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Conservation, Development and Management of Water Resources: An Experience in Himalayan Region, India

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Abstract: The Himalayan region of Tehri Garhwal has scattered habitations with scanty, non-perennial and unsafe water resources like springs and streams. Adverse environmental conditions arising from unsafe drinking water, inadequate sanitary measures result in poor public health. Water conservation and management practices and technologies developed by NEERI were implemented in the select habitations in the region. Environmental protection of the streams and springs for sustained water availability and safe drinking water supply was undertaken with active public participation, training and awareness programs. Rainwater harvesting structures for roof water and spring water harvesting were suggested for optimal utilization of rainfall water. The roof water harvesting structures are provided with sand filters and chlorination facilities for safe potable water supply. Design and commissioning of a small slow sand filtration unit was undertaken at Chhati (Nakot) village for safe drinking water supply. The pre and post intervention assessment of the work carried out included baseline socio-economic survey, parasitic investigations and water quality assessment. The know-how and transfer of technologies by appropriate technological intervention has resulted in improved and safe water supply in project villages. The beneficiaries' opinions, perceptions, apprehensions as well as expectations from this technological intervention are positive due to achievements of anticipated benefits and impacts. The demands and expectations of people of other villages in the region to implement the similar activities in their respective villages indicate success and popularity of the water resources based development project.

Key words: Sanitation • Rainwater harvesting • Slow sand filtration • Chlorination • Disinfection

INTRODUCTION

Water is precious natural resource for sustaining life and environment. It is in a continuous circulatory movement between land, ocean and atmosphere-the hydrological cycle [1]. Once viewed as an infinite and bountiful resource, water today defines human, social and economic development. Water resource management is an important parameter for the development of any nation as it directly relates to the development and growth of the economy [2]. Water scarcity is a serious problem in India for both urban and rural communities. Population growth and irrigation requirements have resulted in overexploitation of ground water, whereas urbanization causes reduction in open soil surface and water infiltration rate and a resultant deterioration in water quality. Poor environmental conditions arising from unsafe drinking water, inadequate sanitary measures, unhygienic disposal of excreta, silage and accumulation of solid wastes resulted in poor public health. The Himalayan region of Tehri Garhwal has scattered habitations in the remote villages and depend upon scanty, non-perennial and unsafe water resources. Therefore the region need be looked with innovative ideas, deviating from conventional concepts and regulatory norms for water sector and sanitation. Community based water supply and treatment system and operation and maintenance with imparting training and awareness was pre-requisites for successful management. An attempt is made to study the sustainable water resources management with particular reference to rainwater harvesting, water quality improvement for safe drinking water supply and sanitation with active public participation, training and awareness programs in Chamba block of Tehri Garhwal district.

Study Area: The study area comprises a group of villages in Chamba block of Tehri Garhwal district in Uttaranchal state, India and falls in the sub-tropical climatic zone of the Himalaya. The area is hilly terrain and lies between 30°18' to 30°25' N latitude and 78°20' to 78°30' E longitude and falls in the catchment of Maniyar river which is a tributary of Bhagirathi river. Being a hilly area, the altitude ranges between 1150 m and 1900 m. The stream courses

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are fairly straight and the general surface slope of the area is up to 30°. The Krol Belt of Lesser Himalayans dominates the geology of the area. The rocks comprise massive gray limestone, dolomite and some bands of phyllite, slate and quartzite. Because of undulating topography, land use is of much diversified nature, which varies from agriculture, horticulture, forestry and wastelands.

Methodology: The selection of study villages was made based on the existing scenario in terms of site-specific situation of water supply necessities. Following factors were considered while selecting the villages for technological intervention and training awareness camps.

- Willingness and cooperation from people of the villages
- Existing sources of water supply
- Perennial source of water within 25 m elevation difference and within 500 m distance from the place identified for public stand post (PSP)
- Feasibility and suitability of technology intervention in terms of rain water harvesting, water filtration and chlorination systems
- Social, financial and administrative support from the village authority.
- Training and awareness

Some of the Innovative Ideas Implemented in the Study Are:

- Delineation of strategies for sustainable availability of water
- Protection of streams and springs
- Construction and demonstration of rain water harvesting structures
- Application of water treatment technologies for safe drinking water supply to villages
- Development of water distribution techniques availing natural elevation gradient
- Demonstration of benefits of environmentally compatible intervention
- Training and awareness programs
- Health survey-pre and post intervention

RESULTS AND DISCUSSIONS

Water Supply and Qualityl: Springs are the major natural sources of drinking water in the area. The water quality assessment of sources of water supply for the study village was carried out to assess the water quality. The water quality varies from place to place depending upon the characteristics of the strata and time of contact of water with the bed rock (Table 1). All the physico-chemical parameters are within desirable limits (BIS:10500-[3]), but the water is bacteriologically contaminated.

Table 1: Physico-chemical characteristics and heavy metal contents of water

		Source / Sample Code								
S.N.	Parameter	C1	C2	N1	N2	R1	K1	S1	S2	RC1
Physico-chemical										
1	Temperature (°C)	18	19	19	19	19	19	18	18	18
2	pH	6.7	7.0	7.1	7.0	7.2	6.8	8.1	7.4	7.1
3	Dissolve Oxygen (mg/L)	1.4	0.9	1.5	1.5	1.5	1.4	1.7	1.5	1.4
4	Conductivity (uS/cm)	179	220	88	108	74	63	269	396	143
5	Total Dissolved Solids (mg/L)	107	132	53	65	44	38	161	238	86
6	Total Alkalinity as $CaCO_3$ (mg/L)	62	78	28	26	18	22	104	90	38
7	Total Hardness as $CaCO_3$ (mg/L)	68.2	82.4	21.8	32	20	24	143	139	51.8
8	Calcium as Ca (mg/L)	19.4	24.3	5.4	8.2	5.0	5.6	31.2	39.9	14.6
9	Magnesium as Mg (mg/L)	4.8	5.3	2.0	2.8	1.8	2.4	15.7	9.5	4.0
10	Chloride as Cl (mg/L)	24	25	22	21	24	15	15	39	26
11	Sulphate as SO_4 (mg/L)	4.8	7.1	4.9	10.1	4.6	2.6	13.2	74.5	5.9
12	Nitrate as NO_3 (mg/L)	ND	ND	0.5	0.4	ND	ND	ND	0.2	0.5
13	Phosphate as PO_4 (mg/L)	0.4	ND	4.8	ND	0.0	0.2	ND	0.7	0.4
14	Fluoride as F (mg/L)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.6
15	Sodium as Na (mg/L)	10.5	12.1	9.3	9.8	7.8	4.1	3.4	19.3	8.7
16	Potassium as K (mg/L)	1.1	3.3	0.6	1.7	0.2	1.1	2	15.4	0.5
Heavy metals										
17	Fe (mg/L)	0.016	0.111	0.471	0.019	0.205	0.177	ND	ND	0.376
18	Mn (mg/L)	0.018	0.159	0.495	0.042	0.024	0.007	ND	ND	0.003
19	Cu, Cd, Cr, Zn, Co, Pb (mg/L)	ND								
24	Al (mg/L)	0.230	0.178	0.505	0.166	0.207	0.217	0.261	0.130	0.431

C1- Spring at Chhati (Nakot), C2-Storage tank at Chhati (Nakot), N1and N2 Springs at Nakot (Ramgarh), R1- Spring at Kodiya (Ramgarh), K1- Spring at Kotmaniyar, S1- Heavel River at Sabli, S2-Spring at Sabli, RC1-Spring at Rani Chouri

Table 2: Bacteriological quality of water (sources and household)

S.N.	Source	Source Quality T.C. (CFU/100ml)	Source Quality F.C.	Household Quality T.C. (Range)	Household Quality F.C.
1	Kothi Spring, Chhati	60	8	60-2400	4-304
	Storage tank,(Chhati)	700	180		
2	Spring (storage), Nakot (Ramgarh)	TNC	96	180-TNC	16-28
	Spring, Nakot (Ramgarh)	540	56		
3	Spring, Kodiya (Ramgarh)	840	80	120-1200	52-38
4	Spring, Kotmaniyar	60	28	60-260	4-52
5	Heavel River, Sabli	540	52	40-260	4-40
	Spring, Sabli	160	52		
6	Spring, Rani Chouri	940	16	80-940	8-92

T.C.- Total Coliforms, F.C.- Faecal Coliforms, TNC-Too Numerous to count

Table 3: Bacteriological quality of water (after technological intervention)

S.N.	Source	T.C. (CFU/100ml)	F.C.
Village: Chhati (Nakot)			
1	Spring-Raw Water	900	94
2	Slow Sand Filter Plant	8	ND
3	Slow Sand Filter Plant	4	ND
4	SSF Storage Tank (after chlorination)	ND	ND
Households / Consumer end (after chlorination)			
5	Tap-near Shri Bachan Singh's house	ND	ND
6	Tap-near Smt. Roshnadevi Fundir's house	27	ND
7	Tap-near Smt. Narayandevi's house	10	ND
8	Shri KumarSingh Rawat	20	ND
9	Shri Kedar Singh Chavan	ND	ND
10	Shir Vijay Singh Chavan	8	ND
11	Smt. Narayanadevi	20	ND
12	Shri Gabbar Singh	ND	ND
13	Shri Surendra Singh Dhanola	22	ND
14	Shri Jai Singh Kutti	ND	ND
15	Shri Anand Singh Rawat	20	3
16	Shri Devchand Chavan	10	2
Village: Ranichouri			
17	Shankar Shroat Tank (after chlorination)	5	ND
18	Shri Indradev Bahuguna	ND	ND

TNC:Too Numerous to Count; ND:Not Detected; CFU:Colony Forming Unit

Bacteriological analysis was carried out to assess the stream and households water used by the community. The water samples from stream as well as from households were bacteriologically positive. The total coliforms (TC) from source were found in the range of 60-700 CFU/100 ml while faecal coliforms (FC) were in the range of 8-180 CFU/100 ml. On the contrary the range of both TC and FC were found more (in case of households water samples (Table 2). This may be attributed to the unsanitary and unhygienic conditions. But, after technological intervention (Slow Sand Filter [SSF] and Pot-Chlorination) the water samples at consumer end were observed to be negative for the presence of TC and FC (Table 3).

Rainwater Harvesting Structures: In hilly region, people use water from springs or seepage from hills coming out as through flow. Many times such water is not fit for drinking purposes. Women have to fetch water from wells, ponds, lakes etc. from long distances and climb few hundred meters which consume lot of time and energy. Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams [4]. Rainwater is collected from roofs or other impermeable surfaces and is stored for later use especially during scarcity period. The water can be used for non-potable uses such as irrigation,

Fig. 1: Rooftop rainwater harvesting

Fig. 2: Development of chaals/ponds

Fig. 3: Recharge structures

Fig. 4: Health survey

toilet flushing etc. Additionally, if the water is properly treated, it can be used for human consumption. Rainwater harvesting helps us to retain the rainwater to recharge the groundwater resources [5, 6]. Various rainwater structures like roof top rainwater harvesting structures, percolation pits and bunds, development of chaals etc. were prepared in the study area (Fig. 1-3). Chlorination pots were recommended in the roof top rainwater harvesting structures for disinfection of harvested water for drinking purpose. Water filtration units were installed at the top of roof water harvesting tanks for the removal of roof dust coming into tanks with roof top water. The filter units comprised of gravels and graded sands. Chlorination pots have been suggested for rainwater harvesting tanks for disinfection of water and safe water supply for drinking purpose.

Parasitic Investigation: A parasitic investigation, an important indicator to assess the overall health status of the community was carried out on random basis in the study area. It is seen that the parasitic infections was more in female (32%) than male (27%) (Fig. 4). This may be attributed to more exposure of females to in sanitary and unhygienic conditions during house-keeping, farming and doing other work like looking after domestic animals washing and cleaning (Table 4), apart from poverty, low literacy, mal nutrition, lack of basic amenities such as water supply, sanitation, medical aid and primary requisites of good health.

Slow Sand Filtrationl: Slow sand filers are used in water purification for treating raw water to produce potable water [7]. Slow sand filtration (SSF) is a water treatment process in which the water to be purified is passed through a porous bed of filter medium and filtrate is collected from the bottom [8, 9]. During this passage the water quality improves considerably by reduction, removal and changes in biological, physical and chemical composition of raw water. In a mature bed the formation of a gelatinous layer (or biofilm/the hypogeal layer/schmutzdecke layer) forms on the surface of the bed [10]. It consists of a great variety of biologically active

Table 4: Parasitic Investigation (Village-Chhati)

		Stool Examination									
		Sex		+ ve				-ve			
S.N.	Age group	M	F	M	%	F	%	M	%	F	%
1.	Upto 5	4	6	2	50	5	83.0	2	50	1	17
2.	6-15	15	25	6	40	6	24	9	60	19	76
3.	16-25	0	2	0	0	1	50	0	0	1	50
4.	26-35	3	10	0	0	3	30	3	100	7	70
5.	36-45	2	3	0	0	0	0	2	100	3	100
6.	46-55	1	0	0	0	0	0	1	100	0	0
7.	56-65	2	1	0	0	0	0	2	100	1	100
8.	66andabove	3	0	0	0	0	0	3	100	0	0
	Total	30	47	8	27	15	32	22	73	32	68

Fig. 5: Slow sand filter

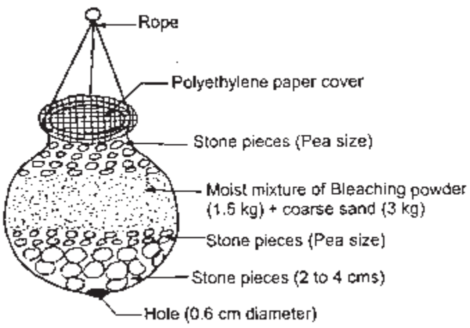

Fig. 6: Chlorine pot

microorganisms, which break down organic matter, while a great deal of suspended inorganic matter is retained by straining.

Plant designed,SSF, (Fig. 5) by NEERI was constructed and commissioned at village Chaati in Chamba block of Tehri Garhwal district. The construction of filter was made using local material including sand media. The capacity of SSF plant is 9 m^3/d. The raw water stream is located at upstream of the village. Raw spring water is collected in a small sump and transported by gravity through G.I. pipes to the SSF plant. Filtered water is stored in ground level tank and distributed in the village again by gravity through PSPs. The plant is adequate for a population of 450 @ 40 lpcd. This plant will be effective in propagating the technology specifically for small community water supply in hilly region. It is worth mentioning that this is a water treatment technology without any power requirement. OandM is limited to removing upper sand layer once in 3-4 months.

The Pot Chlorinator: If water is contaminated but clear, disinfection can be used to kill microorganisms it contains. Using chlorine for this purpose provide a residual that helps in preventing re-contamination [11]. A method or device developed by NEERI has effective chlorination of storage tanks and wells in rural areas for about 12 to 15 days. At village Chhati, the filtered water from SSF-plant is stored in a reservoir for supply to consumers. Pot chlorinator (Fig. 6) is being used to disinfect the water from reservoir prior to public supply. Pot chlorinators also installed in rain water harvesting tanks wherefrom water is used for drinking purpose. A plastic pot of 7 to 8 litre capacity is used in this system. Holes (2 to 3) of 0.5 cm diameter are made at the bottom, which. The holes are covered with stones or pebbles of 2 to 4 cm size which is further covered with gravel of smaller size. A dry mixture of 1.5 kg of bleaching powder and 3 kg of coarse sand is placed over the gravel. The pot is then filled with pebbles or stones up to the neck to facilitate its immersion in the water. It is lowered in a tank about 1 m below water level with the help of a rope. The leaching and diffusion of bleaching powder occurred from the bottom hole of the pot into the tank. The chlorine from the bleaching powder in the pot oozes out slowly and maintained residual chlorine of about 0.5 and 0.2 ppm in the beginning and at consumer end, respectively.

The existing storage tank capacity is about 5000 liters and the intermittent supply is about 3000 to 4000 liters per day. The tank receives water continuously from SSF plant. The 30 to 45 minutes of contact time with chlorine destroy microbes and maintained residual chlorine of 0.2 ppm at consumer end for a fortnight. However, periodical monitoring of residual chlorine at consumer end is advisable. These technologies are very economical and simple; do not involve any complicated machinery or skill for OandM and can be very conveniently adopted for use under the rural conditions.

Training and Awareness Programs: Twenty three villages were selected for imparting training to villagers. The participants included Gram pradhan, Elected leaders of the villages, Members of village-panchayat, Ex Gram pradhan, President and representatives of Mahila mandal, Teachers, Health workers, Local social workers and project personnel working in the area (Fig. 6). A group of people from 4 to 6 adjoining villages were selected in one batch for attending the above program, at Kodiya (Ramgarh), Chhati (Nakot) and Sabli villages covering the following topics.

- Project awareness: Aims and objectives, implementation, consumer's role in OandM of water supply, significance of awareness.
- Sustainable water resources management.
- Environmental protection of streams for safe drinking water supply.
- Rain and spring water harvesting.
- Wastewater and solid waste management at village level.
- Importance of sanitation and health, water and health, morbidity and mortality, hygienic habits for healthy living.
- Land use pattern of the area.

Social Survey: The social aspect of population, especially those residing in the project area is one of the most important considerations for any developmental project. To visualize the scenario with project and its likely impacts, it was necessary to understand the people's opinion, perceptions, apprehensions as well as expectations from the project. In view of this, a post social survey on random basis in village Chhati was conducted after the training programs. Amongst the respondents 37% were males and 63% females. Awareness about the safe potable water supply was 100% amongst the respondents in the village. Villagers using SSF plant represent 39.%, as source of drinking water, while others were using both SSF plant and spring water. Duration of water availability from SSF plant as reported by 57% respondent varies from 30 minutes to 1 hour daily. The appreciation was received from 41% beneficiaries amongst respondents for clean, odourless, satisfactory taste of water from SSF plant. The majority of the respondents (78%) expressed satisfaction over water quality of SSF plant. The people were convinced that the SSF plant with pot chlorination can make dirty and polluted water potable. It makes easy availability of good water from SSF plant in village hence, need not go at long distance for fetching water. Because of SSF plant, an alternate and additional source is made available other than traditional source of spring. The information and awareness regarding such type of water supply scheme should reach to every village of hilly region.

Summary Findings: The salient observations and discussion pertaining to work carried out are as follows:

- Water conservation structures improved water availability in the region.
- Development of Chhals /Ponds were found suitable for groundwater recharge in the area.
- Rooftop water harvesting structures found suitable for fulfilling the water need of individual houses for domestic uses during scarcity period.
- The filtration units in rooftop water harvesting structures and pot chlorinator system are successful in safe water supply. This technology is simple, economical and most practically suitable hence, conveniently adopted in rural area
- It was noticed that the rural people in general understood and realized the importance of water management and look forward to learn the new things and practicing them in the village.
- Such activities were also demanded by the people of other villages in the region, which showed the significance and development of interest in the people. This also indicated the popularity and positive impact of the work done in this project.

CONCLUSIONS

The development of technologies for sustainable water resources management in Himalayan villages by rainwater harvesting for groundwater recharge and safe drinking water supply with environmental protection was the main focus for implementing the project. The design, development and commissioning of rainwater harvesting structures with the introduction of pot chlorinator has resulted in improved groundwater recharge and safe water supply respectively in study area. The design, development, commissioning of appropriate technological intervention through SSF plant with the introduction of pot chlorinator has resulted in improved and safe water supply in the village Chhati. The environmental awareness programs and training had interactive participation to change current non-scientific thinking and practices. The pre and post assessment of socio-economic survey, water quality, health survey and beneficiary's opinion reflect positively in achievements of anticipated benefits and impacts. Improved sense of belonging expressed by way of active participation by the community encouraged the activities of the project. The demand and expectations expressed by people of other villages in the region to implement the same project in their respective villages is self explanatory towards the success and popularity of the approach adapted for safe water supply.

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