifted, 1ml of water sample was put with disposable pipette holding perpendicular, covered with cover, incubated at 37C for overnight, colonies without gas and with gas were counted and interpreted accordingly. Diarrheagenic protozoan parasites were detected by fluorescent microscopy of polytetrafluoroethylene (PTFE) filter (pore size: 5.0um)[25] after filtration of 10~20L of raw and filtered water (Fig. 4). *Giardia lamblia* and *Cryptosporidium parvum* were detected using Easy Stain (bioMerieux, France) whereas other protozoa were detected on the basis of their auto fluorescence.

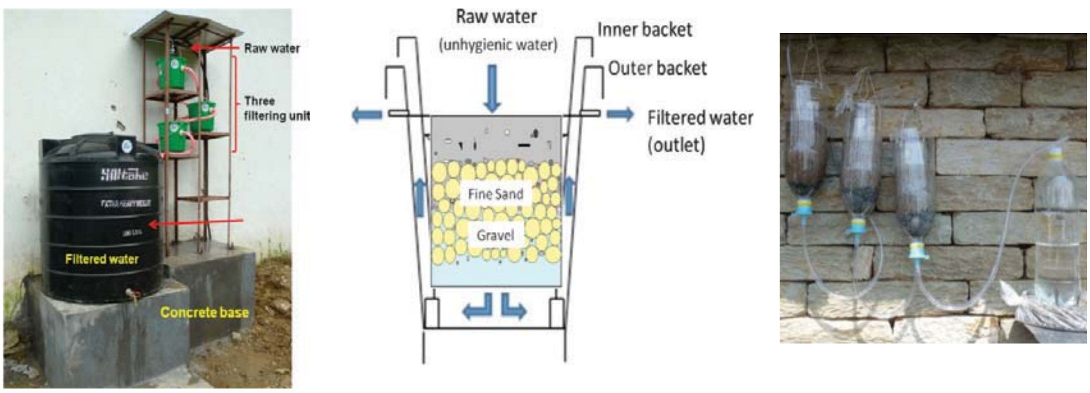

Fig. 3: SFD (made of plastic buckets) with concrete base, metal frame (a); inner part of SFD unit and its functioning system (b) and SFD made of pet bottles (c).

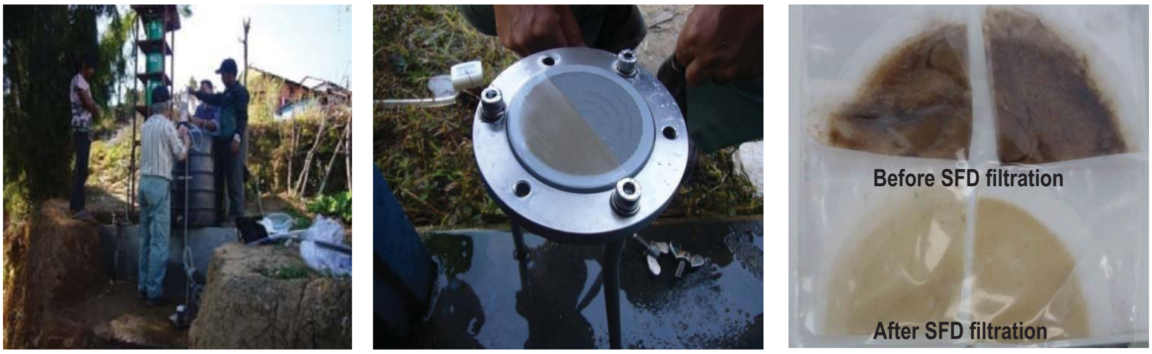

Fig. 4: Bacteriological checking of water (left), membrane filtration device (with PTFE membrane filter) (center) and membrane filters (before and after SFD filtration) (right)

Maintenance and repair of SFD: Seven persons were sent for a week-long observational training in Gifu Prefecture, Japan (S*mall-scale:* Nakayama Water Treatment Facility supplying for 76 persons; M*edium-scale:* Kurabashira Water Treatment Facility supplying for 385 persons and a *Private water treatment facility:* of Takayama Green Hotel). For each of 15 SFD sites, a group consisted of WMC members and respective SMC and mother groups together with trainees trained in Japan were formed and were trained for maintenance [(a) regular inspection, (b) removal of dirty/clogged top unit, (c) washing of clogged unit, and (d) protection of from dirt/bird feces] and repair of SFD using a manual prepared in Nepali language and tool box (given to all 15 groups). For sustainability, maintenance cost coverage mechanism was also decided (up to Rs. 500 to be borne local consumer community/school while cost more than Rs. 500 to be borne VDC Office), and the system was handed over to VDC Water Purification Distribution Committee (WFDC) amid a closing ceremony.

RESULTS

Based on heavy contamination of drinking water we found during preliminary survey (all samples were positive for coliform bacilli and 80% of them had fecal coliform), a total of 15 SFDs were installed in the VDC (nine at schools and six at community sites). Sand filtration significantly removed the dirt present in the raw water making the water look clean (on looking). While filtering the 10 to 20 liters of raw water, the PTFE filter was almost clogged due to large amount of dirt whereas there was very little dirt after sand filtration (Fig. 4). SFD removed not only the dirt (turbidity), but also removed the microbes significantly. Of the water samples tested before and after sand filtration, the microbes in the sand filtered water were reduced with the removal rate of 23.1% for bacteria (bacterial number was reduced to 10^4/ml or less) and 88.2% for protozoan parasites (Table-1). Because of incomplete removal of microbes present in water, local residents were residents advised to treat the filtered water either by boiling or SoDis (solar disinfection) before drinking.

Table-1: Microbial (both bacterial and protozoan) contamination of raw drinking water and removal rate of enteropathogen by SFD

Types of microbes	Number of positive samples (%)		McNemar's test (P value)	% removal rate (overall) (B-A/B)
	Before filtration (Raw) (n=51) (A)	After filtration (n=51) (B)		
Bacteria				
Coliform bacteria	41 (80.4%)	38 (74.5%)	0.08	**23.1**
Fecal coliform (*Esch. coli*)	8 (15.7%)	6 (11.8%)	0.50	
Parasites				
Giardia	3 (5.9%)	0 (0.0%)	0.25	**88.2**
Cryptosporidium	5 (9.8%)	0 (0.0%)	0.028 *(S)*	
Cyclospora	18 (35.3%)	2 (3.9%)	0.0 *(VHS)*	
Emeria	22 (43.1%)	12 (23.5%)	0.029 *(S)*	
Sarcocystis	2 (3.9%)	0 (0.0%)	0.50	

Before introduction of SFD in village, only 24.0% of households were drinking water after some kind of treatment (such as clay candle filtration or boiling) which increased to over 90% after the introduction SFD at all 15 sites (nine schools and six different communities) together with various awareness programs launched during the study period including the song competition (on water treatment and reduction of diseases theme) among mother groups (n=17) in the VDC.

Table-2: Reduction of diarrheal disease cases and other infectious diseases after the introduction of SFD as recorded at the local community health clinic (CHC)

Diseases	**Before*** (total n recorded at CHC=591)		**After**** (total n recorded at CHC=264)	
	n	%	n	%
Diarrheal diseases	109	18.4	13	4.9
Infectious diseases other than diarrheal diseases	181	30.6	64	24.2

*Record of one year just before the introduction of SFD, **Record of one year just after the introduction of SFD at all 15 locations.

The overall diarrheal disease cases in the VDC was found to be reduced from 18.4% before the introduction of SFD to 4.9% after the introduction of SFD at all 15 locations (χ^2=4.671, df=1, $p<0.05$) (Pearson chi-square test) (Table-2). This finding was significant statistically and correlated well with percent removal rate of microbes by SFD shown in Table-1.

Table-3: Diarrheal diseases cases among people drinking SFD filtered and raw water

Type of water	**Number of cases**	**%**
People drinking SFD filtered water (n=232)	8	3.4
People drinking raw (unfiltered) water (n=32)	5	15.6

The frequency of diarrheal diseases cases was significanly low among locals drinking SFD filtered water (with or without boiling and/or SoDis) 3.4% compared to 15.6% among those drinking raw wáter (x^2=8.906; p=0.012) (Table-3). These findings indicated that the diarrheal disease in the village was associated with the contamination of drinking water, and the diarrheal disease was reduced due to the introduction of SFD in the VDC. Based on these results, WFDC was established at VDC level as to make the SFD functional and sustainable as well as to replicate the pet-bottle type of SFD system to each household.

DISCUSSION

Despite the availability of a simple treatment solution,diarrhea remains a leading killer of young children.[26] Nearly 1.7 billion cases of childhood diarrheal disease occur every year and constitute the second leading cause of death in children under-five year (kills about 525,000 children each year).[27] About 88% of diarrhea-associated deaths are attributable to unsafe water, inadequate sanitation, and insufficient hygiene[28] and about 94% of the diarrheal burden is attributable to environment, and is associated with risk factors such as unsafe drinking water, poor sanitation and hygiene.[29] Nearly one million (842,000) deaths in low- and middle-income countries are caused by inadequate water, sanitation and hygiene, representing 58% of total diarrheal deaths, and 1.5% of the total disease burden.[30] In neighboring country India, diarrheal disease alone is responsible for 13.0% of all deaths in children under-five years.[31]

Though the UN MDG Report-2015[5] has mentioned that Nepal was on track in meeting MDG goal with regard to improving drinking water source (to 95%) the integrity of the water supply system in many places is not only poor but completely non-functional[8-11] resulting into low water safety and sustainability.[6,8-10,12,13] Dhital VDC was an exact example of this situation where the water supply system was not only poor and but also completely non-functional at some places (Fig. 2) and whatsoever water people were drinking was found to be highly contaminated both in preliminary and present study. Of the several point-of-use water technologies are available, ceramic and bio-sand household water filters are identified as most effective in improving household water quality to reduce waterborne disease and death.[32] Prevention of diarrheal disease focused on safe water and improved hygiene and sanitation is proved to be not only possible, but also cost effective: every \$1 invested yields an average return of \$25.50.[33] Because of established cost-effectiveness and sustainability of bio-sand filtration especially in developing world,[32] we did a three year project aimed at reduction of diarrheal diseases cases by the introduction of sand-filtered drinking water in Dhital VDC area whereby locals could be helped increase their economic status.

Firstly, the sand filtration system we introduced removed the dirt (turbidity) present in the raw water making the water clean (while filtering the 10 to 20 liters of raw water, the PTFE filter was almost clogged due to large amount of dirt whereas there was very little dirt in sand filtered water). Secondly, SFD removed not only the dirt, but also the microbes at significant rate. The removal rate for bacteria was 23.1% (the number of the bacteria was reduced to 10^4/ml or less) and whereas protozoan parasites were removed by 88.2%. High removal rate of protozoan parasite appeared to be due to their bigger size compared the bacteria. However, the removal rate for bacteria and protozoan parasites we found was lower than the lab based slow sand filtration results (99.98% for protozoa and 90 to 99% for bacteria) study conducted by CDC.[21] Sand filtration has been reported to eliminates protozoan parasites, bacteria as well as viruses[21,34,35] by biological activity as well as straining and adsorption.[34] In this study, however, we did not check for presence and removal of viruses. However, in this study, we found a relatively low removal rate of bacteria observed. This appeared to be due to the high amount of dirt (turbidity) and high microbial burden in raw (source) water and/or due to the use of locally available sand SFD.

In a field study, CDC reported 44 to 47% reduction in diarrheal disease incidence among sand filter water users.[21] In another study done in a rural area in Ghana, bio-sand filtration reduced diarrheal diseases cases by 60.0% among filtered water users.[23] Our findings also showed reduction in diarrheal diseases cases from 18.4% (before the introduction of sand filtration) to 4.9% (after the introduction of sand filtration) as recorded at the local CHC. The reduction rate might have been higher had house-to-house survey was done. Tiwarii *et al*[20] have also reported the effectiveness of intermittent slow sand filtration for preventing diarrhea among children in Kenyan households using unimproved water sources. In addition, the frequency of diarrheal disease cases were significantly low among locals drinking SFD filtered water (with and/or without boiling or SoDis) 3.4% compared with 15.6% among those drinking raw (untreated) water. Though significantly low, occurrence diarrheal disease among people drinking SFD filtered water (with and/or without boiling or SoDis) could be due to infections acquired away from their home (while visiting elsewhere outside of VDC area) as drinking water everywhere in Nepal has been reported to be heavily contaminated with coliform and well as fecal coliform bacteria[8-11,13,14,15] including the bottled water.[16] As the microbial water analysis did not show complete removal of microbes after filtration, the locals were advised to treat the filtered water either by using boiling or SoDis as SoDis is reported to remove the microbes present in the water.[36,37] About one-third of the household began to either boil or carry out SoDis of SFD filtered water.

In this study, SFD made of locally available materials showed significant reduction of diarrheagenic microbes and thereby, reduction of diarrheal disease cases in this rural hilly village. Based on this fact, we also demonstrated/trained the locals (WMC members, SMC members/school teacher, mother groups and other villagers) to make the SFD at household level using empty pet bottles (soft drink bottles of 1.5 and/or 2.0 liter capacity) and other locally available materials (Fig. 3c). For the sustainability, seven persons selected on the basis of cooperation and participation in the installation of SFD, were sent to Japan a week-long observational training in Gifu Prefecture, Japan. Their experience was effective in implementation of the SFD in the village. In addition, for each of 15 SFD sites, a group consisted of WMC members, respective SMC members/school teachers and mother groups together with trainees trained in Japan was formed and trained locally for the maintenance and repair of SFD [(a) regular inspection, (b) removal of dirty/clogged top unit, (c) washing of clogged unit, and (d) protection from dirt/bird feces] using a manual prepared in Nepali language. One maintenance/repair tool box was given to each of 15 SFD sites. For regular maintenance and repair, a mechanism of funding was also developed (for instance, up to Rs. 500 to be borne local consumer community/school while cost more than Rs. 500 to be borne VDC Office).

Because of significant removal rate of dirt/turbidity and diarrheagenic microbes, high filtration rate as well as low cost and ease in maintenance/repair, now the SFD system we established in Dital VDC is being installed (replicated) at schools, hotel/lodges and communities of nearby VDCs of Kaski District as well as of other districts, namely, Tanahu, Parbat and Syanja Districts. The SFD we introduced in this rural hilly village has contributed in the reduction of prevailing diarrheal diseases cases and in lifting the economic status/livelihood of locals.[38] This, in turn, contributing in achieving unmet MDG-4 as well as in achieving sustainable development goal (SDG) 2016~2030.[39] Based on our present findings, to tackle the prevailing heavily contamination of drinking water (piped water, natural taps or well water) with coliform and well as fecal coliform bacteria,[8-11,13-14] diarrheal diseases associated morbidity, mortality and economic loss,[1,2-4,19,27,28] we recommend to promote the use of SFD at schools, at community centers including hotels/lodges, in the communities as well as each households together with improvement in sanitation and hygiene[19] which, in turn, contributes in lifting the economic status/livelihood of locals and ultimately of nation as a whole.

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