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PESTICIDE WASTEWATER TREATMENT BY HYDRODYNAMIC CAVITATION PROCESS

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Abstract

Industrial wastewater treatment is practiced using a number of physical, physico-chemical and biological methods of treatment. Quality of wastewater in terms of number and nature of pollutants, usually expressed in terms of Chemical Oxygen Demand (COD) and desired level of reduction in these pollutants dictates the selection of process. In the present work, degradation of pesticide effluent has been investigated using Hydrodynamic Cavitation process. In this study, the effect of Cavitation was examined for the different time intervals from 0 to 150 mins. maximum COD removal achieved was 90.55% and colour removal achieved was 83.21% in 75 mins.

Key words:*Advanced oxidation process, COD removal, pesticide wastewater, Hydrodynamic cavitation.*

I. INTRODUCTION

It is estimated that India approximately loses 18 per cent (%) of crop yield valued at 900 billion due to pest attack each year. The use of pesticides helps in reducing the crop loss, provides economic benefits to farmers, reduces soil erosion and helps in ensuring food safety and security for the nation.

As per the Directorate of Plant Protection, Quarantine and Storage, the production capacity of pesticides in the country is around 1, 39,000 MT annually with more than 125 technical grade/manufacturing units and over 800 formulation units. In the recent years, the consumption of pesticides has shown a downward trend from 75,000 MT in 1991-1992 to around 37,959 MT in 2006-2007 - reasons being the popularization of Integrated Pest Management approach, which includes cultural, physical, mechanical, biological and need-based use of safest chemical pesticides including neem-based bio-pesticides in harmonized manner as well as use of low dose new molecules, ban on the Heptachlor, Chlordane and BHC, etc., and the cultivation of Cotton etc.

Presently, there are about 1, 46,747 sale/distribution points of pesticides in the country to ensure easy availability of pesticides to farmers. Major chemical reactions involved in production of technical grade pesticides are: alkylation, carboxylation, acetylation, condensation, cyclization, dehydration, halogenation, oxidation, sulphonation, nitration.

Every reaction ends with some quantities of un-reacted raw materials and some unwanted products that will remain in the system. Desired products from these reactions may be carefully recovered at every step from the system and unwanted products can be discarded. These inevitably become pollutants in wastewater and solid waste. Some are vented out to the atmosphere. There are some cases where some recyclable materials may be profitably taken back into the system. Impurities present in raw materials may also react with one another and in many cases, which show up as a scum, froth or tar or simply as un-reacted raw material.

General observations with respect to the manufacturing processes of pesticides industry are given below, which are very important as these play a major role on the quality and characteristics of the wastewater (effluent), air emissions and solid/hazardous waste generation:

1. Most of these industries manufacture more than one pesticide. All the products may not have separate process routes. Some products, which are derived from similar reaction chemistry, are manufactured by same unit configuration with minor changes in raw materials. Even if a plant produces more than four products, it is unlikely that more than four lines exist. Not all pesticides are manufactured throughout the year. Some are manufactured only for a part of the year and the process line of this product is used for manufacturing a different products during the remaining part of the year depending on the crop, season, or demand. The same product may be manufactured with different process operations in different industries. Some may start the process of manufacture using basic raw materials, thus making the process lengthy and has pollution potential, while the others may start process using intermediates and manufacturing the product with reduced steps and lesser pollution.
2. The quantity of effluent generated varies widely from 0.5 to 120 kilo liters (kL) per tonne of product. Hence, it is difficult to summarize a specific limit for effluent generation as is usually done for other industries such as distilleries, sugar, and breweries etc., due to diversity of products and

manufacturing routes. However, the pesticide industries may realize that there is a scope of reducing the quantities of effluent generation, which may reduce the cost of treatment.

II. CAVITATION TECHNOLOGY IN WASTEWATER TREATMENT

Cavitation can simply be defined as a physicochemical process employing oxidation mechanism coupled with physical breakage/ thermal decomposition using cavitating device for degradation of chemical species. It proceeds through three main steps : Formation of cavities with the help of cavitating device, Growth of cavities in the space provided by the cavitating device, Collapse of the cavities.

On the basis of cavity creation mechanism, four types of cavitation can be defined.1) Acoustic cavitation- use of sound waves, 2) Hydrodynamic cavitation- hydrodynamic devices producing pressure drop, 3) Optic cavitation- use of laser **,** 4) Particle cavitation- through bombardment of particles.(Sorokhaibam, Bhandari and Ranade ,2014)

The nature of cavitating device controls the quantity and quality of the cavities formed. The cavities, when collapse, release large amount of energy which is used for generating oxidizing agents in wastewater. Subsequent to this step, series of radical reactions occur with complex organic matter present in wastewater leading to destruction of contaminants and also decolourisation of wastewater. The size, shape, growth and implosion of cavity are strongly dependent on the parameters such as nature and type of effluent, bulk fluid temperature, pH, salts, dissolved solids and reactor configuration. For all practical purposes, as of today, only acoustic and hydrodynamic cavitation can be considered to be most relevant for wastewater treatment. While acoustic cavitation requires ultrasound type sound waves for generating cavity in the bulk liquid, hydrodynamic cavitation utilizes constriction such as orifice/ venturi/ vortex diode in the path of flow of fluid.

The cavitating device of hydrodynamic cavitation is required to offer sudden pressure drop below vapour pressure of the liquid so that the liquid flashes into vapour, generating cavities. The number and size of cavities along with mechanism of collapse of cavities determine performance of the cavitation process. The collapse of cavities is important as it creates highly localised extreme high temperature and pressure conditions and consequently hydroxyl radicals and it is believed that the conditions vary depending upon the type of cavitating device. Thus, the design of cavitating device is important for efficient degradation of molecules. However, the overall liquid medium remains close to ambient conditions in the smaller duration of the process. Chakinala et. Al have reported the applicability of a combination of hydrodynamic cavitation and advanced Fenton process for treatment of industrial effluents. Gogate et.al have studied removal of p-nitrophenol using venturi and orifice plate as cavitating device and Fenton chemistry. It was observed that extent of removal increased with an increase in inlet pressure. The extent of removal was higher for lower initial concentration of pollutant.

In the case of acoustic Cavitation, Cavitation is produced using the high frequency sound waves, usually ultrasound, with frequencies in the range of 16 kHz–100 MHz Alternate compression and rarefaction cycles of the sound waves results in various phases of Cavitation such as generation of the bubble/cavity, growth phase and finally collapse. Acoustic Cavitation (tiny micro bubbles) are created when it reaches rarefaction cycle where a negative acoustic pressure is sufficiently large to pull the water molecules from each other (the critical molecular distance, R for water molecules is 10^{-8} cm).

Different types of acoustic cavitational reactors are being used including ultrasonic horn, ultrasonic bath and multiple frequency cells. Since 1990, there has been an increasing interest in the use of ultrasound to destroy organic contaminants present in wastewater (Bagal and Gogate, 2012). Many researchers have reported that ultrasonic irradiation process was capable of degrading various recalcitrant organic compounds such as phenol compounds, chloroaromatic compounds, aqueous carbon tetrachloride, pesticides, herbicides, benzene compounds, polycyclic aromatic hydrocarbons and organic dyes. The frequency of ultrasound, irradiating surface, intensity of sound wave, calorimetric efficiency of ultrasonic equipment (power dissipated into the system per unit power supplied), physicochemical properties of the liquid medium and the presence of air and solid particles are the important parameters which affects the cavitational efficiency of acoustic cavitational reactor.(Chakinala,2009)

One of the alternative techniques for the generation of cavitation is the use of hydraulic devices where cavitation is generated by the passage of the liquid through a constriction such as valve, orifice plate, venturi etc. (Gogate and Pandit, 2005). There are not many reports depicting the use of these equipments for wastewater treatment, but these offer higher energy efficiencies, more flexibility and higher potential for scale-up as compared to their acoustic counterparts. In the case of hydrodynamic cavitation (HC) the intensity of the cavity collapses and hence the cavitational yield is very much dependent on the surrounding pressure field. The intensity of turbulence depends on the magnitude of the pressure drop and the rate of pressure recovery, which, in turn, depends on the geometry of the constriction and the flow conditions of the liquid, i.e., the scale of turbulence. The intensity of turbulence has a profound effect on cavitation intensity.(Gogate,2014)

III. FACTORS AFFECTING HYDRODYNAMIC CAVITATION

Cavitation number, Inlet pressure, Diameter of the constriction, Physicochemical properties of the liquid and the initial size of nuclei, Percentage of free area for the flow(Chanda S K, 2008)

Hydrodynamic cavitation has great potential in water disinfection due to its capability to generate highly reactive free radicals and turbulence. The mechanism involved in disinfection of microorganisms by cavitation is thought to involve the following effects (Gogate and Kabadi, 2009).It has been observed that in hydrodynamic Cavitation, chemical and thermal effects play supporting roles to mechanical effects in microbial disinfection. (Jyoti and Pandit, 2004) applied ozone and hydrodynamic Cavitation to bore well water and found this technique much more effective in water disinfection compared to other individual physical-chemical techniques including ozonation, hydrodynamic Cavitation and acoustic Cavitation.

Cavitation can also be used as supplementary technique to a conventional biological oxidation process to increase substrate biodegradability or to reduce toxicity by degrading bio refractory materials (Gogate and Kabadi, 2009). It can also be used with an anaerobic digestion process to improve the digestibility of the sludge by solubilising it.

IV. METHODOLOGY

The untreated waste water sample of pesticide industry was collect from the inlet of the effluent treatment plant of the industry located near Vadodara, Gujarat. Sample was stored at 4 °C immediately after collection of the waste water.

For hydrodynamic Cavitation, experiments were performed in reactor of capacity 50 litres in which effluent was lifted and circulate by the pump of capacity 1 H.P. for different intervals of time and chlorine was used an oxidizing agent. Sample was kept for quiescent condition for 2 hours for the settlement of the precipitates. All experiments were carried out in batch mode. Several set of experiments were carried out to check the optimum range of time. All the Experiments were carried out in normal atmospheric temperature at 28°C.The Cavitation reactor was fabricated at perfect engineering services,vadodara.All the chemicals used for the measurement of parameters were obtained from MERCK.

Figure. 1 Hydrodynamic Cavitation Reactor

V. RESULT AND DISCUSSION

Table 1:Raw Effluent Characteristics

SR. NO.	CHARACTERISTICS	RAW EFFLUENT	AFTER TREATMENT(75 min)
1	pH	8.1-8.5	6.6-6.8
2	COD	10200-10800 mg/L	1020 mg/L
3	TDS	90000 mg/L	18200 mg/L
4	TSS	13500 mg/L	2160 mg/L
5	Colour	7970 (Pt-Co Scale)	1338(Pt-Co Scale)

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

The wastewater characteristics play a significant role on its treatment. Raw wastewater characteristics 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.

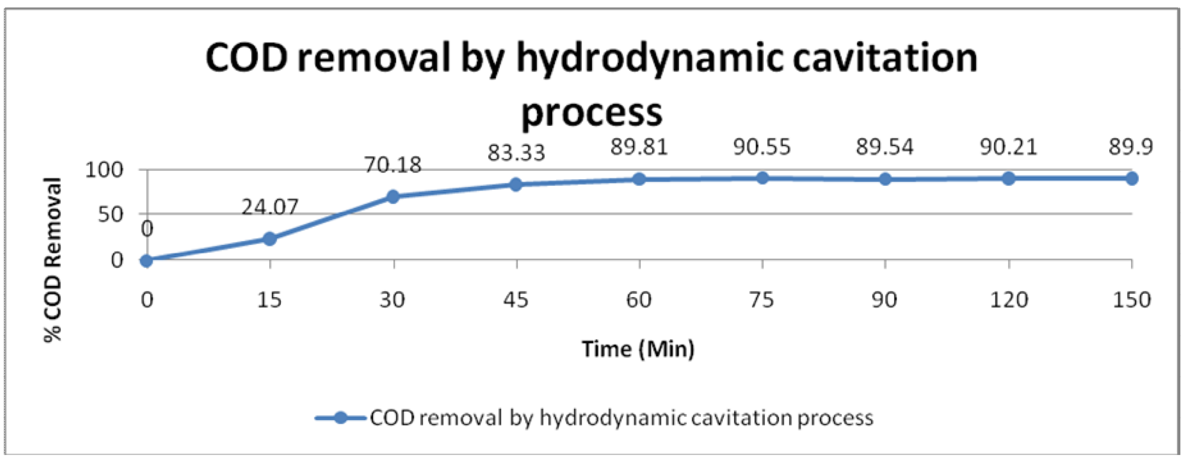

Figure. 2 % COD removal by hydrodynamic cavitation process

In this study, the effect of Cavitation was examined for the different time intervals from 0 to 150mins. In hydrodynamic cavitation pump was used of 1 H.P capacity and reactor was 50 liters. With hydrodynamic Cavitation, maximum COD removal achieved was 90.55% in 75 mins as shown in the graph.also it is observed that between 60-150mins the removal efficiency is almost same.

Also the Reduction of TDS was observed by 79.77% and TSS reduction by 84.00% in 75 mins. there was also significant reduction in colour. the colour removal on Pt-Co Scale was observed as 83.21%.All the experiments were carried out according to APHA,Standard methods for the examination of water and wastewater, 21st edition, American Public health association. Washington D.C, USA, 2005.

VI. CONCLUSION

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 also very less.The COD Obtained after the treatment is under the inlet standards of CETP near vadodara.

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