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Hydrodynamic Cavitation, A promising Technique for Pre-Treatment of Common Effluent Treatment Plant (CETP) Influent Wastewater

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***Abstract:* In this work treatment of influent wastewater at Common Effluent Treatment Plant (CETP) has been investigated using Hydrodynamic Cavitation (HC) using single hole orifice plate. Various methods like DAP (Di Ammonium phosphate), RO (Reverse Osmosis) has been widely investigated but HC arouses some promising outcomes hence is being investigated. The optimization of the treatment process by investigating the effect of parameters viz inlet pressure and residence time has been done by analyzing Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD). The effect of inlet pressure on cavitational yield has also been investigated. Further under optimized conditions of 5 kg/cm2 inlet pressure, reduction of COD and BOD has been analyzed. Under optimized condition COD reduces from 832 to 457 mg/L and BOD from 330 mg/L to 118 mg/L. This work is a rare report on treatment of CETP wastewater using HC.**

***Index Terms:* Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Common Effluent Treatment Plant(CETP), Hydrodynamic cavitation, wastewater**

I. INTRODUCTION

Today one of the utmost concern of the modern society has been drawn by the complex nature of waste products and its proper disposal requirement. The experiences from some of the epidemic incidents especially from human health point of view led to necessity of treatment of waste. However the advancement in technology for treatment of waste did not kept its pace similar to that of waste producing industries which continuously evolved the complex nature of waste requiring more efficient treatment technology [1]. In India, the small and medium enterprises (SME's) contribute significantly to the economy. Consequently they generate about 50% of the total polluted waste coming from industries. The water act 1974 (amended in 1988) made mandatory to comply with disposal norms set by Central Pollution Control Board (CPCB) or State Pollution Control Board (SPCB). But operating individual effluent treatment plant is out of reach of each SME's owing to the fact that they lack financially, technically, land unavailability or other constraint. Hence to treat the waste from cluster of small and medium scale industries, the concept of Common effluent Treatment Plant (CETP) emerged and is being promoted actively by public authorities. [2]

Various methods such as physicochemical, advanced oxidation, biological process, and often a combination of these processes are applied for the treatment of the wastewater to meet disposal norms. The chemical methods are able to reduce the toxicity of wastewater, but simultaneously, they produces large amount of sludge, disposal of which is again a problem. Moreover, these are costly and energy consuming processes. The problem with widely operated and economical biological treatment processes is that they are not able to completely degrade the dye effluent because of the complex and refractory nature of the dye molecules. The other methods available such as coagulation/flocculation and adsorption merely transfers waste components from one phase to another, thus producing secondary pollutant which requires further treatment. Therefore need for self-sufficient and ecofriendly physical process has gained vast attention in wastewater treatment.

1.1 Hydrodynamic Cavitation

Originally, Hydrodynamic Cavitation (HC) was seen as a possible alternative to ultrasonic cavitation (UC) in advanced oxidation processes (AOP). Useful properties of cavitation in liquid are widely studied regarding their application to chemistry, in particular, in environmental chemistry: in water purification from organic impurities. The highly reactive free radical producing potential of cavitation can be used to treat real wastewater. Infact Sivakumar and Pandit have used Ultrasonic cavitation successfully to treat various pollutants on laboratory scale [3]. However scale up of Ultrasonic cavitation for industrial application do not result in similar efficiency due to irregular distribution of cavitational activity on large scale and inefficient performance of transducer at higher power dissipation [3].

Anand G. et al has reported in his work that highly successful cavitational reactors (particularly sonochemical) in laboratory scale are difficult to result in similar success in industrial scale due to inefficient operation at levels of power dissipation and comparatively more cost of treatment [4]. Anand G. et al in his another work has reported that Hydrodynamic cavitation are energy efficient and easy to scale up compared to acoustics cavitation. He has shown that hydrodynamic cavitation are 60-65% energy efficient whereas sonochemical reactors are merely 10-20% energy efficient [3].The importance of this work increases with respect to the fact that there have been very few work on the application of hydrodynamic cavitation on real industrial wastewater. However many authors have suggested Hydrodynamic cavitation as a pretreatment technology [4].

Hydrodynamic cavitation occurs when a liquid is passed through constriction devices like orifice, venturi, throttling valve etc. The velocity of liquid increases at the expense of pressure, if the pressure of the liquid falls below its vapour pressure, large number of cavities filled with vapour-gas mixture are formed which expands and consequently bursts downstream of the constriction. Hence high turbulence is present downstream of the constriction. The bursting of cavities promotes the radical formation and its subsequent reactions. The pollutants in the reactor are now prone to OH radical attack and hence the degradation of wastewater takes place [5][6].

II MATERIALS AND METHODOLOGY

2.1 Materials

Influent wastewater at CETP (for secrecy name of CETP cannot be revealed). The wastewater in CETP is of complex nature being contributed by a number of different industries of varied nature with pH, COD, BOD. This work is important owing to the fact that majority of work done on hydrodynamic cavitation deals with a synthetic sample and hence may not reproduce similar results when dealt with real sample as real sample consist of different components which may act as scavenger for OH radicals.

2.2 Experimental setup

The experimental setup used for hydrodynamic cavitation basically consists of a feed tank of 20 L capacity, a multistage centrifugal pump of power rating 1.1 kW and 1.5 HP, control valves, a main line and a bypass line. The main line has flanges which houses the orifice plate, used as a cavitating device and the bypass line is used to control the flow through main line. The main line and bypass line should terminate deep inside the tank, atleast below the liquid level so that no air comes in contact with the sample being circulated. The temperature in the feed tank was Maintained constant using a cooling bath around the feed tank which results in a variation of ± 2O C temperature. The schematic representation of setup is shwon in fig. no. 1.

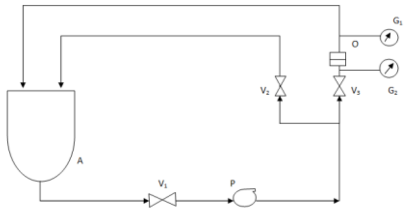

Fig. No. 1 - Schematic representation of hydrodynamic cavitation reactor set-up. A – Feed tank; G1, G2 – Pressure Gauge ; O – orifice plate ; P – multistage centrifugal pump ; V1 ,V2 ,V3 – Control valve

2.3 Methodology

The degradation using HC (Hydrodynamic cavitation) will be carried out using circular orifice plate as a cavitating device. The degradation of influent wastewater at CETP will be conducted using HC alone at different inlet pressure (3–7 kg/cm2) to the cavitating device to establish the optimum conditions (time and pressure) for getting maximum possible degradation using HC. Ten liters of influent wastewater at CETP will be subjected to hydrodynamic cavitation for a total circulation time of 180 min. The samples will be regularly withdrawn at a regular interval of 30 minutes and will be analyzed for the extent of reduction in COD and BOD. Further the cavitational yield for the treatment will be analyzed under the effect of different inlet pressure.

III RESULTS AND DISCUSSION

3.1 Effect of inlet pressure

It was observed that with increase in inlet pressure the reduction in COD and BOD increases upto a certain pressure after that increase in pressure results in decrease in

COD and BOD reduction (Graph shown below- Fig. No. 2). With increase in pressure the COD and BOD reduction increases because of increase in OH radical formation in the wastewater because of increase in bubble formation due to cavitation activity which bursts and disperses in the form on OH radical however after certain pressure, increase in pressure results in decrease in COD and BOD reduction because of a phenomenon called Super-cavitation. In super-cavitation just downstream of constricting device cloud formation takes place where the bubbles formed due to cavitation activity do not bursts but rather moves forward thus there is a decrease in OH radical formation leading to decrease in COD and BOD reduction. The certain pressure after which COD and BOD reduction decreases in called Optimum Pressure because at this pressure maximum reduction has been achieved, here in this case it is 5 kg/sq.cm.

3.2 Effect of residence time

It was observed that initially the reduction increases upto 60 minutes of treatment after which the reduction increases marginally upto 90 minutes which further becomes almost constant for any further residence duration. This observation could be attributed to the fact that every water or wastewater has a finite capacity to produce OH radical thus after certain duration when the wastewater reaches saturation in terms of producing OH radical the reduction becomes constant. This time after which reduction in COD increases marginally or becomes constant is called Optimum residence time, here in this case it is 60 minutes.
It should be noted that the optimum parameters (pressure and time) will change in everycase and cannot be generalized as it depends on the characteristics of sample to be treated, the cavitating device employed (orifice plate, venture, throttling device etc) and the geometrics of cavitating device (like for orifice plate, number of holes and the arrangement of holes).

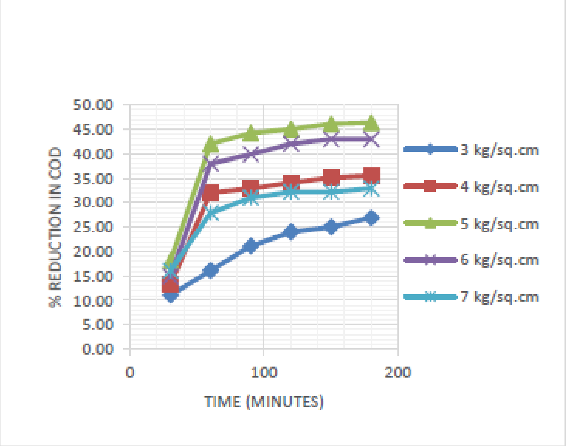

Fig. No. 2 : % COD reduction v/s Time for different inlet pressure.

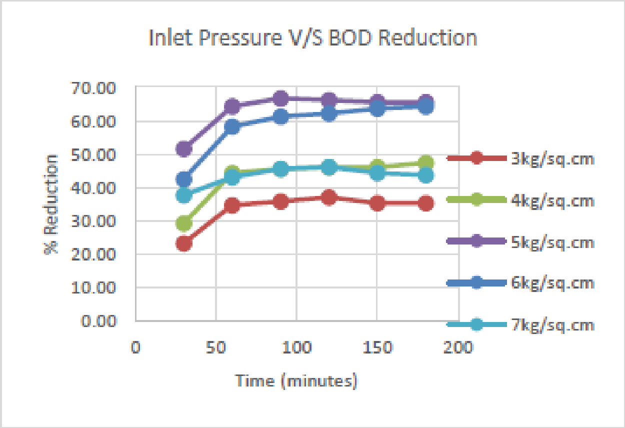

Fig.No. 3: % BOD reduction v/s Time for different inlet pressure

3.3 Effect of inlet pressure on cavitational yield

Cavitational yield can be defined as the ratio of degradation of wastewater to the energy supplied to the treatment process represented in gm/J units. Here the degradation of wastewater has been computed with respect to COD reduction during the treatment. In this HC system the main energy consuming device in the multistage centrifugal pump which is used to circulate the wastewater in the system. It was observed that pressure 5 kg/sq.cm gave the best cavitational yield, also cavitational yield during inlet pressure 5 kg/sq.cm is twice the cavitational yield during 3 kg/sq.cm.

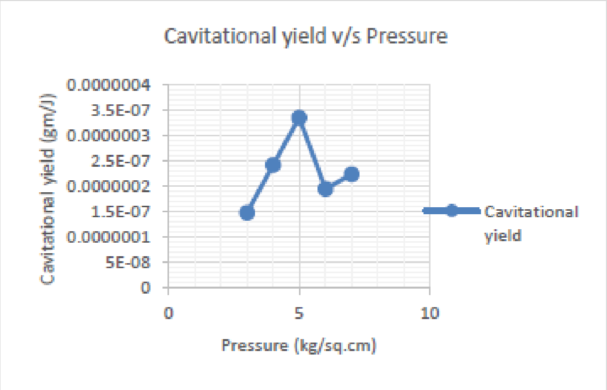

Fig. No. 4 – Cavitational Yield v/s Inlet Pressure

IV CONCLUSION

The study shows that there is about 45% reduction in initial 832mg/L COD and 60% reduction in initial 330mg/L BOD under optimum parameters. Also the cavitational yield for optimum condition is least, which aids to its economy. Thus HC represents a promising alternative with better results. However since optimum condition varies with every case, which needs to be worked out, also further investigation with respect to combination of HC with some other methods can be done in order to achieve enhanced results.

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