Recalcitrant Waste Water Treatment By Hydrodynamic Cavitation Process

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1. Introduction

Hydrodynamic cavitation describes the bubble generation, bubble implosion and process of vaporisation, which occurs in a flowing liquid as a result of a decrease and subsequent increase in pressure.

The process of bubble generation, and the subsequent growth and collapse of the cavitation bubbles, results in very high energy densities and in very high temperatures and pressures at the surface of the bubbles for a very short time.

The overall liquid medium environment, therefore, remains at ambient conditions. Controlled cavitation can be used to enhance chemical reactions or propagate certain unexpected reactions because free radicals (OHions) are generated in the process due to disassociation of vapors trapped in the cavitating bubbles.

This principle is used in the mineralization of bio-refractory compounds which otherwise would need extremely high temperature and pressure conditions since free radicals are generated in the process due to the dissociation of vapors trapped in the cavitating bubbles, which results in either the intensification of the chemical reaction or may even result in the propagation of certain reactions not possible under otherwise ambient conditions

In the last decade, hydrodynamic cavitation (HC) was increasingly used in the field of wastewater treatment. Due to its oxidative capability, HC was applied to treat aqueous effluents polluted by organic, toxic and bio-refractory contaminants, whereas its mechanical and chemical effects have allowed to disintegrate cells of microorganisms in biological applications. Due to their geometries, HC can be detected in some reactors, in which a variation of hydraulic parameters in the fluid such as flow pressure and flow velocity is induced. HC process involves the formation, growth, implosion and subsequent collapse of cavities, occurring in a very short period of time and releasing large magnitudes of power. In this Report, the vast literature on HC is critically reviewed, focusing on the basic principles behind it, in terms of process definition and analysis of governing mechanisms of both HC generation and pollutants degradation. The influence of various parameters on HC effectiveness was assessed, considering fluid properties, construction features of HC devices and technological aspects of processes. The synergetic effect of HC combined with chemicals or other techniques was discussed. An overview of the main devices used for HC generation and different existing methods to evaluate the cavitation effectiveness was provided. Knowledge build up and optimization for such complex systems from mathematical modelling was highlighted.

2. Need of the Study

In Gujarat, Vapi to Vatva popularly known as “The Golden Corridor” comprises of Industries manufacturing.

Pharma & Pharma Intermediates.

1) Dyes and Dye Intermediates.
2) Synthetic Organic Chemicals.
3) Pesticides etc.

80-90% of these industries are micro, small scale industries with 10-20% medium and large scale industries.
All these industries give good employment to Chemical, Mechanical, Electrical, Computer & Civil Engineers, Chemists, Environmental Chemists, skill and unskilled work force.
60-70% of the industries are exporting their products and generating good foreign exchange to the Central and State Govt.

However

All these industries are having waste water treatment issues which hampers the production. Industries are generating highly recalcitrant waste waters bearing high COD, high Ammonical Nitrogen, high phenolic compounds
Sometimes the treatment issues becomes a survival problem for the micro and small scale industries.
Many CETPs took over the Operations of Effluent Treatment to rectify the problems of Effluent treatment.
At the time of take over, the CETPs were a typical Sewage treatment Plant design

CETP where no concept of primary treatment was in built into the system.

Any type of shock loads, would kill the bacteria overnight and the next 2 months would be devoted to the development of the biomass with the primary treatment bypassing the aeration tank thereby not meeting the Outlet Norms

CETPs have tried all types of available technologies with inlet COD

Hydrogen peroxide treatment (Fenton's Reagent) – Outlet COD will not go below 800 ~ 1000 mg/L

Ozone Treatment – Outlet COD will not go below 800 ~ 1200 mg/L

MEE treatment – The condensate received had COD 800 ~1000 mg/L due to soluble Volatile organic compounds. The cost of treatment is > Rs. 2.5 ~ Rs. 7.5 per Litre

Spray drier – VOC matter goes out of the stack into the atmosphere. You are converting liquid effluent into solid effluent. The solid sludge which is nothing but salt laden with organic matter goes to the landfill and comes out as leachate during rainy season. The leachate generated from the landfill has a COD of 35,000 ~ 40,000 mg/L (concentrated wastewater) which has to treated.

Electro-oxidation – Industries ran the CETP successfully for 3 years with 26 electrodes running simultaneously. But the life of the electrode was only 4 ~ 6 months and each electrode cost was Rs. 24 Lacs. So treatment cost was very high for the small scale industries.

New Techniques are being added to Waste Water treatment Schemes for meeting the high standards of Environmental regulations. The present work highlights the use of one such Technique.

Cavitation for Waste Water treatment Applications, Cavitation Phenomena depending on the type of generation have been discussed and the optimum operating and geometric parameters have been presented for maximum efficiency.

Experimental Results have been given for Hydrodynamic Cavitation reactors for the degradation of Organic matters and recalcitrant.

3. Scope of the Study:

In Jubilant Lifesciences Limited the Effluent generated from Process Was treated in their Captive Effluent Treatment Plant having Capacity of 100 KL/Day.

Major Concern for treatment was faced by them for reduction of Ammonical Nitrogen and Chemical Oxygen demand as per requirement of CETP norms in which Final treated effluent is being disposed.

The Discharge Norms for Jubilant Lifesciences Limited is as given below.

Chemical Oxygen Demand : < 2000ppm

Ammonical Nitrogen : < 50ppm

To Comply with the Norms of Common Effluent Treatment Plant (CETP) effluent was being treated by applying Primary treatment Methods in existing ETP.

As part of Primary treatment Effluent was Filtered from Sludge Filtration Bed and After that it was treated with Sodium Hypochlorite for reduction of Ammonical Nitrogen.

Approximately 120 Liter Sodium Hypochloride was being consumed for treatment of 20 KL effluent which was economically not viable and Also Ammonical Nitrogen was not braught below 50 ppm as per their CETP Norms.

So to treat the effluent Hydrodynamic cavitation process combined with Chlorine dosing system started for reduction of Ammonical Nitrogen.

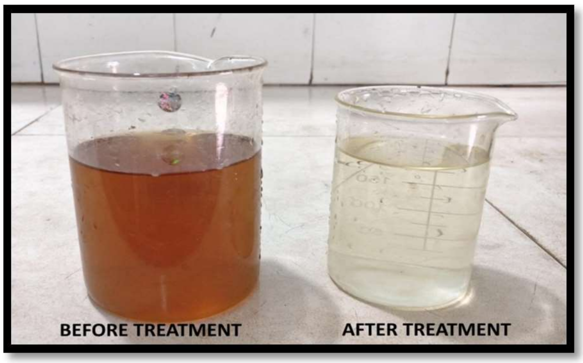
4. Effluent Characteristics

Random Sampling was carried out from below mentioned Tanks:

1) Effluent Inlet Tank : COD = 8000ppm to 15000ppm
   Ammonical Nitrogen : 120ppm to 200ppm
2) Effluent Outlet Tank : COD = 1000ppm to 1500 ppm
   Ammonical Nitrogen: 10 to 30ppm

Effluent receiving Tank:

Effluent Quality (Before and After Treatment.)



5. Methodology

Hydrodynamic Cavitation :

Hydrodynamic cavitation often occurs by forcing of water to pass through a constriction device such as a venturi, an orifice plate or a convergent divergent nozzle.

Numerous cavities are generated in HC because of a constriction, subsequently the cavity collapse violently down stream due to recovery of pressure, forming strong mechanical waves and high speed micro jets.

In HC process geometrical and operational parameters directly influence bubble dynamics and chemical reactions in the various phases.

Acoustic Cavitation :

In acoustic cavitation (AC) cavities are created by the vibration of the sound waves passing through the liquid.

Cavitation occurs in rarefaction cycles where negative pressure is sufficient to pull apart the liquid molecules from each other.

Cavities can be formed when the distance between adjacent molecules exceeds the critical value.

Subsequently the cavities are compressed in positive pressure and some of them may collapse within an extremely tiny time interval.

Local high temperature (up to 10000 K) and high pressure (10-500mpa) can be produced in cavitation process owing to the collapse of the bubbles.

Besides the high temperature and pressure the collapse of cavitation bubble can bring about physico chemical effects as well .

The physical effect includes the production of micro jets and shear forces, whereas the chemical effect results in the generation of radicals.
During bubble collapse, OH and H radicals are released by the dissociation of trapped water molecules, then OH radicals diffuse into liquid and react with refractory organics.
The attack of OH radicals is one of the governing mechanisms of cavitation.

Hydrodynamic Cavitation Set Up.

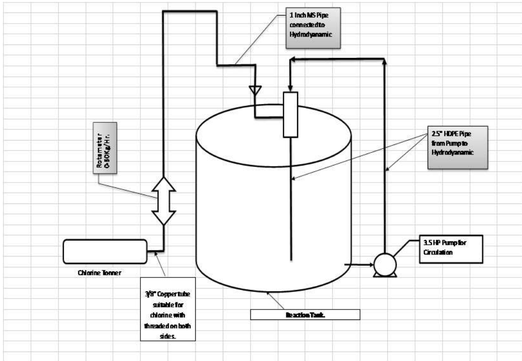


Figure-Schematic representation of cavitation set up

6. Treatment Process:

The pH of the wastewater is raised to 10.5 by hydrated lime. The wastewater is then pumped through a hydrodynamic cavitator. This is a batch process and the system is kept under recirculation till the COD is reached to desired limit. This is filtered in the filter press and the filtered wastewater is sent for further treatment or disposal or to water recycling unit.

At low flowrate, water is everywhere free of cavitation. Velocity is maximum in the section of minimum area and pressure is then minimum. When the flow rate is progressively increased, the minimum pressure decreases and there will be a critical flowrate for which the vapour pressure is obtained at the throat. At this operating point, cavitation appears in the section of minimum area. In Figure, two bubbles are clearly visible in the upper part of the Venturi. This is the start of the cavitation state.

If the flow rate through the Venturi is further increased, the extent of cavitation increases. At this point the chlorine when injected will oxidise the organic matter in exploded bubble and due to the large surface area available, the oxidation by chlorine molecule and hydroxyl ions is almost instantaneous.

Conclusion :

Hydrodynamic cavitation is a new, advanced technology for the decomposition of complex compounds and an alternative to ultrasound-induced cavitation. The use of hydrodynamic cavitation in environmental engineering technologies allows processes to be greatly effective during water and effluent treatment.

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