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TREATMENT OF PHARMACEUTICAL WASTEWATER BY ACOUSTIC CAVITATION

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Abstract

In a laboratory study, treatment of dye wastewater having high chemical oxygen demand (COD) in the range of 9000 to 10000 mg/L. by sonolysis was examined. Batch experiments were conducted to determine optimal sonolysis time (with and without dipping) to obtain the best results. In the present work, degradation of pharmaceutical effluent has been investigated using acoustic cavitation process. In this study, the effect of acoustic cavitation was examined for the different time intervals from 0 to 90 mins. In acoustic cavitation high frequency probe was used of 20 KHz capacity and reactor capacity was 1 liter. With acoustic cavitation, maximum COD removal achieved was 75.53% in 75 mins.

Key word: *Advanced oxidation process, COD removal, pharmaceutical wastewater, acoustic cavitation*

I. INTRODUCTION

The existence of pharmaceutical substances in the aquatic environment and their possible effects on living organisms are a growing concern. The treatment of pharmaceutical wastewater to the desired effluent standards has always been difficult due to the wide variety of the products that are produced in a drug manufacturing plant. Variable wastewater composition and fluctuations in pollutant concentrations cannot be treated by conventional treatment plants. Activated sludge process is a well-for removing various organic contaminants and organic carbon. However, the substances synthesized by pharmaceutical industries are organic chemicals that are structurally complex and resistant to biological degradation. The treatment of pharmaceutical wastewater requires some complementary techniques that could efficiently remove pollutants and enable the wastewater to be discharged into receiving water or be reused for industrial purposes.

Pharmaceutical and antibiotic residues from human, animal and medical waste enter in the water and soil from

1) The effluent treatment plants of manufacturing facilities, 2) The municipal sewage treatment plant, 3) Hospital waste treatment plants, or 4) Animal farms.

Most pharmaceutical substances are, by nature, biologically active and hydrophilic, in order that the human body can take them up easily, and persistent, to avoid degradation before they have a curing effect. Depending on the pharmacology of a medical substance it will be excreted as a mixture of metabolites, as unchanged substance, or conjugated with an inactivating compound attached to the molecule. When they enter a wastewater treatment plant, xenobiotic are not usually completely mineralized. They are either partially retained in the sludge, or metabolized to a more hydrophilic but still persistent form and, therefore, pass through the wastewater-treatment plant and end up in the receiving waters.

II. TREATMENT TECHNOLOGY

Cavitation is described as the formation of micro bubbles in solution that implode violently after reaching a critical resonance size. These micro bubbles can be produced by a number of mechanisms (**Madhu G M, Rajanandam K S, Thomas A, 2010)**

1) Local increase in water velocity as in eddies or vortices, or over boundary contours; 2) Rapid vibration of the boundary through sonication; 3) Separation or parting of a liquid column owing to water hammer; or 4) An overall reduction in static pressure.

The rapid implosion of cavitation micro bubbles results in high temperatures at the bubble/water interface, which can trigger thermal decomposition of the toxic elements in solution or thermal dissociation of water molecules to form extremely reactive radicals. The extreme conditions generated during cavitation decomposes water to create both oxidizing (•OH) and reducing (•H) radical (**Gogate P R and Pandit A B, 2000)**.

There are three known methods of producing hydroxyl radicals using cavitation — namely, ultrasonic irradiation or sonication, pulse plasma cavitation, and hydrodynamic cavitation. Sonication causes the formation of micro bubbles through successive ultrasonic frequency cycles until the bubbles reach a critical resonance frequency size that results in their violent collapse. Pulse plasma cavitation utilizes a high voltage discharge through water to create micro bubbles. In hydrodynamic cavitation, micro bubbles are generated using high velocity or pressure gradients (**Gore M M and Chavan P V, 2013)**.

A. ACOUSTIC CAVITATION

In acoustic cavitation, high frequency sound waves, usually ultrasound, are used to generate cavities. Normally the frequencies of the sound waves are between 16 KHz and 100 MHz Bubbles and cavities are generated and collapsed by using alternate compression and rarefaction cycles of the sound (**Lorimer and Mason, 1987; Shah et al., 1999; Suslick et al., 1990**).

Multiple frequencies/multiple transducers have been found to be more beneficial than the equipment using a single frequency (**Gogate et al., 2001, 2003; Hua et al., 1995; Sivakumar and Pandit, 2002; Thoma et al., 1997**). A newly developed ultrasonic horn vibrating in the radial direction was found to be a promising device for medium to large scale application for its improved energy dissipation ability due to its larger irradiating area (**Dahlem et al., 1998, 1999**). More work needs to be done to find out the behavior of this instrument under high frequency and high dissipation conditions.

To enhance the cavitational effect, pre-treatment may be applied to a waste stream to dilute the pollutant concentration, as a lower initial concentration of pollutant increases the rate of sonochemical degradation. However, an optimum value should be selected as it has a negative effect on the power density (**Sivakumar and Pandit, 2001**). Presence of gases (oxygen, ozone), aeration or addition of catalyst can increase the degradation by a sonochemical reactor. However the presence of a catalyst can also interfere with the propagation of the sound waves. Thus, optimization of catalyst concentration is required (**Gogate et al., 2002**). Temperature is another important factor, as the rate of bubble destruction is inversely proportional to the temperature (**Sivakumar and Pandit, 2002; Suslick et al., 1997**).

B. FACTORS AFFECTING ACOUSTIC CAVITATION

The performance of a sonochemical reactor is also affected by the physicochemical properties of the medium such as vapour pressure, surface tension, viscosity, presence of impurities, etc. These liquid properties affect the cavitation inception, the number of cavities generated and also the initial size of nuclei. The minimum power required for the onset of cavitation is defined as cavitation inception. The cumulative pressure/temperature pulse generated due to cavitation is the product of the total number of cavities and pulse generated from the collapse of a single cavity. Thus it is advisable to produce a large number of cavitation events in a reactor with smaller cavitation nuclei (**Gogate, 2002; Gogate and Pandit, 2000a**).

C. HYDRODYNAMIC VS. ACOUSTIC CAVITATION

Acoustic cavitation in the form of ultrasound has been observed capable of removing a wide variety of contaminants from water. Significant research has been done in this field compared to hydrodynamic cavitation, but most of the studies have been done at laboratory scale. Scale-up is a big issue in acoustic cavitation compared to hydrodynamic cavitation. Designing large scale acoustic cavitation equipment involves information from a variety of fields compared to the hydrodynamic cavitation. Hydrodynamic cavitation reactors offer versatility and ease of operation. Several studies have proven that hydrodynamic cavitation is much more energy efficient and effective than acoustic cavitation (Gogate and Pandit, 2005; Gogate and Kabadi, 2009; Jyoti and Pandit, 2004; Kalumuck and Chahine, 2001; Save et al., 1997).

D. SAMPLE ANALYSIS

pH of the sample is adjusted by using NaOH and measured by pH meter from the company EI products, Parwanoo (H.P), India. pH meter is calibrated by using commercially available Thallate buffer. Waste water sample is mixed with the help of Magnetic Stirrer from the company Remi Scientific Instruments ltd., Mumbai, India. Raw and treated waste water sample is analyzed for COD according to the methods summarized in the standard methods for the analysis of wastewater.

III. EXPERIMENTAL PROCEDURE

The experiments were performed in a round-bottomed flask. Thereafter, For Sonication, ultrasound stirrer is used with a frequency of 20 kHz for different time interval. Sample was kept for quiescent condition for 2 hours for the settlement of the precipitate. All experiments were carried out in batch mode. Several set of experiments were carried out to check the optimum range of sonication time.

FIG. 1 ACOUSTIC CAVITATION APPARATUS

IV. RESULT AND DISCUSSION

TABLE 1:- RAW EFFLUENT CHARACTERISTICS

SR. NO.	CHARACTERISTICS	VALUES
1	CHEMICAL OXYGEN DEMAND (COD)	9000 – 10000 mg/L
2	pH	7.8 – 8.2
3	TDS	47500 mg/L
4	TSS	8300 mg/L

The wastewater characteristics play a significant role on its treatment. Raw wastewater parameters were measured and listed in Table 1. These results indicate that this wastewater contains high load of organic and inorganic matter. Therefore, this wastewater can cause damage to the environment when discharged directly without proper treatment.

In this study, the effect of acoustic cavitation was examined for the different time intervals from 0 to 90 mins. The acoustic cavitation apparatus used was of 500W. With acoustic cavitation maximum COD removal achieved was 75.53% in 75 mins as shown in Fig 2. After 75 mins the degradation efficiency decreases as shown in the comparative Fig 2.

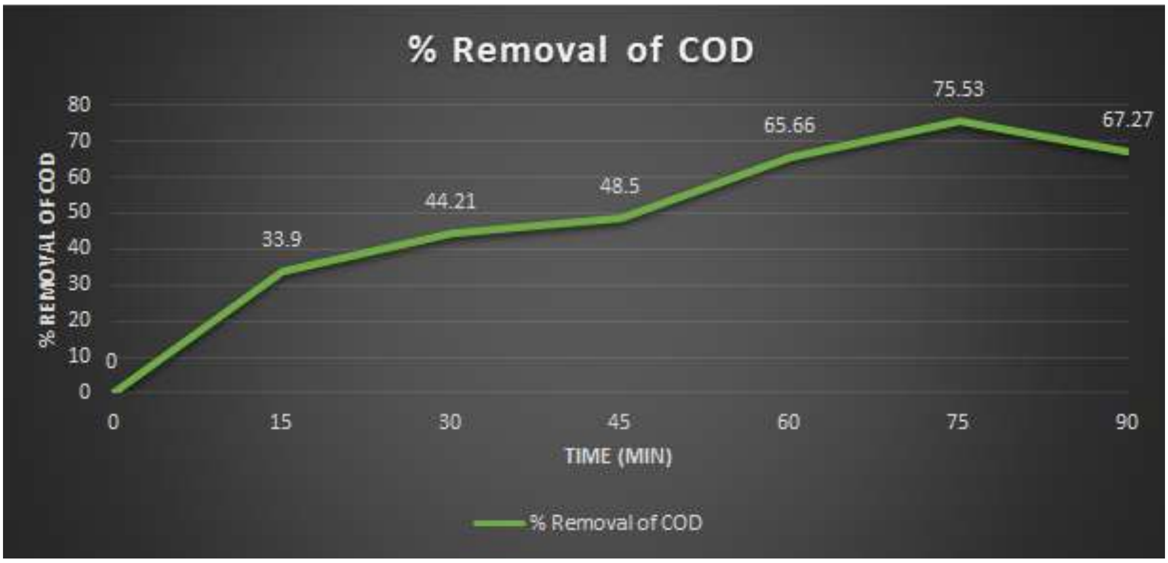

FIG. 2 % COD REMOVAL WITH ACOUSTICCAVITATION PROCESS

V. CONCLUSION

The degradation of wastewater from pharmaceutical wastewater was investigated by the cavitation process. The cavitation process was done by acoustic. Therefore, maximum efficiency of COD removal is achieved at 75 mins, 75.53% with acoustic cavitation without any use of chemical.

Cavitation is eco-friendly way to reduce the pollution load of wastewater. These processes differ from the other treatments processes because wastewater compounds are degraded rather than concentrated or transferred into a different phase and secondary waste materials are not generated. Sludge generation is very less compare to other processes.

VI. REFERENCES

[1] **APHA,** Standard methods for the examination of water and wastewater, 21st edition, American Public health association. Washington D.C, USA, 2005

[2] **Chanda S K**, "Disintegration of sludge using ozone-hydrodynamic cavitation", Bangladesh university, 2008

[3] **Chivate M M and Pandit A B**, "Effect of sonic and hydrodynamic cavitation on aqueous polymeric solutions", Industrial chemical engineering, v. 35, p. 52, 1993

[4] **Dahlem O, Demaiffe V, Halloin V and Reisse J,** "Direct sonication system suitable for medium-scale sonochemical reactors", AICHE Journal, 44(12), 2724-2730, 1998

[5] **Dahlem O, Reisse J and Halloin V,** "The radially vibrating horn: A scaling-up possibility for sonochemical reactions", Chemical Engineering Science, 54(13-14), 2829-2838, 1999

[6] **Gogate P R and Kabadi A M,** "A review of applications of cavitation in biochemical engineering biotechnology", Biochemical Engineering Journal, 44(1), 60-72, 2009

[7] **Gogate P R and Pandit A B,** "A review and assessment of hydrodynamic cavitation as a technology for the future". Ultrasonic Sonochemistry, 12(1-2), 21-27, 2005

[8] **Gogate P R and Pandit A B,** "Engineering design method for cavitational reactors: I", sonochemical reactors. AICHE Journal, 46(2), 372-379, 2000

[9] **Gogate P R and Pandit A B,** Engineering Design Methods for Cavitation Reactors II: Hydrodynamic Cavitation, AIChE J., 46, 1641-1649, 2000.

[10] **Gogate P R,** "Cavitation: An auxiliary technique in wastewater treatment schemes", Advances in Environmental Research, 6(3), 335-358, 2002

[11] **Gogate P R, Mujumdar S and Pandit A B,** "A sonophotochemical reactor for the removal of formic acid from wastewater", Industrial & Engineering Chemistry Research, 41(14), 3370-3378, 2002

[12] **Gogate P R, Mujumdar S and Pandit A B,** "Sonochemical reactors for waste water treatment: Comparison using formic acid degradation as a model reaction", Advances in Environmental Research, 7(2), 283-299, 2003

[13] **Gogate P.R,** Treatment of wastewater streams containing phenolic compounds using hybrid techniques based on cavitation: A review of the current status and the way forward, Ultrasonics Sonochemistry 15, 1–15, 2008

[14] **Gore M M and Chavan P V,** "Hydrodynamic cavitation using degradation of reactive orange 4 dye", Int. j.chem, 11, 1314, 2013

[15] **Hua I, Hochemer R H and Hoffmann M R,** "Sonochemical degradation of p-nitrophenol in a parallel-plate near-field acoustical processor", Environmental Science & Technology, 29(11), 2790-2796, 1995

[16] **Jyoti K and Pandit A,** "Ozone and cavitation for water disinfection". Biochemical Engineering Journal, 18(1), 9-19, 2004

[17] **Kalumuck K M and Chahine G L,** "The use of cavitating jets to oxidize organic compounds in water". Http://resolver.Caltech.edu/cav2001: SessionA4.006, 2001

[18] **Lalwani P K, Devadasan M D,** "Reduction of COD and BOD by oxidation", IJERA, vol. 3, issue 3, 108-112, 2013

[19] **Lesko TM,** Chemical effects of acoustic cavitation. Ph.D. thesis reported in California Institute of Technology, Pasadena, California, USA, 2004

[20] **Lorimer, J P and Mason T J,** "Sonochemistry. Part 1", the physical aspects. Chem.Soc.Rev, 16(0), 239-274, 1987

[21] **Madhu G M, Rajanandam K S, Thomas A**, "Cavitation techniques for wastewater treatment", Journal of chemical Engg., 3, 58, 2010

[22] **Mazumder D**, "Process evaluation and treatability study of wastewater in a textile dyeing industry", IJEE, volume 2, issue 6, 1053-1066, 2011

[23] **Mohammad M "**Advanced oxidation processes for water treatment: reactor design and case studies", 1977

[24] **Nair R R, Patel R L,** "Comparative Study Of Treatment Of Dye Wastewater By Advanced Oxidation Processes", unpublished dissertation thesis Gujarat Technological University, may 2014

[25] **Neppiras EA,** Acoustic cavitation. Phys Rep, 61:159-251, 1980

[26] **Pandit A B and Moholkar V S**, "Harness cavitation to improve processing", Chemical engineering progress, v. 92, n. 7, p. 57, 1996

[27] **Pisani J A**, "Cavitation induced hydroxyl radical oxidation", AICHE spring national meeting, session 95a, Houston, Texas, March 1997

[28] **Shah Y T, Pandit A B, Moholkar V S,** "Cavitation Reaction Engineering. Plenum Publishers", USA, 1999

[29] **Sharma S, Ruparelia J P and Patel M L, "**A general review on advanced oxidation processes for waste water treatment", Nirma university, 2011

[30] **Siva Kumar M and Pandit A B,** "Wastewater treatment: A novel energy efficient hydrodynamic cavitation technique". Ultrasonic Sonochemistry, 9(3), 123-131, 2002

[31] **Sivakumar M and Pandit A B,** "Ultrasound enhanced degradation of rhodamine B: Optimization with power density" Ultrasonic Sonochemistry, 8(3), 233-240, 2001

[32] **Suslick K S, Mdleleni M M and Ries J T,** "Chemistry induced by hydrodynamic cavitation", Journal of the American Chemical Society, 119(39), 9303-9304, 1997

[33] **Suslick K, Doktycz S and Flint E,** "On the origin of sonoluminescence and sonochemistry", Ultrasonic, 28(5), 280-290, 1990

[34] **Thakare Y D, Prof. S M Jadhav,** "Degradation of brilliant green dye using cavitation based hybrid

techniques", International journal of advanced engineering technology.

[35] **Thoma G, Swofford J, Popov V and Som M,** "Sonochemical destruction of dichloromethane and o-dichlorobenzene in aqueous solution using a near field acoustic processor" Adv. Environ. Res, 1, 178, 1997