Disinfection of Groundwater by Modified Shallow Water Hand Pump using Hydrodynamic Cavitating Technique

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ABSTRACT

The Waterborne diseases are major concern in rural areas due to lack of pathogens free water. Groundwater is main source of drinking water in rural areas of India, hand pumps are widely used medium to exploit groundwater. Existing water treatment technologies at household level are not feasible for low-income family. Direct consumption of pathogenically contaminated groundwater leads to various diseases such as Cholera, Diarrhoea, Typhoid etc. In Gorakhpur and nearby districts of Gorakhpur use of shallow water hand pumps are very common for groundwater exploitation. In this research work we modified the shallow water hand pump using hydrodynamic cavitating techniques to achieve disinfection. It is found that groundwater bacterial population varies frequently with seasons and locations, 500 to 700 CFU/ml is average bacterial count found in groundwater drawn from shallow water handpump in campus of Madan Mohan Malaviya University of Technology, Gorakhpur. Experiments were conducted on shallow water handpump installed in chemical engineering department building with cavitating device (orifice). Different configuration of orifice was used in study, maximum 70% disinfection were achieved by orifice with 95 holes of 1 mm diameter each.

Keywords: Water disinfection, Shallow water handpump, Hydrodynamic Cavitation

1 Introduction

Water disinfection is a major challenge in supplying potable water supply in rural areas specially for the developing countries where long extend of population still depends for hands for their daily needs of water consumption [1]– [4]. Microbial contamination in groundwater and surface water is potential thread for several diseases and responsible for numerous deaths across the globe. According to the report of World health organisation (WHO) diseases such diarrhoea, cholera, dysentery, typhoid, and polio are responsible for the more than half millions of deaths [5], [6]. Emerging waterborne bacterial and virus families for example Acanthamoeba, Adenoviruses, Aeromonas hydrophila, Caliciviruses, Cryptosporidium, Cyanobacteria, Helicobacter pylori, Microsporidia, Mycobacteria, Picobirnaviruses, etc. is also responsible for the several fatal diseases [3], [7], [8]. In Indian context microbial contamination and water borne diseases are more concerning, groundwater of many cities and rural areas due to several anthropogenic activities is causing potential thread to those whoever consuming it in absence of any water disinfection methods [2], [7], [9]– [12]. Water disinfection using hydrodynamic cavitation is extensively studied by researchers, applying cavitating techniques in real world problems to solve common man is very useful in developing and under developing countries where still heavy numbers of population dependent on the hand pump for their daily needs. This study utilises the hydrodynamic cavitational technique to achieve water disinfection of groundwater by applying simple modifications in shallow water hand pump [13]– [16]. By applying the concepts of simple hydrodynamic cavitation, we were able to achieve up to 70.00% reduction in bacteriologically contaminated groundwater. Cavitating device (Orifice) was installed in shallow water hand pump. We have chosen shallow water hand pump for this research purpose due to high numbers of such hand pumps can be easily found in Gorakhpur and nearby cities due to high groundwater water level and

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easy installation. Achieving significant degree of disinfection by hydrodynamic cavitation without use of any electricity or chemical oxidants have very large scope in rural and remote location areas.

2 Materials and Methodology

2.1 Shallow water Hand pump

Shallow water hand pump was procured from the local vendor, configuration of shallow water handpump is given below. Table 1 contains typical configuration of shallow water hand pump such as weight, material of construction, suction capacity etc.

Table 1: *Configuration of Shallow water hand pump*

Height Without Handle	=	57 cm
Height With Handle	=	77 cm
Weight	=	15.7 Kgs. Approx
Material Used	=	Cast Iron
Suction Capacity	=	20 to 30 Feet
Pipe Fitting Size (Base Flange)	=	1¼" Thread

2.2 Groundwater

Groundwater used for the disinfection purposes collected from the shallow water hand pump installed in the Madan Mohan Malaviya University of Technology (MMMUT), Gorakhpur Campus. Groundwater collection was done very carefully to avoid in external bacterial contamination, 200 Litre of groundwater was collected in tank and ported to tank of experimental setup installed in Department of Chemical Engineering MMMUT. Continuous monitoring of bacterial aspects reveals that groundwater was free from any fecal contamination, but total plate count was observed in between 500 to 700 CFU/ml. normal physiochemical characteristics of groundwater is given in Table 2.

Table 2: *Groundwater physio-chemical characteristics*

pH	7
TDS (mg/L)	264
Turbidity (NTU)	0
Conductivity(μS/cm)	527
Salinity(ppt)	0.26
Resistivity(kΩ)	1.87
DO	4-5mg/L
Fecal Contamination	NIL
TPC	600-700 CFU/ml

2.3 Chemicals

Plate Count Agar (PCA) and HiCromeTM Chromatic Coliform Agar (CCA M1991I) was purchased from Himedia for microbial enumeration. The colonies of different bacterial species such as Enterobacter (Pink

to red color colonies), E. coli (Blue color colonies), and other coliforms such as Salmonella (white color colonies) were identified using CCA agar.

2.4 Microbial Analysis

For microorganism colony count analysis, American Public Health Association Guidelines (APHA) practices were followed. The spread plate method was used for microbial enumeration. All glassware and accessories use for analysis were sterilized at 120 ℃ and 15 psi in an autoclave (Model: SSI-001A, Make: Swastik Scientific). Himedia HiCrome™ Chromogenic Coliform Agar (CCA M1991I) was used to enumerate Escherichia coli, Enterobacter, and other coliform based on chromogenic differences. All necessary preparation for analysis was performed in a Laminar flow cabinet (Model: SSI-HFL3, Make: Swastik Scientific), and the cabinet was disinfected using 70% alcohol before preparation. For different type of fecal contamination enumeration 30.92 g of CCA was dissolved in 1000 mL of distilled water, and prepare solution was boiled, followed by cooling to 40±5 ℃. Cooled agar mixture was spread on sterilized Petri dishes and allow to solidify. For Place count bacterial analysis, 23.5 grams of PCA was boiled to dissolved in 1000 ml purified/distilled water. Heat to boiling to dissolve the medium completely. Sterilize by autoclaving at 15 lbs pressure (121 °C) for 15 minutes. Cool to 45- 50 ^{0}C The prepared Petri-dishes was used for microbial enumeration. Withdrawn samples at a specific interval of time were spread over the prepared petri dish and incubate (Model: SSI-020, Make: Swastik Scientific) for 24 hrs at 37±3 ℃. CCA identified the bacterial colonies present in water base on color. A chromogenic substance present in CCA identifies bacterial colonies. e. g. Enterobacter aerogenes grow in pink to the red color colony, E. Coli. the colony grows in dark blue; colony of salmonella grows in shiny white color. The bacterial colony grown in the petri dish was counted using automatic colony counter (Make: Interscience, Model: Scan 300). The decrease in bacterial colony count was analyzed to understand the microbial disinfection performance.

3 Theory and Calculation Experimental Set up

3.1 Hand Pump Setup

Hand pumps are widely used device for extraction of groundwater in rural areas [17]. Shallow water hand pump was installed on the roof of Department with 25 Feet head length. Schematic diagram of experimental setup is shown in Figure 2. Water tank was filled with bacterially contaminated groundwater. Cavitating device (Orifice) was installed in below the hand pump using flange type assembly. Flange assembly was fitted with rubber gasket to avoid leakage problem.

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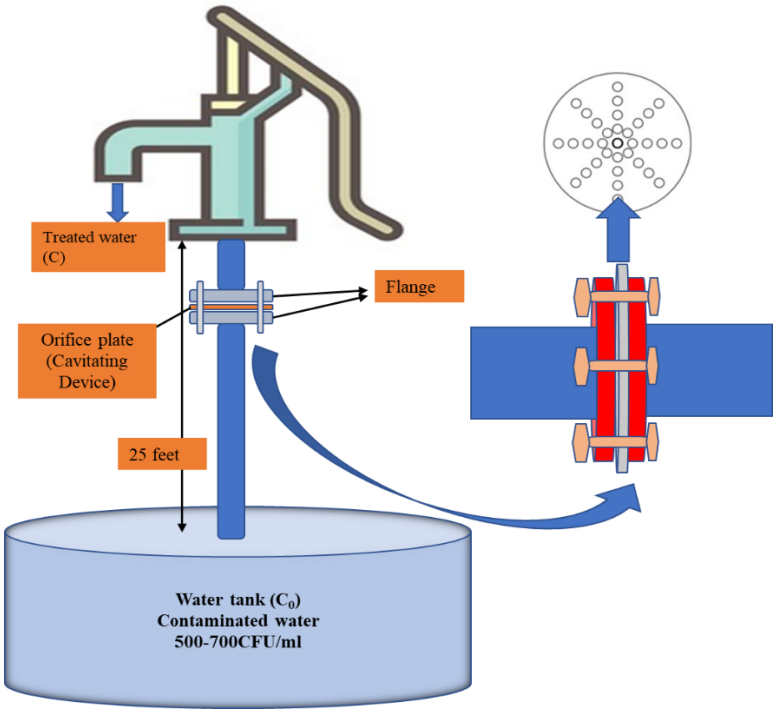

Figure 2: *Experimental Setup of Shallow Water Hand Pump*

3.2 Orifice

Orifice is well known and very suitable hydrodynamic cavitating device widely used in field of water disinfection and treatment [18]– [20]. Multiple hole orifice has certain advantage over the single hole orifice, in this research we have used multiple hole orifice of smaller diameter to achieve significant degree of disinfection. Details of various orifice and its configuration is given in table 3. Orifice plate was made by using 1 mm thick Galvanised iron sheet, holes was made by Die Punching Machine as shown in Figure 3.

Table 3: *Configurations of Orifice Plates*

Sr. No.	Number of Opening	Diameter of Opening (mm)	Flow Area (mm^2)
1	4	3	28.274
2	7	3	49.455
3	9	3	63.616
4	45	1	33.77
5	85	1	66.75
6	95	1	74.61

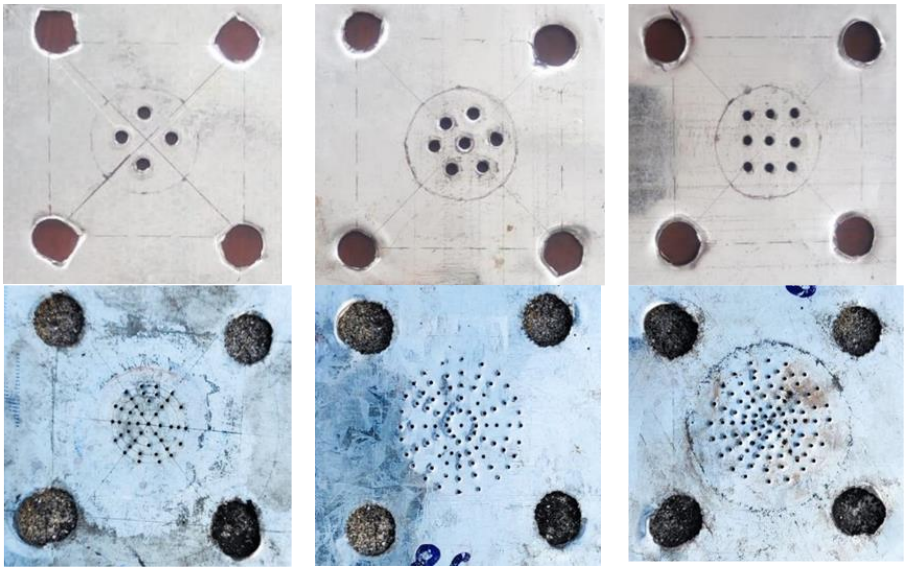

Figure 3: *Orifice of Different Openings, 4, 7, 9, 45, 85 and 95 openings respectively*

4 Results and Discussion

Current study was aimed to achieve significant amount of bacterial reduction using simple assembly of flange with easy installation of different orifice plates. Hand pump was first operated thoroughly 40 to 50 strokes without any orifice plate, it was observed not impact on bacterial colony was reduced when hand pump was operated in standard condition. Experiments was repeatedly performed several times to ensure that standard hand pump set up is not able to reduce bacterial population to any extends. Operation of shallow water hand pump in standard condition discharge around 13.5 L of water in 30 strokes. A common healthy person generally operates 30 to 40 strokes of hand pump in a minute, keeping this in mind we analyzed discharged obtained in 30 strokes. Decreasing the flow areas reduces the as total opening flow area reduces. Flow reduces to below 7.0 L when Orifice -45 was used which has 33.77 mm^2 area, 10.0 discharge was obtained using Orifice-95, which have flow area 74.61. significant disinfection of contaminated groundwater was obtained by using Orifice 45 to Orifice -95. Orifice 4 to Orifice -9 was not able to perform any disinfection.

Hand pump was cleaned and washed properly using Distilled water before using it for any particular experiments, to avoid any previous contamination. sample for each experiment was taken after at least 50 to 80 strokes of operation.

Table 4 showing results obtained for the different configuration, maximum disinfection was achieved by Orifice -95 which is up to 70%. Standard to Orifice 4-9 was not able to perform any microbial reduction. Other orifice such as Orifice-45, Orifice-65 and Orifice-85 able to disinfect groundwater 30, 32 and 40% microbial disinfection respectively.

Table 4: *Bacterial Reduction achieved by different orifice configuration*

Orifice	No. of Opening	Opening Dia.(mm)	Discharge (Litre) after 30 Strokes (approx..)	Flow Area(mm^2)	% Disinfection
Standard	1	22.2	13.5	386.87	0
Orifice-45	45	1	7.0	33.77	30
Orifice-65	65	1	7.5	51.05	32
Orifice-85	85	1	9.0	66.75	40
Orifice-95	95	1	10.0	74.61	70

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Bacterial degradation can be seen on colony formed on petri dishes, Figure 4 representing colony of bacteria of water tank and after passing it with orifice-95 installed in shallow water hand pump. Hydrodynamic cavitation is potential technique to achieve disinfection using different cavitating device. Further extensive research needed to improve the disinfection up to >99.0% to achieve bacterial free groundwater.

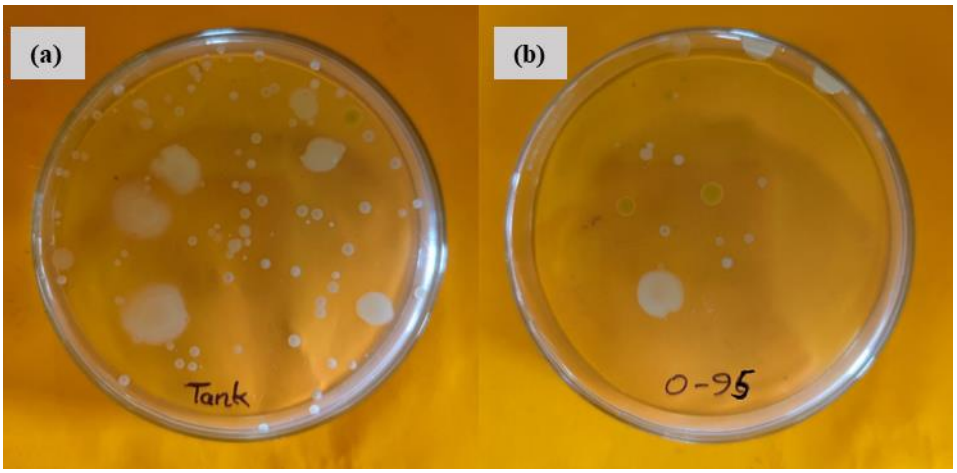

Figure 4: *Microbial Reduction using Orifice with 95 openings (1 mm dia. of each opening)*

5 Conclusions

Countering the water borne diseases in rural areas with low-income countries is major challenges for technology, in this research we tried to provide potential solution for disinfection without use of any external electricity or chemical disinfectants. Orifice with multiple openings and smaller diameter (Orifice 95) found to be suitable for enhancing the disinfection of groundwater. Shallow water hand, which is highly suitable for the high groundwater level areas can be modified to achieve disinfection by orifice of multiple small openings. Further study needed for the enhance the disinfection up to 99.00%. Applying cavitation device directly at hand pump suction section or outlet section will make it easily replaceable. No maintenance requires for such extra arrangement of cavitating device.

6 Publisher's Note

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