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"HYDRODYNAMIC CAVITATION": A Noble Approach For Waste Water Treatment.

Mayuri Parmar[1], Pratibha Gautam[2], Priyanka Misrty[3], Harshit Patel[4], Karan Solanki[5]

[1,2,3,4,5] *Department of Environmental science & technology*
Shroff SR Rotary Institute of Chemical Technology, Vataria - 393135, Bharuch.

Abstract: *Waste water treatment is practiced using a number of physical, physico-chemical and biological methods of treatment. Quality of waste water can be defined by the presence various biodegradable and non-biodegradable pollutants, out of which Chemical Oxygen Demand (COD) has been considered as one of the major pollutants in the industrial effluent. In order to achieve desired level of COD reduction, numbers of conventional processes are available but because of their low efficiency these processes are nowadays being replaced by advanced oxidation processes (AOPs). Different AOPs such as Fenton, electro-Fenton, and electro-oxidation etc. have been observed to give better results in terms of COD reduction but at the same time they are associated with other operational restrictions such as huge chemical requirement and excessive sludge generation.*

Hydrodynamic cavitation has emerged as promising technology for COD reduction as it does not require chemicals and sludge generation is also very less in this process. This process results in sudden drop and increase of pressure in a liquid, which creates cavities and bubbles followed by sudden and violent collapse. This process results in generation of shock waves leading to generation of hydroxyl free radical. This hydroxyl free radical causes the development of localized forces which have destructive effects on the solids in dispersions, emulsions and slurries affecting particle size and distribution resulting to reduction in COD.

Therefore, through this review paper an attempt will be made to combine hydrodynamic cavitation with one on the AOP so that on the one hand, overall efficiency of the COD removal can be improved and on the other hand, chemical requirement and sludge generation can be reduced.

Key words: *Hydrodynamic Cavitation, Advanced Oxidation Process (AOPs), COD removal.*

1. INTRODUCTION :

Chemical Oxygen Demand (COD) is one of the major pollutants in the industrial effluent. In order to achieve desired level of COD reduction, numbers of conventional processes are available such as physical, chemical, biological process. In case used of chemical process, chemical consumption and capital cost is high. Biological processes take more time and generate high sludge. Hydrodynamic cavitation has emerged as promising technology for COD reduction as it does not require chemicals and sludge generation is also very less in this process. If hydrodynamic cavitation process is use alone it gives less efficiency. In order to achieve desired level of COD reduction, number of conventional processes is available but because of their low efficiency these processes are nowadays being replaced by advanced oxidation processes (AOPs).

2. HYDRODYNAMIC CAVITATION:

This process results in sudden drop and increase of pressure in a liquid, which creates cavities and bubbles followed by sudden and violent collapse. This process results in generation of shock waves leading to generation of hydroxyl free radical. This hydroxyl free radical causes the development of localized forces which have destructive effects on the solids in dispersions, emulsions and slurries affecting particle size and distribution resulting to reduction in COD.

ADVANTAGES OF HYDRODYNAMIC CAVITATION:

- Less sludge generation
- Less chemical consumption
- Less time required
- Eco-friendly way to reduce the pollution load of wastewater.

DISADVANTAGES OF HYDRODYNAMIC CAVITATION:

- More energy required

FACTORS AFFECTING HYDRODYNAMIC CAVITATION:

- Inlet pressure.
- Diameter of the, constriction.
- Properties of the liquid.
- Percentage of free area for the flow. [1]

Hydrodynamic cavitation again divided in four parts.

2.1 TRAVELING CAVITATION: Travelling cavitation means it is composed of individual transient cavities or bubble that from in the liquid and move with the liquid. As they expand, shrink and then collapses. [18] This cavities appear at the low pressure points within the fluid, usually along the solid boundary or in a high turbulence region.

2.2 FIXED CAVITATION:

Fixed cavitation is the situation where the liquid. Flow separates from the boundary of an immersed body. And form a cavity fixed to the boundary. This fixed cavity sometime looks like highly turbulent boiling surface [18].the maximum cavity length depends on the pressure field.

2.3 VORTEX CAVITATION:

Vortex cavitation forms in thr high shear zones in side vortices. Since vortex cavitation often occurs on the blade tips of ships propellers, it is also called tip cavitation .Cavitation occurs in a vertical movement of liquid is known as vortex cavitation [18].

2.4 VIBRATORY CAVITATION:

In vibratory cavitation each individual fluid element does not passed through the cavitation zone only once. Since the fluid velocity is so low, a given element of liquid is exposed to many cycles of cavitation rather than only one. The blade of a rapidly rotating propeller any surface vibrating in the liquid with sufficient acceleration.[16]

2.4 MECHANISM OF HYDRDYNAMIC CAVITATION:

The process of hydrodynamic generation of cavitation bubbles is shown schematically in the figure. The cavitation process begins with a flowing stream of material. A high pressure, P_1 is generated in chamber 1 by a localized flow constriction at point 2. In this localized flow constriction, the velocity of the flow increases. This causes the hydrostatic pressure to drop to a pressure below the saturated vapour pressure of the liquid phase flow. This phenomenon creates the physical conditions necessary for the development of cavitation bubbles in the stream. A high velocity jet (point 3) is formed by the localized flow constriction that becomes saturated with cavitation bubbles at point 4. This cavitating jet penetrates into the second chamber 5, which is under a hydrostatic pressure of P_2.

This hydrostatic pressure initiates a violent collapse of the cavitation bubbles, which results in the energy accumulated by the bubbles during the growth process being transferred to the flowing material. It is important to note that the higher the velocity of the cavitating jet at point 3, the higher is the hydrostatic pressure P_2 in region 5. With respect to higher values of P_2, maintaining a low pressure in the cavitating jet is required for the development of cavitation bubbles, and this is only possible by increasing the velocity of this jet in the localized flow constriction at point 2 [2] .

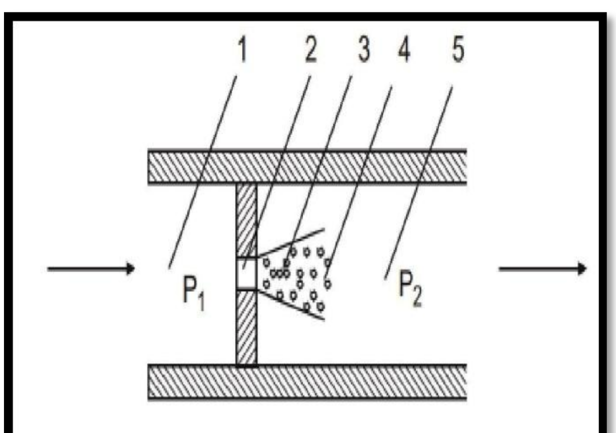


Fig.2- (Schematic illustrating the generation of cavitation in a fluid)

The idea of using the energy from collapsing cavitation bubbles to intensify material processing led to the creation of controlled flow cavitation devices. Hydrodynamic cavitation can be purposefully created in these devices through a variety of different designs and configurations.

The most effective designs are easy to use in the laboratory as well as industrial applications and are known as static hydrodynamic cavitation mixers or reactors. Cavitation devices each, containing a bluff body, a flow-through transit channel and a local constriction for the liquid flow. In order to control and specify the required structure of the cavitation bubble field, the bluff body may have various shapes. This results in the flow-through transit channel having various shapes which produce a local constriction of the flow around the baffle. The flow-through transit channel may also have a cross-section that has one linear section and a circular or irregularly shaped cross section, such as a semi-circle.

Fluids are fed into a hydrodynamic cavitation device with the aid of a pump. The type of pump selected is determined by the physicochemical properties of the fluid medium and the hydrodynamic parameters necessary to accomplish cavitation.

2.5 METHODOLOGY & DESIGN FOR THE CAVITATION PROCESS

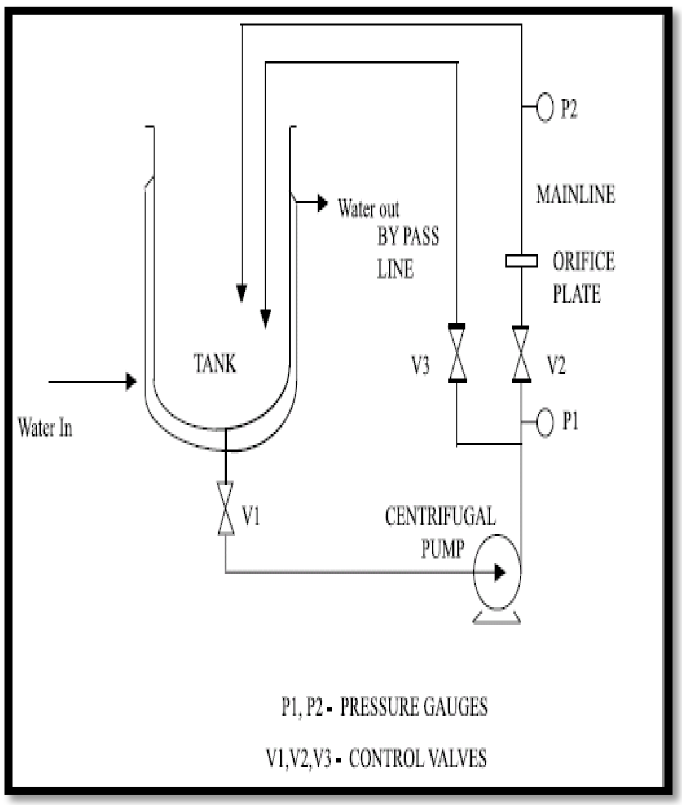


Fig.8 Design for the cavitation process

2.6 SPECIFICATION OF THE COMPONENTS

Wastewater tank – 64 lit.

500 mm height

Support arrangement to the tank – 300 mm length

Pump – 1800 lit/hr

5 kg/cm^2 g

Fluid pipeline- 25mm/40 mm

Tank jacket – 1.5 inch thick

Plug drains

MOC – SS 304 / SS 316

3. METHODOLOGY OF THE EXPERIMENTAL RUN

The above figure shows the pilot scale of our project's experiment. The pilot model contains the above mentioned components. The reaction will be exothermic hence jacket has been provided with the tank for heat transfer. The waste water is stored in the holding tank before the start up of the experiment. The other components of the system are centrifugal pump, valves, and flanges to accommodate the orifice plate, mainline and bypass line. The discharge from the pump branches into two lines; mainline and the bypass line. The mainline consist of flange which hosts the orifice plate and a hard glass tube is next to the flange for visual observation of the movement of the fluid. The bypass line is provided to control the liquid flow through the mainline. Valves are provided at appropriate places control the flow rate through the mainline. Also the tank is provided with the cooling jacket and with this the temperature of the medium was maintained within the temperature ranges of 35-40 ^oC.

In the present study, six orifice plates have been considered. All plates are made up of stainless steel 316. Incorporation of the different multiple holes orifice plates result in different intensities of cavitation and hence in different magnitude of pressures generated due to collapse of cavities. The magnitude of collapse pressure depends on the percentage flow area offered and also the perimeter of the holes present in the orifice plates.

During the experiment the valve V1 and V2 are kept fully open while the valve V3 was then partially throttled to keep the discharge pressure to fixed value. Samples were collected after every 1 hour of operation at same operating condition and the COD was determined.

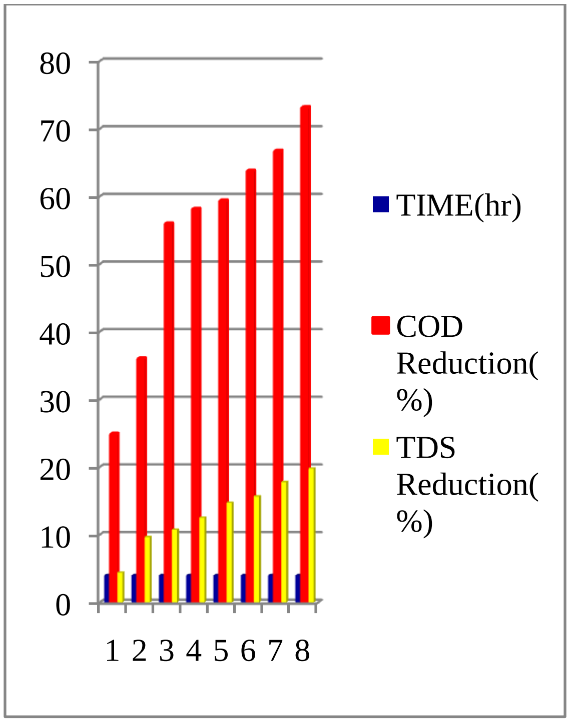
The tank contains a pressurized stirrer for addition of acid, base, ferrous sulphate catalyst solution and industrial strength 35-50% of H_2O_2. The tank should be coated with acid resistant material, as the Fenton reagent is very aggressive and corrosion can be a serious problem. The pH of the solution will be adjusted for maintaining the stability of the catalyst at pH value of 6, usually iron hydroxide is formed. For many chemicals, ideal pH for the Fenton reaction is between 3 and 4, and the optimum catalyst to peroxide ratio is usually 1:5 wt/wt.

Addition of reactants is done in following sequence:

1) Filling of wastewater tank.
2) Addition of dilute sulfuric acid or sodium hydroxide for maintaining the optimum pH for reaction.
3) Addition of Catalyst in acidic solutions, base or acid for adjustment of pH at a constant value and lastly.

Result

SR.NO	TIME(hr)	COD Reduction(%)	TDS Reduction(%)
1	4	24.8546	4.3657
2	4	36	9.6385
3	4	55.9366	10.7142
4	4	58.1081	12.5
5	4	59.3373	14.7023
6	4	63.7254	15.6417
7	4	66.6663	17.7531
8	4	73.125	19.7596



CONCLUSION

Hydrodynamic Cavitation is eco- friendly way to reduce the pollution load of waste water. Sludge generation is very less because of less chemical consumption. The visibility, flexibility in the design and on-line measuring devices of the new cavitation loop will be a step forward in the understanding of the Phenomenon of hydrodynamic cavitation. The extended experimental procedures And optimization of the technique with the new cavitation loop will determine the Real potential of this technique for its application as an AOP for wastewater Treatment, confirming or refuting the promising results that have been obtained
So far. [12]

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