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Performance of Portable Instant Water Filter Developed for Emergency Water Supply

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Abstract: Portable instant water filter "NEERI-ZAR" is the water purification system developed for rapid treatment of safe potable water supply under emergency situations like floods, heavy rainfall, or cyclones. The unit works on the principles of oxidation, filtration and disinfection. Unit produces filtered water with turbidity in the range of 1.1 to 2.8 NTU from the raw water with the turbidity in the range 14-300 NTU with 93-99% reduction in bacterial load. There are no changes in the dissolved mineral concentrations in raw and filtered water. The performance of the unit was tested in the field during the floods in Barmer district in Rajasthan state in 2006. The results indicated that the units produced filtered water with turbidity in the range of 0.9 to 1.1 NTU from the raw water (flood water) with the turbidity in the range of 15 and 25 NTU. Total coliforms and *E. coli* counts were nil in the treated water samples. Major zooplankton such as *Cyclopes, Nauplius, Daphnia, Branchionus, Keretella* and *Trichocera* observed in the raw water in the range 600-800 per m^3 were nil in the filtered water. One filter can serve a population of 20-30 persons when operated for 10 hours a day on the basis of 6-10 litres/day requirements for drinking and cooking purposes. The unit which is easy to fabricate using the locally available material, simple to operate and maintain and needs no power is readily acceptable by the people in India and may be also useful in other developing countries.

Key words: Water supply · Filter · Treatment · Oxidation · Disinfection

INTRODUCTION

A safe drinking water supply is a fundamental requirement worldwide. Any natural disaster can disrupts, severely damages, or destroy the physical infrastructure of a village or town. In the absence of treated potable water supply, waterborne diseases often present the greatest risk to human health. This happens in both developed and developing world settings. Water supply under these situations may be biologically contaminated by anthropogenic organic matter or by sewage effluents that mix with floodwaters and physically contaminated with mud and soil that enter the water supply and hinder disinfection efforts. In such situations, there is a need for the portable water treatment plant, which can produce on site safe potable water for the affected people.

Various transportable, self-contained water purification systems capable of treating and supplying significantly large quantities of potable water are available in the market. These plants use various chemicals and filter processes. Many of the water treatments involve large and expensive plants, which require the use of metered amounts of chemicals, such as flocculants to remove turbidity, various filtration materials such as membranes and activated carbon and ozonator for disinfection of water. These plants are generally mounted on big vehicles for transporting to the various places. The utility of these systems is restricted during natural disaster due to following reasons:

- Such plants are not economical for smaller population groups, such as, remote towns or small groups of people;
- They cannot transported to the places where approachability of the villages is lost due to flooding or cyclones;
- Such complex prior art plants require sophisticated monitoring systems and skilled manpower to manage the operation of the plant;
- Expertise is difficult to find in rural or smaller communities in developing countries
- All these plants also require power supply, which may not be available in the flood affected urban and rural areas.

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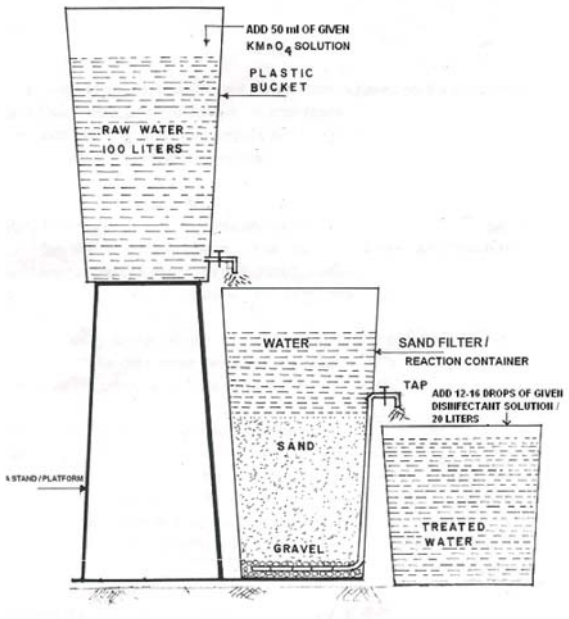

Fig. 1: Portable Instant Water Filter "NEERI-ZAR

To provide the safe water supply during the natural disaster, what is needed is a simple scalable process and apparatus using the locally available material for the treatment of raw water without use of even electric power to render the same fit for human consumption.

Neeri-Zar: Portable Instant Water Filter: Keeping in view the above drawbacks, portable instant water filter was developed which provides a technically simple, cost-effective and reliable community water treatment system for supplying drinking water, which meets the guidelines of the World Health Organization (WHO) for turbidity and microbiological quality. It is well suited for those situations in which the operators and maintenance workers are not highly trained technicians, such as in rural or remote locations and during emergencies. The developed water (NEERI-ZAR) filter uses totally new concept for rapid treatment of safe potable water supply under emergency situations like floods, heavy rainfall, or cyclones when the villages are not approachable, have no electric supply and do not have potable water to drink.

The filter is named as NEERI-ZAR. NEERI stands for the name of the institute (National Environmental Engineering Research Institute) and NEER also stands for water in Hindi (local language). ZAR stands for zarana means stream. Thus NEERI-ZAR stands for water stream of NEERI. The unit is made of 3 plastic containers (Fig.1). Capacity of the 2 plastic containers is about 100 liters each (45-50 cm diameter and 65-70 cm height) and the third container is having the capacity of 20 liters. Platform of 80-85 cm height is prepared for keeping the plastic container. Plastic tap is attached to this top container at about 5 cm height from the bottom of the container for regulating the raw water flow. Second plastic container of 100 lit capacity is used as a sand filter. The L-shape plastic pipe of 10 mm inner diameter is fitted inside the filter. Holes of 4 mm diameter at the distance of 5 cm (center to center) are drilled in the pipe arm (40 cm) facing the bottom of the filter for collection of filtered water. Open end of this pipe arm is plugged. Other end of the pipe is connected to the plastic tap attached to the outer side of the filter at the height of 47 cm from the bottom of the filter. Two layers of gravels are added at the bottom of the filter upto the total height of 5 cm above this layer, sieved sand is placed up to a height of 38 cm. The sand is evened out and Nylobolt cloth is spread over the bed and 5 cm layer of sand was placed on it. The third container of 20 liter capacity is kept below the tap for collection of treated water.

Principle of Neeri-Zar: The NEERI-ZAR is based on the principle of oxidation of matter in the raw turbid water associated with turbidity, filtration through sand bed to remove turbidity and bring down the bacterial load and disinfection by chemical agent to disinfect the water. Contaminated flood water or lake/pond water needs pre-oxidant for the removal of the unspecified organic matter. Potassium permanganate ($KMnO_4$) is used for this purpose as it reacts more rapidly than other oxidants and its distinctive pink colour in water is an advantage since it indicates when overdosing is occurring in destructive oxidation. KMnO4 is a very effective pre-oxidant for the oxidation of unspecific organic matters [1] removal of algae and their metabolites [2, 3] and reduction in tastes and odors in waters [4].

Sand filter provided in the unit is based on the principle of slow sand filtration (SSF) technology. SSF is one of the earliest forms of potable water treatment and remains an important process for water purification throughout the world [5, 6]. High efficiency of water treatment achieved by slow sand filters is due to slow filtration rate (0.1-0.3 m h^{-1}) and fine effective size of the sand (0.1-0.3 mm) [7]. Particles are trapped and organic matter is biologically degraded while passing through the top layer of the filter [8, 9]. Mostly unwanted and harmful biological contaminants are removed by this layer [10, 11]. Slow sand filter removes natural organic matter and organic precursor materials as quantified by dissolved organic carbon [12]. The filter works with constant rate

and increasing water head. As the residue accumulates due to turbidity removal, the sand bed imparts resistance and the water head increases and the filtration rate are maintained.

For the disinfection of drinking water, chemical methods using disinfectants have been the most widely used [13]. The most common disinfectant used today is chlorine [14]. Sodium hypochlorite is used in NEERI-ZAR as a disinfectant. It not only disinfects the filtered water from the system but its residual effect takes care of the possible contamination during storage and handling of the treated water due to unhygienic conditions.

Operation of Neeri-zar: Raw water is filled in the top plastic container and required quantity of oxidizing chemical solution is added to the raw water. Raw water tap is adjusted at a flow rate between 200 and 400 ml/minute and water is allowed to flow into the filter. The filtered water is collected in third container. About 5-8 drops (0.4 ml) of disinfectant (sodium hypochlorite) is added per 10 litres of filtered water collected in the container. Safe potable water is ready for use within half an hour. One cycle of filtration lasts for about 5 hours. The filter cycles depend on the raw water turbidity. As the filter starts clogging, the water head in the filter starts increasing. When the water level reaches top of the filter container, filter bed needs cleaning. Water from the filter container is removed by a mug up to sand layer. The Nylobolt cloth along with 5 cm of sand layer is lifted. The sand is washed separately in a tub or bucket. The Nylobolt cloth is cleaned and replaced on the sand bed. Washed sand is again placed over the Nylobolt cloth. The filter is ready to use. Raw water plastic container needs cleaning periodically. One filter can serve a population of 20-30 persons, when operated for 10 hours a day, on the basis of 6-10 litres/day requirements for drinking and cooking purposes.

Performance of Neeri-Zar

Laboratory Testing: The NEERI-ZAR was tested in the laboratory for the treatment of raw water spiked with turbidity and bacterial contamination. Artificial turbid water was prepared in 600 liter HDPE tank by mixing the black cotton soil in the tap water. The mixture was aerated for an hour and allowed to settle for an hour. The supernatant water was used as raw water, which was spiked with bacterial contamination by adding, settled sewage. The raw water was filled in the top plastic container and 25 ml of 1% potassium permanganate solution was added in the raw water. The tap was adjusted at flow rate of 300-500 ml/min. Samples of raw water and filtered water were collected for turbidity and bacteriological quality (Total coliform and E. Coli.). Composite samples of raw and filtered water were also collected for physicochemical quality and analyzed as per the standard methods [15] Results are presented in Table 1 through 3.

Table 1: Performance of NEERI-ZAR - Turbidity Removal (Laboratory Testing)

		Turbidity (NTU)	
Run No.	Raw water flow rate (ml/min)	Raw	Filtrate
I	500	300 - 320	1.2 - 2.5
II	300	190-210	1.8-2.1
III	300	70-120	1.1-2.1
IV	300	90-150	1.5-2.1

Table 2: Performance of NEERI-ZAR - Bacteriological Quality (Laboratory Testing)

	Bacterial Quality (CFU/100 ml)					
	Total Coliform			E. Coli		
Run No	Raw water	After adding $KMnO_4$	Filtered water	Raw water	After adding $KMnO_4$	Filtered water
I	78300	39500	790	720	360	50
II	75200	7500	800	7900	100	80
III	11200	6450	640	850	40	ND
IV	6800	220	80	100	60	ND

Table 3 : Performance of NEERI-ZAR - Physico-chemical Quality (Laboratory Testing)

Sl. No.	Parameters	Raw water	Treated water
1	Turbidity (NTU)	155 - 300	1.6 - 1.8
2	pH	7.7 - 7.8	7.8 - 7.9
3	Conductivity (μS/cm)	246 - 250	253 - 255
4	Total Dissolved Solids (mg/L)	148 - 150	152 -153
5	Total Alkalinity (mg/L as $CaCO_3$)	104 - 106	104 - 108
6	Total Hardness (mg/L as $CaCO_3$)	104 - 110	104 - 108
7	Ca Hardness (mg/L as $CaCO_3$)	38 - 40	30 - 32
8	Mg Hardness (mg/L as $CaCO_3$)	66 - 70	74 - 76
9	Chloride (mg/L as Cl)	16 - 18	14 - 15
10	Sulphate (mg/L as SO_4)	6 - 8	6 - 7
11	Nitrate (mg/L as NO_3)	3 - 5	4 - 5

Fig. 2 : Location of Barmer District, Rajasthan

Field Testing of the Unit: The Barmer District in Rajasthan State (Fig. 2), where people walk few kilometers to fetch drinking water was ravaged by excessive rains in the last week of August 2006. Over 750 mm of rains in a week converted many villages, in this otherwise sandy and water starved district, into natural lakes all over but with not a drop of potable water. NEERI had installed 100 units free of cost under its societal mission program in the flood affected remote areas of Barmer District in October 2006 in co-operation with Child Relief and You (CRY), India and Lok Kalyan Sanstha, the NGOs working in the area to convert the turbid and contaminated rainwater into potable water. The performance of these units under field conditions was evaluated. Samples of raw and treated

Table 4: Performance of NEERI-ZAR - Physico-chemical and Bacteriological Quality (Field Testing)

Sl. No.	Parameters	Raw water	Treated water
1	Turbidity (NTU)	15-25	0.9 -1.1
2	pH	7.3-7.5	7.6 - 7.7
3	Conductivity (μS/cm)	231- 240	228 -236
4	Total Dissolved Solids (mg/L)	139 -136	137- 140
5	Total Alkalinity (mg/L as $CaCO_3$)	56 -60	52- 54
6	Total Hardness (mg/L as $CaCO_3$)	68 -70	64 -68
7	Ca Hardness (mg/L as $CaCO_3$)	22 -24	21-23
8	Mg Hardness (mg/L as $CaCO_3$)	46 -50	43 - 47
9	Chloride (mg/L as Cl)	18 -22	20 -22
10	Sulphate (mg/L as SO_4)	23 -25	22 24
11	Nitrate (mg/L as NO_3)	4-6	4-6
12	Total Coliform (CFU/100 ml)	2900-10000	ND
13	E. Coli. (CFU/100 ml)	220 - 5400	ND

Table 5: Performance of NEERI-ZAR - Biological Quality (Field Testing)

	Zooplankton		Count per m^3	
Sl. No.	Species	Class	Raw water	Filtered water
1	Cyclops sp.	Crustacea	460 - 550	ND
2	Nauplius	Crustacea	25 - 120	ND
3	Daphnia sp.	Crustacea	40 - 500	ND
4	Branchionus sp.	Monogononta	44 - 60	ND
5	Keratella sp.	Monogononta	20 - 40	ND
6	Trichocera sp.	Monogononta	25 - 50	ND

ND - Not Detected

water were collected from the NEERI-ZAR installed in various villages and tested for physicochemical, biological and bacterial parameters. The results are presented in Tables 4 and 5.

RESULTS AND DISCUSSION

The laboratory testing results indicated that the unit produces filtered water with turbidity in the range of 1.1 to 2.8 NTU from the raw water with the turbidity in the range of 65 - 300 NTU. Total coliform and *E. coli* counts in the raw water were in the range of 6800 -78300 CFU/100ml and 100-7900 CFU/100 ml respectively. The respective counts in the filtered water were 80-800 CFU/100ml and ND-80 CFU/100ml indicating 93-99.% reduction in bacterial load. After disinfection by NaOCl/ Bleaching power solution, total coliforms and *E. coli* count was nil in the treated water samples. There was no significant change in dissolved minerals in raw and filtered water.

The field testing results indicate that the units produced filtered water with turbidity in the range 0.9 to 1.1 NTU from the raw water (flood water) with the turbidity in the range 15 and 25 NTU. Total coliforms and *E. coli* counts which were in the range 2900-10000 CFU/100ml and 220 - 5400 CFU/100ml respectively in flood water, were nil in the treated water samples. Major zooplankton observed in the raw water were *Cyclopes* and *Nauplius* under order copepod (class: crustacea), *Daphnia* in order cladocera (class: crustacea) and *Branchionus, Keretella* and *Trichocera,* which come under order ploimida (class: monogononta). The total count is in the range 600-800 per m^3. Filtered water does not show the presence of zooplankton. No change in other dissolved mineral concentrations is observed in raw and filtered waters.

Social Impacts of the Neeri-zar: Barmer District in Rajasthan State, where people walk few kilometers to fetch drinking water was ravaged by excessive rains in the last week of August 2006. Over 750 mm of rains in a week converted many villages, in this otherwise sandy and water starved district, into natural lakes all over but with not a drop of potable water due contaminated water sources and lost in approachability to the villages.

NEERI-ZAR units were installed in this flood affected areas at a critical time. People were surprised to see the crystal clear potable water produced by NEERI-ZAR from nearby available contaminated flood water at their door step. Villagers who were habituated to drink salty water with total dissolved solids (TDS) more than 2000 mg/l. liked the taste of 'Sweet' water produced from flood water with TDS less than 150 mg/l. Simple operation of the unit by villagers themselves without use of any power supply created the highly positive impacts on the people. They were very happy with the quality of water produced by NEERI-ZAR units. They expressed their gratitude for timely help provided by NEERI team for the supply of potable water at the time when all their water sources were either destroyed or contaminated due to flood; even tanker water supply was not available due to non approachability of the villages. Even after the restoration of tanker water supply to some villages, people from these villages treated the tanker water using NEERI-ZAR. This indicates the faith and satisfaction for this technology for potable water supply under emergency situation.

In West Bengal state every village has 2-3 ponds for growing of the fish. About 300 NEERI-ZAR units were installed in 2009 at villages in Sundarban district to treat the pond water for drinking purpose. People in these villages were very happy with the quality of treated water. People from the nearby villages were protesting for not providing them the NEERI-ZAR units. For development of NEERI-ZAR, NEERI team got the Nina Saxena Excellence in Technology Award 2008, a first of its kind India - Wide technical innovation award instituted by Indian Institute of Technology (IIT) for innovativeness, applicability, benefit to the nation and most importantly the potential of the application for social development with specific reference to backward areas in India.

CONCLUSION

The Laboratory and Field Performance of Neeri-zar indicates that the unit can provide onsite treatment to wide range of contamination in water sources and flood water with respect to organic matter, suspended solids and bacterial load to produce the potable water within few hours using the locally available material and without using electric power supply. It may reduce the expenditure on providing safe drinking water during emergency situation for which costly water treatment systems are utilized and sometimes military helicopter services are used when the villages are not approachable by surface transport. Due to availability of safe water supply within time during emergency situations, there can be considerable reduction in epidemic, morbidity and mortality rate due to water borne diseases thereby improvement in quality of life. NEERI-ZAR can also be used to provide water supply to isolated small villages or temporary camps where safe water supply sources are not available in vicinity.

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