Design of Cavitation Chamber for Non Chemical Water Treatment

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Abstract

The proposed research work is focused on designing a Cavitation Chamber and identifying, experimenting and concluding ways and means to enhance the cooling tower life by natural mechanical methods. Since water is becoming a scarce resource, reducing the quantity of water evaporation and wastage is also an important aspect to be investigated.

The scaling in the walls of the cooling tower is the sizeable and important problem to be addressed. The continuous evaporation of water leads to increase in the dissolved salts concentration which further leads to choking of the fins thereby reducing the performance of the cooling tower. This attracts frequent replacement of the filling material which is an expensive task .It is estimated that the cost of filling material is 30% of the total cost of cooling tower and thus the maintenance cost is considerable problem for the industry.

The Cavitation Chamber unit works primarily on the principles of Hydrodynamic Cavitation (HDC).

The HDC technology destroys microbial cell walls and converts dissolved calcium and magnesium into calcium carbonate ($CaCO_3$) & magnesium carbonate ($MgCO_3$), when cooling water is supplied through the cooling tower. The separation unit is used to remove the precipitated calcium carbonate and other suspended solids.

In view of addressing this challenge for the industrial needs, the cost effective method of cracking the dissolved salts by natural mechanical means is the only identifiable solution. The proposed research work is aimed at designing this cost effective water treating system by developing the CAVITATION CHAMBER.

Keywords: *Cavitation Chamber, Design of Nozzles, Non-Chemical water treatment, Air Compressor, tangential flow in the nozzle, VORTEX flow mechanism, Flow Velocity, Acrylic tube length, Nozzle diameter, Total Dissolved Solids (TDS), Hardness of water ($CaCo_3$),Axial Air Flow.*

1.0 Introduction

Overview of Cooling Tower Operation:

The cooling tower is used to remove heat from various sources such as machinery or heated process material, industrial system used cooled tower is to remove the heat absorbed in the circulating water used in power plants, petroleum refineries, petrochemical plants ,natural gas processing plants, food processing plants, semi-conductor plants, and other industrial facilities[1,2].

The utility function determines the configuration of various cooling towers.[3] .Buoyancy draft large cooling towers are used in large conventional power plants and nuclear power plants. [4,5]. The parameters such as WBT, Entropy, Water temperature are critical in elimination of drift and the fill area.[6-14].

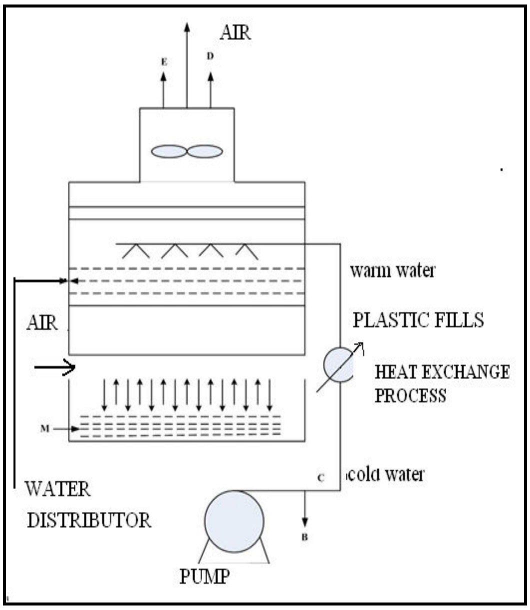

Fig: 1: Cooling Tower

1.1. Hydrodynamic Cavitation principle:

For enhancing precipitation formation, HDC appears to be most suitable for non chemical method of removing precipitates from the cooling tower water [1].

In fig no.2, the HDC technology system which includes namely two parts: A nozzle system and filtration tank are shown.

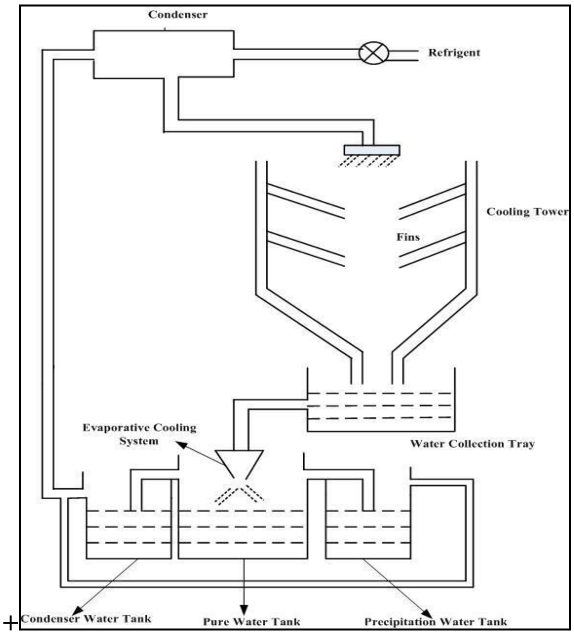

Fig: 2: Schematic Diagram Of a Modern Cooling Tower With HDC Mechanism

The filtration system is used to dig out the precipitated calcium carbonate and other suspended solids from the circulating cooling water.

The system works on the principle of Hydrodynamic Cavitation = (HDC). The hydrodynamic cavitation method is referred to "Evaluation of Non Chemical Treatment Technologies for Cooling Towers at Select California Facilities.et al. (February 2009)".

In turbulent liquids, and at high velocity, hydrodynamic cavitation will occur. Cavitation is the dynamic process in a fluid where micro-sized bubbles form, grow, and collapse [3]. When pressure decreases to a low values, cavities are formed in the liquid[4]. When pressure increases, the cavities cannot sustain the surrounding pressure, and consequently, collapse creating localized points of high pressure. As the bubble collapses, the pressure of the vapour within it increases which is familiar to very fast condensation.[15,16].

The bubble will eventually collapse to a minute fraction of its original size, at which point the gas within dissipates into the surrounding liquid via a rather violent mechanism, which releases a significant amount of energy in the form of an acoustic shock-wave and as visible light. At the point of total collapse, the pressure and temperature rise results in the chemical reaction settling in and will release co_2 and other dissolved gases from the solution. By this technology we can allow the formation of precipitation of calcium carbonate, and other micro organisms.

The Hydrodynamic cavitation has been successfully used for cell disruption [17,18] and it has been a most suitable method of non chemical water treatment by creating an enhanced precipitation formation which results in higher cavitation reactions.[19,24].

1.2. Mechanism OF tangential flow of HDC :

1. Water from the sump is pumped under pressure into the cavitation chamber, where it is forced to rotate at high velocity through nozzles.
2. The opposing water streams collide in the cavitation zone, causing millions of high energy, micro-sized cavitations bubbles to rapidly form and collapse. This stresses the` bacteria and forces calcium carbonate to form a precipitate in the water.
3. The treated water exiting the cavitation chamber is returned to sump where the precipitated calcium carbonate is removed by the filtration system.

1.3. Design Parameters of Nozzle :

The nozzle parameters are such designed to ensure maximum performance with minimum energy losses. [23].

Table:1: Nozzle dimensions

Cover plate Diameter	75mm
Nozzle inlet diameter	30mm
Length of nozzle	75mm
Nozzle exit diameters	16,14,12mm
Width of the cover plate	20mm
Water entry from Tangential hole of nozzle diameter	8mm
Air entry from cover plate nozzle	3mm

1.3 Design parameters of filtering tank & acrylic tube:

Table: 2: Tank & acrylic tube dimensions

Length	130cm
Width	130cm
Height	130cm
Acrylic tube length	200,300,400mm

Fig: 3 Vortex Mechanisms in Acrylic

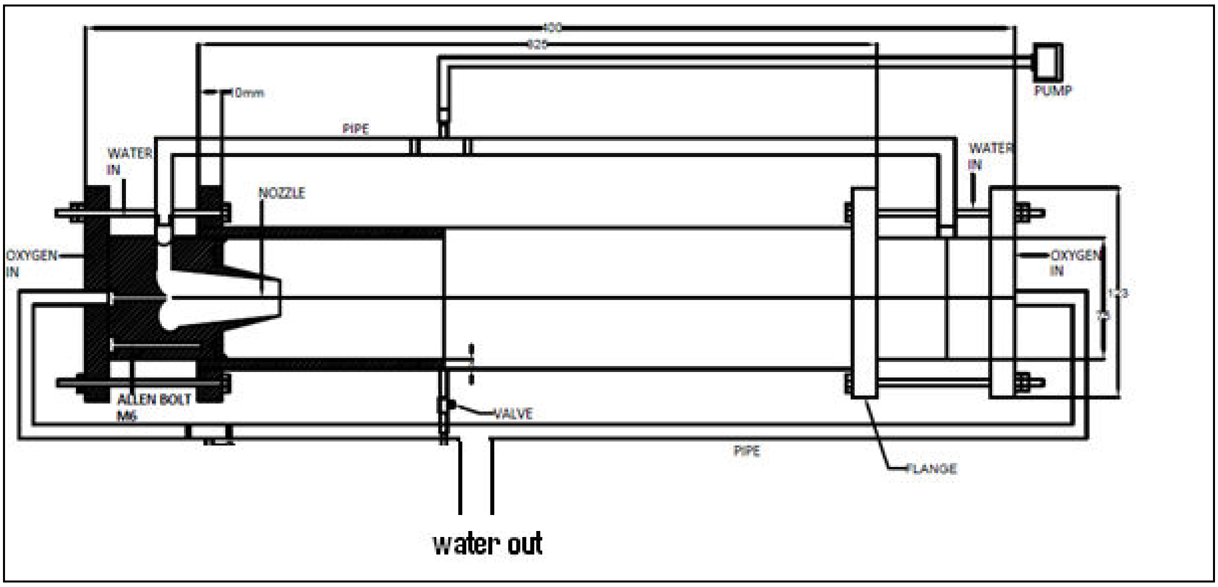

Fig: 4: layout of tangential flow Nozzle

2 Model of A Nozzle:

Initially in experimental work, a tangential opposite holes of a nozzle is designed Nozzle designs are shown in the fig.

Fig: 5: Nozzle With Top Plate

2. Assembly Of HDC With Filtration Tank

The equipment consist of two nozzles and these set up is immersed in a tank so that the water can be re-circulated in the tank.1HP motor is connected to circulate water from tank to nozzles, and all pipe fittings are made properly, A flow meters connected to the nozzles and fitted properly to the tank. An air compressor at a capacity of 8bar is attached to the nozzles , and the flow can be regulated through the a value.

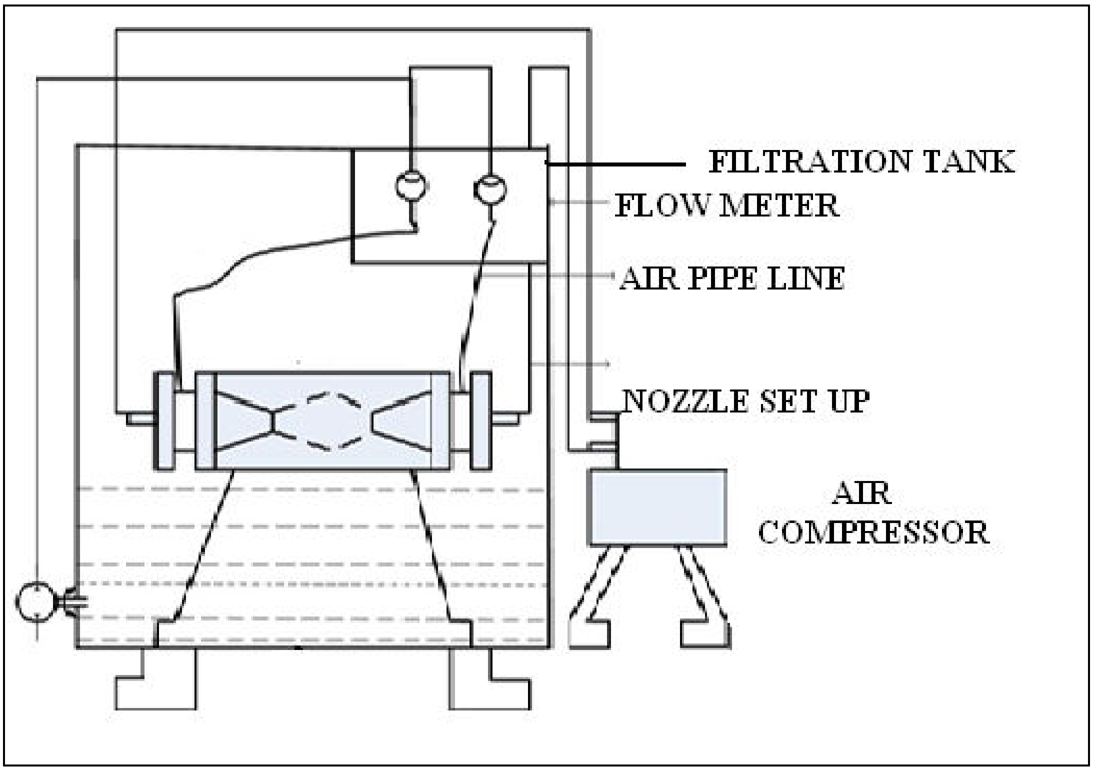

Fig: 6: Assembly Of HDF With Filtration Tank

3. Experiments

Ground water sample is collected, and water analysis has done as per IS: 10500:2012.so, the results obtained are

Table: 3: Ground water sample results

SI.NO.	Characteristic	Test method	Results	Acceptable Limit
1	Total Dissolved Solids, mg/l	IS:3025(pt-16)	946	< 500
2	Total Hardness as $caco_3$,mg/l	IS:3025(pt-21)	528	< 200
3	Calcium as ca ,mg/l	IS:3025(pt-40)	121.6	< 75
4	Magnesium as Mg ,mg/l	IS:3025(pt-46)	53.8	< 30
5	pH value	IS:3025(pt-11)	7.10	6.50-8.50

3.1 Experiment

3.1.1.Experiment of Water at Pressure 1, 3, 5&7 bar (sample water collected after 20 min)

At Air Pressure 1,3,5&7 Bar ,acrylic tube of 200,300,400 mm ,water Circulating through a nozzle of 10 ,12,14,16 mm diameter and different Flow rates of nozzle.
Now collect water sample after 20 Minutes (settling time), TDS results obtained for water analysis as mentioned in a graph below.

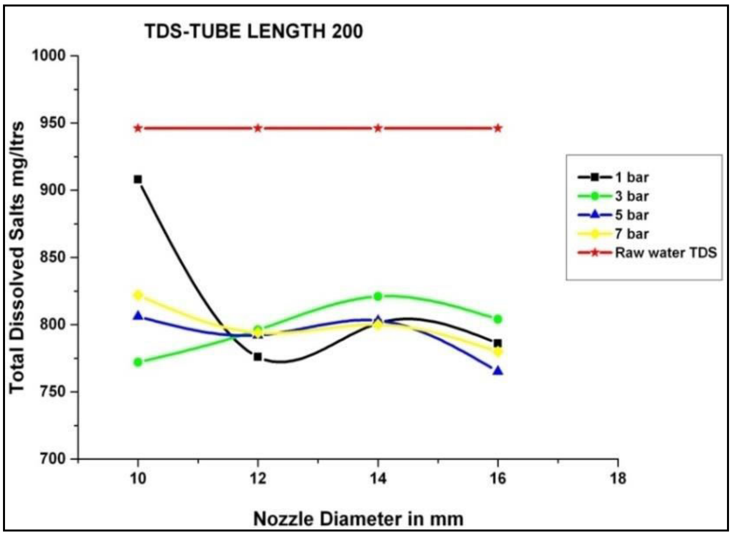

Fig: 7: TDS values obtained by variation of nozzle diameter at different pressures values of acrylic tube 200mm

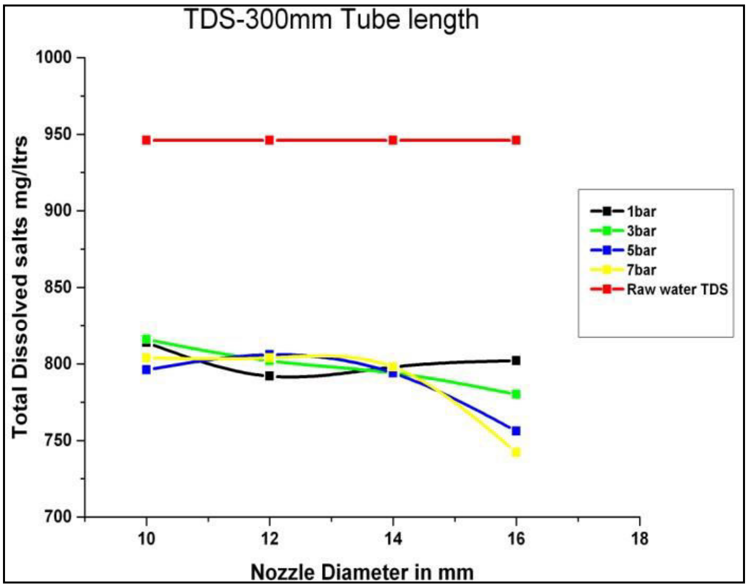

Fig: 8: TDS obtained by variation of nozzle diameter at different pressure values of acrylic tube 300mm

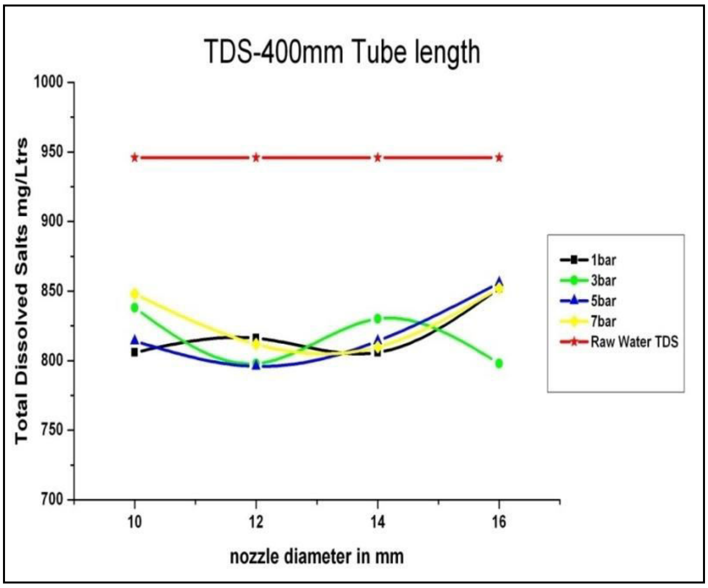

Fig:9: TDS obtained by variation of nozzle diameter at different pressures values of acrylic tube 400mm

3.1.2. Experiment of Water at Pressure 1, 3, 5&7 bar (sample water collected after 20 min)

At Air Pressure 1, 3, 5&7 Bar, acrylic tube of 200, 300, 400 mm, water Circulating through a nozzle of 10, 12, 14, 16 mm diameter and different Flow rates of nozzle.
Now collect water sample after 20 minutes (settling time), Hardness results obtained for water analysis as mentioned in a graph below.

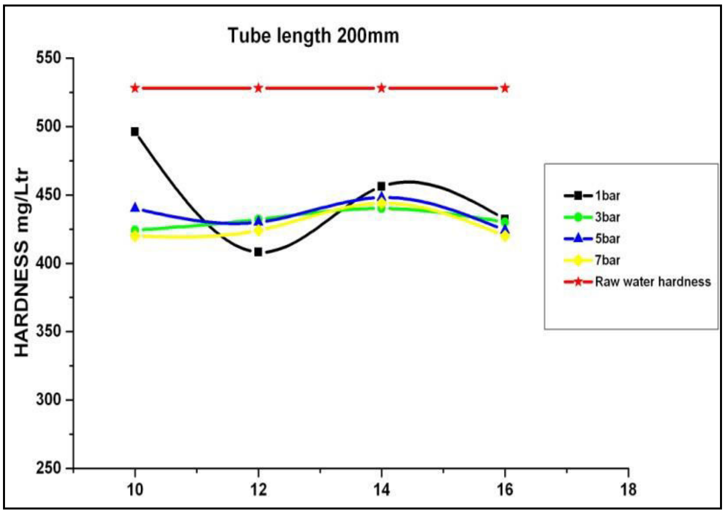

Fig: 10: Hardness obtained by variation of nozzle diameter at different pressures values of acrylic tube 200mm

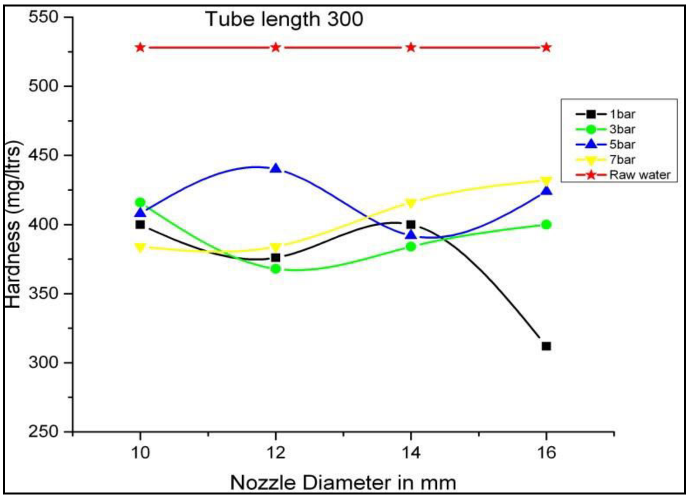

Fig: 11: Hardness obtained by variation of nozzle diameter at different pressures values of acrylic tube 300mm

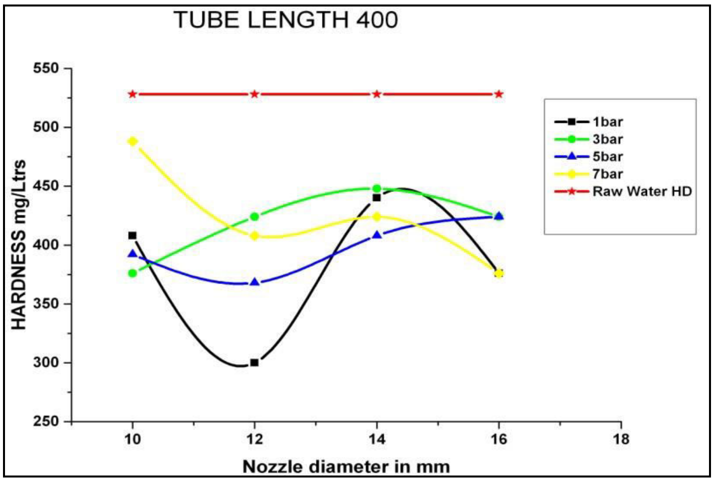

Fig: 12: Hardness obtained by variation of nozzle diameter at different pressures values of acrylic tube 400mmb

3.1.2. Experiment of Water at Pressure 1, 3, 5&7 bar (sample water collected after 20 min)

At Air Pressure 1, 3, 5&7 Bar, acrylic tube of 200,300,400 mm, water Circulating through a nozzle of 10, 12, 14, 16 mm diameter and different Flow rates of nozzle.
Now collect water sample after 20 Minutes (settling time), pH values results obtained for water analysis as mentioned in a graph below.

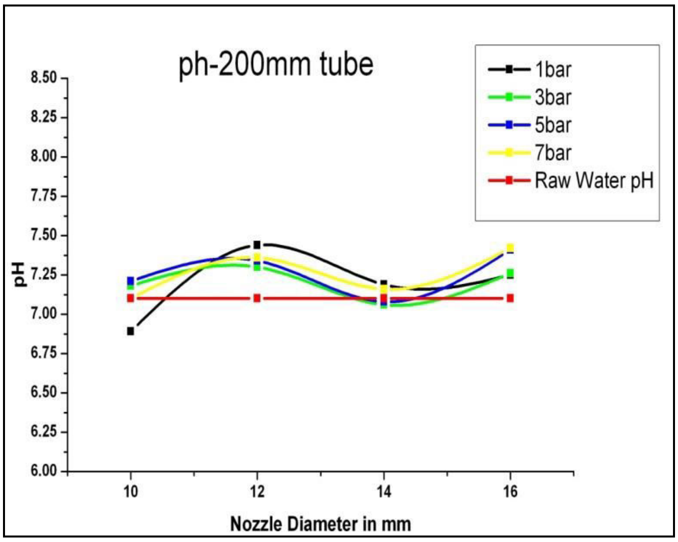

Fig: 13: pH values obtained by variation of nozzle diameter at different pressures values of acrylic tube 200mm

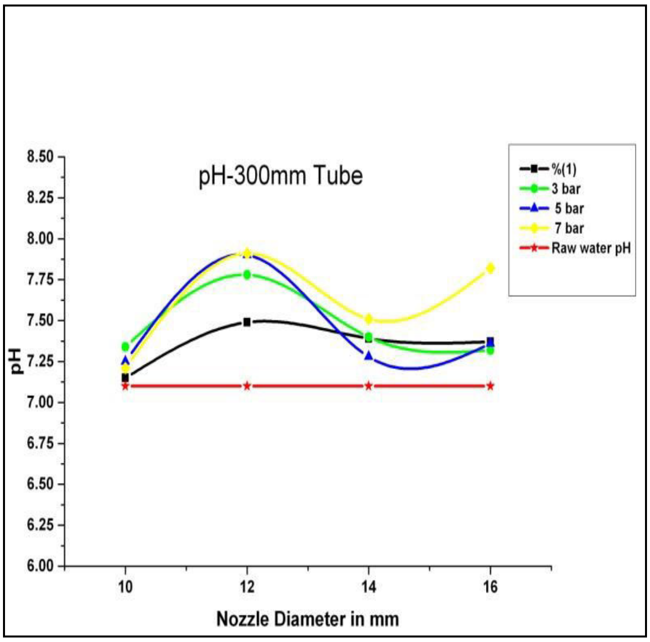

Fig: 14: pH values obtained by variation of nozzle diameter at different pressures values of acrylic tube 300mm

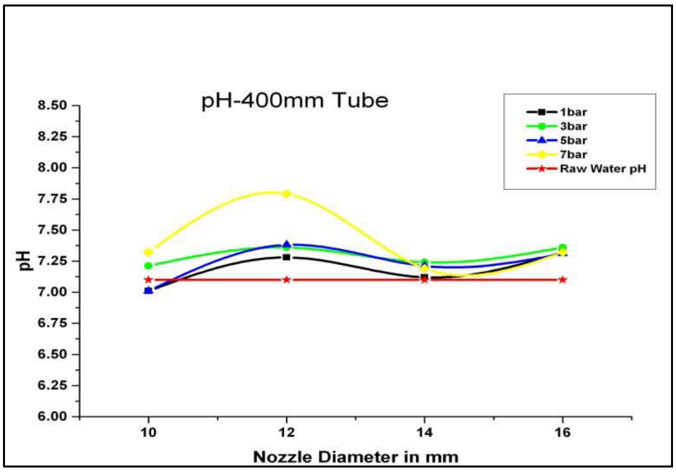

Fig: 15: pH values obtained by variation of nozzle diameter at different pressures values of acrylic tube 400mm

Results and Discussion

- From fig 7for a Cavitation Chamber tube length of 200 mm, it is observed that the total dissolved salts of treated water are reducing when compared to the untreated water.
- From fig 8, for a Cavitation Chamber length of 200mm, it is observed that the total dissolved salts of treated water are reducing when compared with the untreated water.
- From fig 9, for a Cavitation Chamber length of 300mm,it is observed that the total dissolved salts are reduced when compared to untreated water. It also reveals that nozzle at 16 mm diameter; total dissolved salts reduce with increasing air pressure.
- From fig 10, Cavitation Chamber length of 400 mm ,it is observed that at nozzle at 14mm diameter, the total dissolved salts increasing with air pressure at 1,3,5,7 and bar.
- From fig 11, Cavitation Chamber length of 200mm, it is observed that the hardness of Treated water is reducing when compared to the untreated water. It is also studied that at 16mm nozzle diameter the hardness of water reduced with increasing the air pressure.
- From fig 12, Cavitation Chamber length of 300mm, it is observed that the hardness water for Treated water is reducing when compared with the untreated water.

From fig13,14,15, the measured pH value of raw water is 7.1 .By these studies it is observed that the pH values increases at nozzle Diameter 16mm. it is observed that the pH values increases

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