

Feasibility Study of Combined Softening and Disinfection of Water by Hydrodynamic Cavitation

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ABSTRACT: Water is life and without which survival of living organisms is difficult. Water quality affects human health rigorously. Excess presence of Ca^{++} and Mg^{++} in ground water, industrial contaminations and their intrusion is the major reasons for which ground water become hard. Majority of villages in vicinity of landfill sites are victims of extreme hard ground water. It has been observed that for most of the times water is strongest medium for epidemic diseases. For the purpose reducing E – Coli content, low cost & effective treatment is necessary. Conventional water softening & disinfection mechanisms involve costly chemical treatments, complex mechanisms, and requirement of power as well space. Present work is focusing on the approach of hydrodynamic cavitation for ground water softening and disinfection purpose. Here parametric study based on pH, hardness, alkalinity, TDS and MPN has been carried out and the performance of softening and disinfection by versatile approach of hydrodynamic cavitation has been analysed on basis of pressure, orifice diameter, and flow velocity, discharge, pump capacity.

KEYWORDS: hydrodynamic cavitation, water softening, disinfection, parametric analysis, orifice, MPN.

I. INTRODUCTION

“Smart city” is a new initiative launched by the World Bank to make cities from developing countries ecologically and economically sustainable. Water supply and water treatment are one of the important domains being considered in smart city developments as these concerns with human health. As per consideration of low cost housing societies, provision of conventional treatment approach is not feasible. There is a need of efficient and economical hybrid treatment approach. Hydrodynamic cavitation can be best possible solution over conventional treatment approach and which can easily implemented in Smart City mission. Being a plug and play device these modular plants also identified as a problem for in situ maintenance as usually preferred for relocation [1]. Due to low maintenance, operational ease and optimum efficiency Hydrodynamic Cavitation (HC) can be recommended for water treatment. Hydrodynamic Cavitation is formation, growth and subsequent collapse of micro bubbles or cavities within specific interval of time, which releases large magnitudes of energy [2]. The appearance of vapour voids inside the homogeneous medium in liquid form is termed as cavitation and can be defined as the breakdown of a liquid medium under very low pressures [3]. Conventionally water softening mechanism involves filtration at micro-level, ultra-level or nano-level, it needs high end technical support, power and periodic maintenance which ultimately results the financial burden on residents. So it is necessary to develop cost effective treatment approach. Excessive hard water with presence of pathogenic bacteria severely affects human health. For the purpose provided water should follow proper water standards. Permissible limits should be maintained by implementing appropriate treatment methodologies such as softening and disinfection. Water softening is the removal of calcium, magnesium, or certain other ions in hard water. The resulting of soft water requires less soap for the same cleaning effort. As soap is not wasted bonding with calcium ions. Soft water also extends the lifetime of plumbing or reducing by eliminating scale built-up pipes and fittings. Conventionally water softening is achieved using lime softening or ion exchange resin but it increasingly being accomplished using Nano filtration or reverse osmosis membrane. Disinfection is the process designed to kill or inactivate most micro-organisms in wastewater, including essentially all pathogenic organisms. Contrast this to sterilization, which is the removal and destruction of all living micro-organisms, including pathogenic and saprophytic bacteria, vegetative forms and spores. Conventionally ultra filtration and nano filtration methods etc. are used for disinfection purpose. Present study is the result of literature review of significance and performance of HC in water treatment for softening and

disinfection purpose. As per research, erosion effect caused by cavitation in presence of Ca^{++} ions is observed. [4]. According to research, single ozonation process which uses phenomenon of hydrodynamic cavitation, decomposes into free radicals particularly OH radicals [5]. As per author softening approach studied by using cavitation phenomena that accompanied by generation of local high temperature, pressure and reactive radical species (OH, HO_2) via thermal dissociation of water and oxygen [6]. As per the author hydrodynamic cavitation commonly use in variety of applications such as softening [7]. The research focuses on hydrodynamic cavitation, which leads to stratification and activation of water destroying cluster structures and saturating it with nano particles. This phenomenon is used for softening purpose [8]. The article specifies that depending on scale surface hardness and microstructure, as well as the substrate surface roughness, different cavitation erosion mechanism may evolve [9]. As per research study, the magnitude of collapse pressure and temperature as well as the number of free radicals generated at the end of cavitation event are strongly dependant on operating parameters [10]. Combined effect of pressure and cavitation number on disinfection is studied in the research study [11]. The study signifies that rate of degradation of E – coli bacteria is up to 75% after adopting treatment methodology of hydrodynamic cavitation [12]. Cavitation number as treatment variable directly proportional to collapse pressure of each cavity specified by the research [13]. Advance oxidation process provided with cavitation method reduces toxins and disinfects water clarified by the study [14]. As per research, pressure applied during treatment is mainly responsible for reducing number of E – coli bacteria [15].

II. MATERIAL AND METHODOLOGY

Present study needs to fabricate a set up of plumbing frame with one or multiple cavitation devices as per requirement of project frame work with proper plumbing fixtures. After few site visits and case studies to industrial cavitation set ups, plumbing requirement, water flow and plumbing frame is designed for the study. As per location requirement compactly fabricated set up is installed for efficient water treatment with orifice meter as cavitation device. A sampling port is provided in set up to collect effluent sample after treatment. While caring out treatment by using hydrodynamic cavitation, numbers of cycles were designed and within each cycle number of trials are carried out with varying treatment variables. The fabricated set up is provided with plumbing material an its fixtures such as PVC and acrylic pipe of 1.15 inches, orifice meter, valves, pressure gauge etc. The set up is constructed over 15 liters of water tank with submersible pump of $\frac{1}{2}$ Hp.



Figure 1 Laboratory Scale Experimental Set up

Present study focuses on hybrid approach of cavitation adopted for softening and disinfection of subsurface water. In the research work, analysis methodology adopted with grab sampling and composite sampling method with variation in pressure and orifice diameter for each respective cycle, prior the treatment, influent characteristics are analysed. The parametric analysis of pH, TDS, alkalinity, hardness and MPN is performed with laboratory characterisation. Then collected water sample is allowed to circulate through fabricated plumbing frame and through orifice meter where due to cavitation phenomenon water treatment takes place and effluent that is treated water is collected from discharge collection port then laboratory characterisation is performed with same analysis parameters for the effluent. This process is repeated in case of composite sampling method, only the change is for each cycle and its subsequent sub cycles effluent collected is mixed with specific amount to form a composite effluent and then characterisation of effluent is performed. The table below signifies details of trials for both methods with its nomenclature and description.



Table 1 Details of Trial

Sr. No.	Grab Sampling		Composite Sampling	
	Nomenclature	Description	Nomenclature	Description
1	T1	Pressure – 1 bar Diameter – 3 mm No. of opening - 1	T1	Pressure – 1 bar Diameter – 2 mm No. of opening - 2
2	T2	Pressure – 1.5 bar Diameter –1 mm No. of opening - 5	T2	Pressure – 1.5 bar Diameter – 2 mm No. of opening - 1
3	T3	Pressure – 2 bar Diameter – 3 mm No. of opening - 1	T3	Pressure – 1 bar Diameter – 2 mm No. of opening - 5
4	T4	Pressure – 1 bar Diameter –1.5 mm No. of opening - 4	T4	Pressure – 2 bar Diameter – 2 mm No. of opening - 3
5	T5	Pressure – 1.5 bar Diameter – 2 mm No. of opening - 4	T5	Pressure – 1.5 bar Diameter – 2 mm No. of opening - 4

III. RESULT AND DISCUSSION

Cavitation trial tables and results are discussed as below with respect to each cycle containing parametric analysis with each trial. The experimental results below are categorised in three types of treatment analysis with same treatment parameters and different treatment variables for each cycle.

(a) Type I : Grab Sampling Method

For orifice cycles, by grab sampling method treatment parameters used are pH, TDS, Alkalinity, Hardness and MPN analysed for each main and its sub cycles and from which below observations and results are obtained. Below tables indicates the number of observations taken with respect to five main trials and its average with its respective sub trials with pressure variation and change in orifice diameter. From the above mentioned trials five trials are selected and its results are plotted with graphs as well as interpreted as follows.

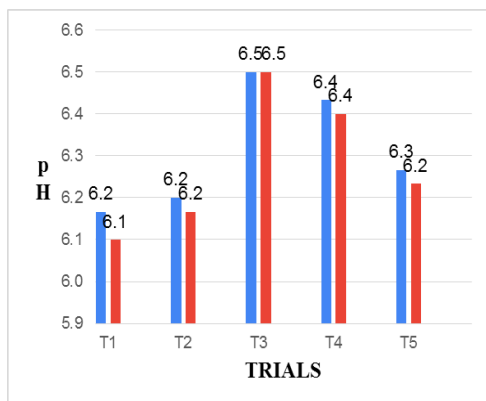


Figure 2 Experimental Results for pH

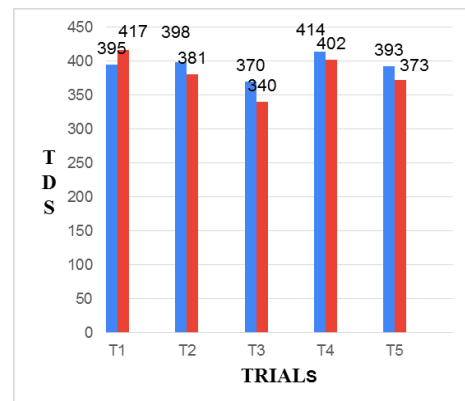


Figure 3 Experimental Results for TDS

The figure 2 indicates the graph of pH variation by grab sampling method. There are no such differential variations are observed for pH parameter during various cycles though change in treatment variables carried out. For all subsequent influent and effluent trials denotes approximately the same pressure range. For the first and last trial pH value observed



to be slight decreasing and for second, third and fourth trials its observed as almost same. Including this graph the next five graphs are obtained by results of the treatment keeping orifice diameter and pressure was kept varying during trials.

As per figure 3, 20% decrease in TDS is observed to all subsequent trials except the first trial. For all influent trials the except the fourth trial TDS is observed to be decreasing and in case of effluent trials, it is observed to be increasing for first trial and then its decrease is observed from second to last trial. Maximum drop down is noted for the third trial. For the fourth trial TDS is observed maximum in comparison with all other trials but reduction percentage in effluent trial is same as other trials.

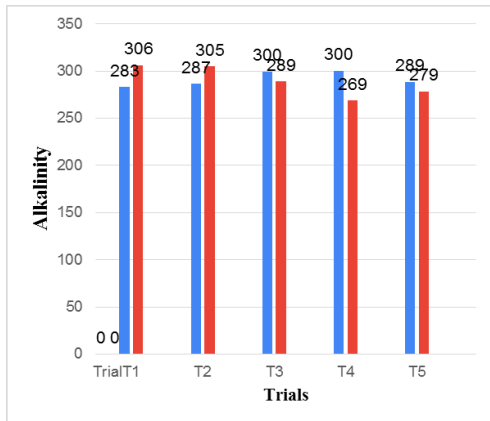


Figure 4 Experimental Results for Alkalinity

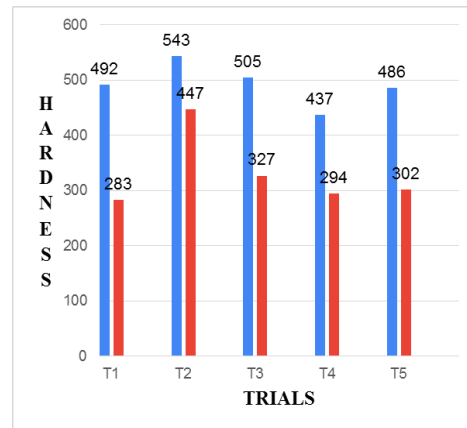


Figure 5 Experimental Results for Hardness

Effect on the treatment parameter alkalinity is represented by graph in figure 4. In case of influent trials all trials observed with near about same readings. For effluent trials, first two trials denotes increased values and from third trial till last trials effluent readings are near about same. For first two trials average 20% rise observed and for remaining trials rate of reduction of alkalinity is upto 30%. Maximum reduction is observed for fourth trial.

The figure 5 indicates the graph of hardness observations for five influent and effluent trials which consists of one main cycle and three sub cycles. Highlighted readings indicates main cycles. For plotting graph of Hardness for respective cycles its average is calculated and then graph is plotted. In case of influent trials, second trial denotes highest rise, first, third and fifth trials are near about same and fourth trial shows minimum value as compared to other trials. As per observations for effluent trials, first, fourth and fifth trials denotes approximately same percentage of hardness reduction. For second and third trials, minimum hardness removal is for second trial and for third trial removal percentage upto 35%. Average 50% of hardness removal is observed for all respective trial except the second trial. Second trial is not so feasible for finding effective combination of treatment variables and trials.

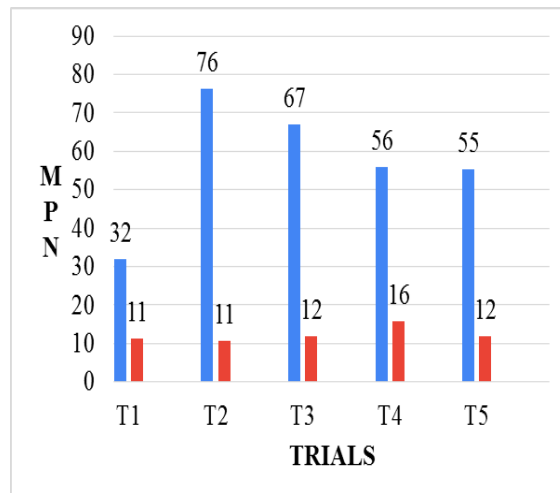


Figure 6 Experimental Results for MPN



As per the graphical representation shown in figure 6 disinfection achieved effectively by cavitation treatment. For influent trials, less MPN count for first trial and maximum MPN value for second trial, from trial third to fifth observed MPN values are approximately same. During effluent treatment maximum reduction in MPN is observed for first and second trials and for third and fifth trial it is same, fourth trial shows lesser MPN reduction as compared to other respective trials. Average 70% disinfection is carried out during the treatment.

(b) Type II : Composite Sampling Method

By grab sampling method, very lesser percentage of hardness and disinfection reduction is observed. So to achieve maximum reduction rate without recirculating water through plumbing range during cavitation composite sampling method is adopted and parametric analysis is performed. For orifice cycles by composite sampling method of treatment parameters used are pH, TDS, Alkalinity, Hardness and MPN analysed for each main and its sub cycles and from which below observations and results are obtained. Below tables indicate the number of observations taken with respect to five main trials and its average with its respective sub trials with pressure variation and change in orifice diameter. From the above mentioned trials five trials are selected and its results are plotted with graphs as well as interpreted as follows.

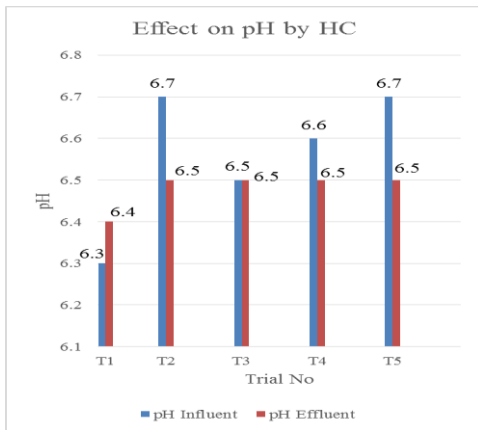


Figure 7 Experimental Results for pH

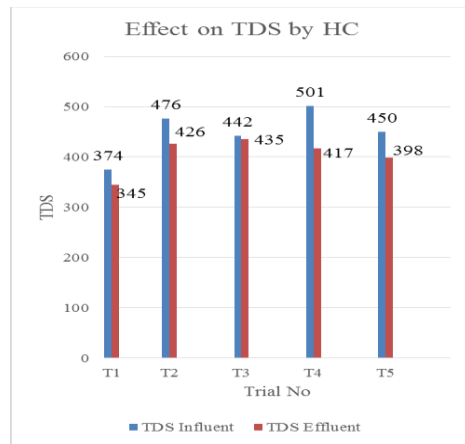


Figure 8 Experimental Results for TDS

Composite sampling method with change in pressure and orifice diameter is adopted for all treatment parameters. The figure 7 graph represents that for maximum trials, 20% reduction in pH is observed except the first trial during effluent treatment. In case of influent trial, pH for first trial is observed minimum and for second and fifth trial it is observed as maximum. For the third trial pH for both influent and effluent trial it is equal.

The figure 8 signifies that from trials second to fifth influent trial observations for TDS are approximately same and slightly lesser for the first trial. Same trend is observed for effluent trials also. Reduction percentage is approximately same for second to fifth trial and slightly lesser for first trial. The graph indicates that after adoption of composite method only 20% decrease in TDS is observed. No sudden decrease as in single sampling method is observed.

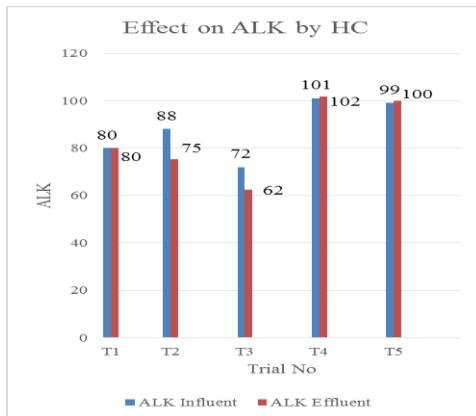


Figure 9 Experimental Results for Alkalinity

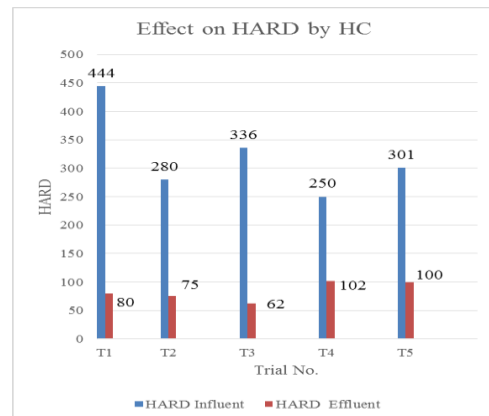


Figure 10 Experimental Results for Hardness

As per the figure 9, graph for influent trials is plotted. For first three trials alkalinity is approximately same for the next trials it is increased. In case of effluent treatment, for first, fourth and fifth cases alkalinity remains constant and for second and third trial it is observed as decreasing.

Composite sampling method is found to be effective for excess hardness. According to figure 10, for influent trial observations, maximum hardness is for first trial and for all remaining trials it is observed approximately same. In case of effluent treatment, the average reduction is 85% of hardness removal is observed by graph. Maximum hardness removal is observed for the first trial. All trials can be taken into consideration for finding effective trial combination w.r.t. treatment parameter.

For the purpose of disinfection, the composite sampling method is applied also and for most of the trials prior treatment MPN that is bacterial count is 12 and for effluent treatment is observed less than 2 for all respective trials. The value less than two does not specifies a particular value so graphical representation is not possible for this case but from observation it is stated that after application of composite method effective reduction of MPN count is observed and it is approximately upto 85%.

IV. CONCLUSION

Hydrodynamic Cavitation is an eco-friendly way and an upcoming hybrid approach over conventional water treatment which is found to be versatile for all engineering and economical aspects. Present study deals with potable ground water only. According to results obtained during study, effective hardness removal is observed and it is approximately up to 75 to 85% with application of composite method. In case of disinfection, reduction is observed in the bacterial count and it is up to 80 to 90%. Effective results are obtained by composite sampling method and by orifice meter as cavitation device. The study fulfils aim of efficient water treatment by using hydrodynamic cavitation as treatment methodology and with orifice, as cavitation device. Due to ease in applicability and cost effectiveness it can be applicable to small townships or residential areas where conventional treatment method can not be applied effectively.

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