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ENHANCEMENT IN BIODEGRADABILITY FOR EFFLUENT OF DISTILLERY WASTEWATER USING HYDRODYNAMIC CAVITATION- A NOVEL APPROACH.

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Abstract:
In the present work, degradation of effluent from distillery wastewater has been carried out using hydrodynamic cavitation, one of the novel upcoming Advance Oxidation Processes for the treatment of industrial wastewater. The multiple hole orifice plates and circular venturi used as cavitating devices. The phenomena of cavitation which is associated with the formation, growth and subsequent collapse of microbubbles with small time of interval as milliseconds and releasing of a large amount of energy at multiple locations in the reactor. The cavitation occurs at various locations in the reactor simultaneously and generates very high temperature and pressure like thousands of atmospheric pressure and thousands of ^{0}K temperature. These cavitation phenomena generated by liquid flow pattern hence termed as hydrodynamic cavitation. The highly color compound present in the effluent reduces sunlight penetration in the rivers, lakes or lagoons which result in decrease both photosynthesis activity and dissolved oxygen concentration that affecting the aquatic life.
The wastewater used as molasses-based distillery effluent called as spent wash obtained from a local site. This wastewater is first diluted by 2-3 time by tap water before experimentation. The applications of hydrodynamic cavitation for distillery wastewater is to study the effect of inlet fluid pressure for mineralization, the effect of dilution for mineralization, the effect of cavitation for color reduction, the effect of cavitation for biodegradability and effect of temperature using oxidizing agent were studied and optimized the parameter to enhance the Biodegradability Index. The effect of venturi inlet pressure on the reduction of COD and TOC was evaluated at 5 bar and 13 bar inlet pressure. The results indicate that there is no significant increase in percentage reduction of COD and TOC with an increase in the inlet pressure. So, 5 bar pressure can be considered as optimum inlet pressure and can be used for further experimentation. The molasses-based distillery wastewater has to be diluted by 25% and 50 % (V/V) using tap water and treated at an optimum inlet pressure of 5 bars. The reported result indicates that reduction of COD & TOC is marginally higher at 50 % dilution. Hydrodynamic Cavitation also used for reduction of color (indirectly toxicity) of molasses-based distillery wastewater. For undiluted wastewater a maximum color reduction was observed as 34%, and for 25% dilution and 50% dilution of wastewater, the maximum color reduction was observed as 41% and 48% respectively. The Biodegradability Index (BI) can be expressed as a ratio of BOD_5: COD. For good biodegradability of any wastewater, a minimum value of BI as 0.3-0.4 is considered to be ideal. The treatment on molasses-based distillery wastewater using ozone as an oxidizing agent. The temperature increases for both the combined application of ozone + cavitation, and cavitation alone, but no changes in temperature were observed with the application of ozone alone.

Keywords: Biodegradability-Index, BOD, COD, Distillery wastewater**,** Hydrodynamic Cavitation**.**

1. Introduction:

1.1 Background:

The distillery effluent stream, also known as spent wash, is the unwanted residual liquid waste generated during alcohol production. Pollution caused by this spent wash is one of the most critical environmental issues worldwide [1]. Molasses based distillery wastewater is dark brown in color because of it contain melanoidin polymers, having very high molecular weights and always exists in the colloidal form [2]. Molasses based distillery wastewater contains high level dissolved organic as well as inorganic matter along with nutrients. They can be very aggressive to the environment if improperly managed [3]. When these effluent released directly into water bodies then it can cause oxygen depletion and if released in soil then reduction of soil alkalinity [4].

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1.2 Effect of Distillery Wastewater on Environment:

The Highly color compound present in the effluent reduces sunlight penetration in the rivers, lakes or lagoons which result in decrease both photosynthesis activity and dissolved oxygen concentration that affecting the aquatic life [5]. The typical characteristics of the molasses based distillery wastewater are tabulated in Table [3].

1.3. Existing Approaches to Treat Distillery Wastewater:

1.3.1 Conventional Technique:

Anaerobic Digestion (AD) is one of the conventional techniques used for the treatment of distillery effluent. In AD process distillery effluent contains a huge amount of biodegradable organic contaminants which can be converted into biogas. This biogas can be used for generation of steam from boilers thereby meeting the demand for energy. This process is effective for COD and BOD reduction but incapable of removing of color associated with the distillery wastewater [6,7].

1.3.2 Membrane Technology:

Membrane Bioreactor (MBRs) is an effective technique for treatment of distillery wastewater. The application of MBRs is limited by two reasons one is high initial membrane cost and other is the progressive membrane fouling [8].

Table 1: Characteristics of the molasses-based distillery wastewater

Parameter	Range
pH	3.8-4.4
Total Solids mg/l	60,000- 90,000
Total Suspended Solid mg/l	2,000 – 14,000
Total Dissolved Solid mg/l	58,000 – 76,000
Total volatile Solids mg/l	45,000 – 65,000
COD mg/l	70,000 – 98,000
BOD (for 5 days at 20^0C) mg/l	45,000 – 60,000
Total Nitrogen as N mg/l	1,000 – 1,200
Potash as K_2O mg/l	5,000 – 12,000
Phosphate as PO_4 mg/l	500 – 1,500
Acidity as $CaCO_3$ mg/l	8,000- 16,000
Temperature (After heat exchanger) ^{0}C	70 – 80

1.3.3 Biological Treatment Method:

The biological treatment methods for distillery spent wash is either anaerobic or aerobic but in most of the cases a combination of anaerobic and aerobic process used. If typically COD/BOD ratio will be 1.8 to 1.9 then biological treatment is suitable for -distillery wastewater [5].

1.3.4 Physico-Chemical Method:

The various Physico-chemical treatment systems used for distillery spent wash treatment are tabulated in the table with their efficiency.

Table 2: Physico-chemical treatment system

Treatment	% COD Removal	%Color Removal	References
Adsorption			
1) Agro based Activated Carbon	23	50	
2) Commercially available activated carbon			[9]
AC (ME)	76	93	
AC (LB)	88	95	
Coagulation–flocculation			
1) Aluminium sulphate ($Al_2(SO_4)_3$)	NR	83	[10]
2) Calcium oxide (CaO)	NR	77	
3) Calcium chloride ($CaCl_2$)	NR	46	
Oxidation processes			
Fenton's oxidation	88	99	[11]
Ozonation	15-25	80	[12]
Membrane technologies			
Reverse osmosis	99.9	--	[12]
Nanofiltration	97.1	100	

In table NR: - Not Reported.

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2. Upcoming Advanced Oxidation Process: Cavitation.

2.1 Introduction:

Cavitation is defined as formation, growth and subsequent collapse of microbubbles with small time of interval as milliseconds and releasing of a large amount of energy at multiple locations in the reactor. The cavitation occurs at various locations in the reactor simultaneously and generates very high temperature and pressure like thousands of atmospheres pressure and thousands of K temperature [13,14].

2.2 Hydrodynamic Cavitation:

The cavitation phenomena generated by liquid flow pattern hence termed as hydrodynamic cavitation. The cavities formed in hydrodynamic cavitation due to liquid passing through the constriction provided in the pipeline such as venturi and orifice plate. When vapor cavity collapse then the creation of hot spots takes place and releasing of highly reactive free radical with transient temperature of 10,000 K, and pressures of about 1000 atm. [12,14].
The reduction of COD/TOC ratio and enhancement of Biodegradation Index (BI: BOD_5: COD ratio) as well as color reduction of distillery wastewater is also possible by this recent method [14].

2.3 Experimental and Cavitating Device Setup:-

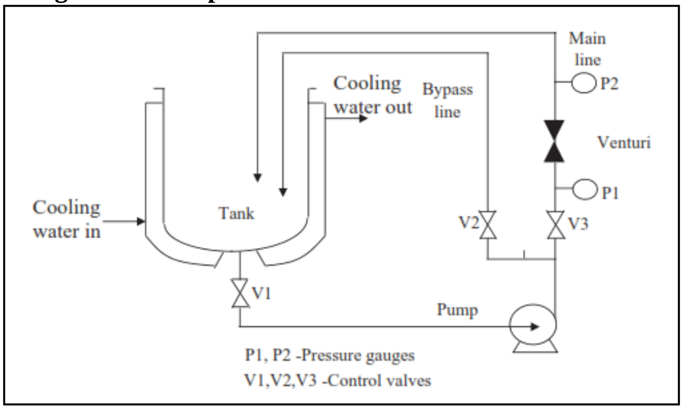

Figure 1: Schematic representation of HC Reactor with venturi.

3. Experimental Work.

The wastewater used as molasses-based distillery effluent called as spent wash obtained from a local site. This wastewater is first diluted by 2-3 time by tap water before experimentation. The applications of hydrodynamic cavitation for distillery wastewater is to study the effect of inlet fluid pressure for mineralization, the effect of dilution for mineralization, the effect of cavitation for color reduction, the effect of cavitation for biodegradability and effect of temperature.

4. Result and Discussion:

4.1 Effect of Inlet Pressure for mineralization:

The effect of venturi inlet pressure on the reduction of COD and TOC was evaluated at 5 bar and 13 bar inlet pressure. The samples were collected at the different time of interval for analysis of COD and TOC. The results indicate that there is no significant increase in percentage reduction of COD and TOC with an increase in the inlet pressure as shown in figure 2. So, 5 bar pressure can be considered as optimum inlet pressure and can be used for further experimentation.

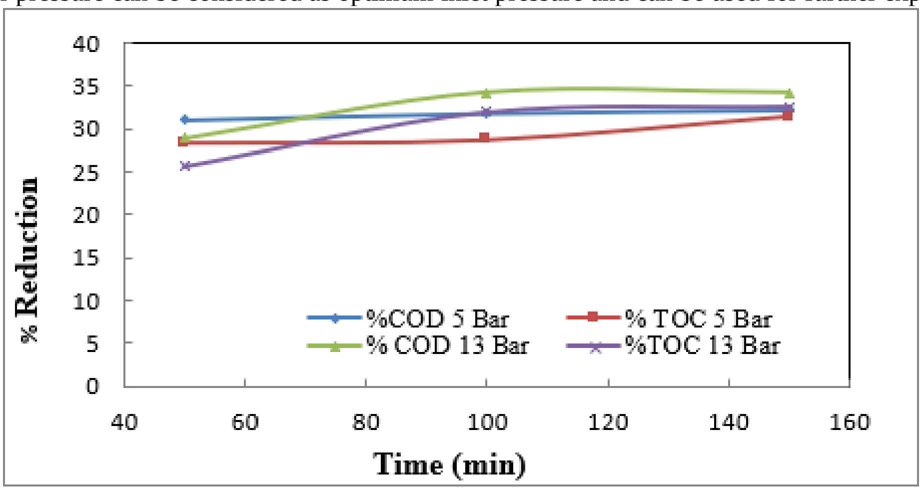

Figure 2: Effect of inlet pressure on mineralization.

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4.2 Effect of Dilution on mineralization:

The molasses-based distillery wastewater has to be diluted by 25% and 50 % (V/V) using tap water and treated at an optimum inlet pressure of 5 bars. The reported result indicates that reduction of COD & TOC is marginally higher at 50 % dilution as shown in figure 3.

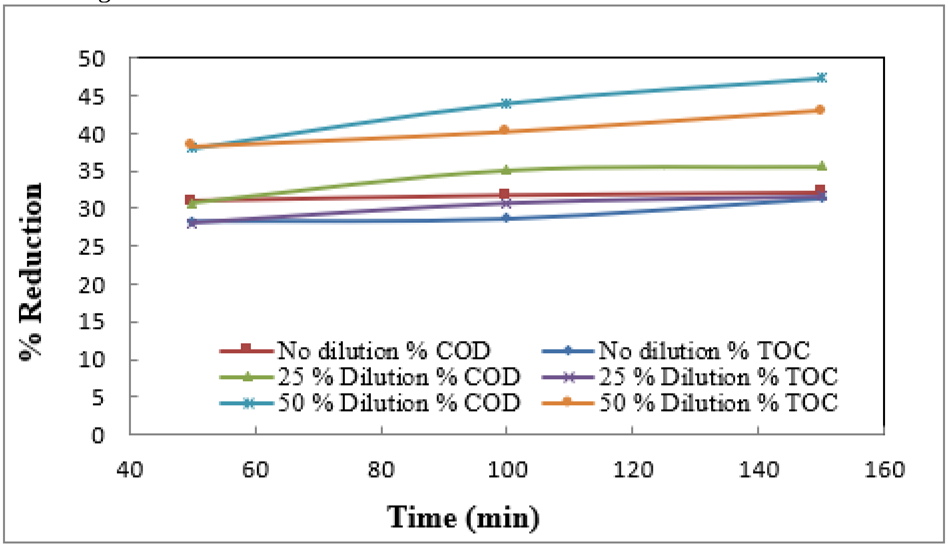

Figure 3: Effect of dilution on mineralization.

4.3 Effect of Cavitation for Color reduction:

Hydrodynamic Cavitation also used for reduction of color (indirectly toxicity) of molasses-based distillery wastewater. For undiluted wastewater, a maximum color reduction was observed as 34%, whereas for 25% and 50% dilution of wastewater the maximum color reduction was observed as 41% and 48% respectively as shown in figure 4.

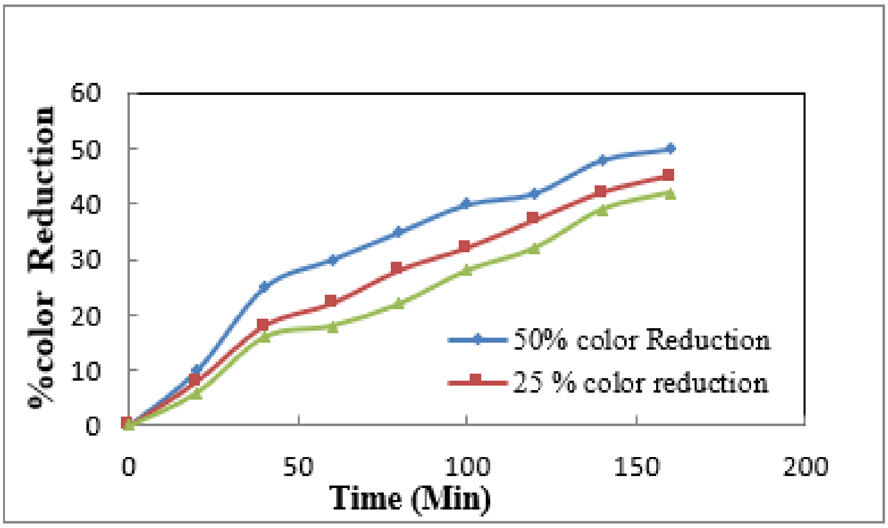

Figure 4: Effect of cavitation for Color Reduction.

4.4 Effect of Cavitation for Biodegradability:

The Biodegradability Index (BI) can be expressed as a ratio of BOD_5: COD. From obtained results as shown in figure 5, it can be suggested for enhanced Biodegradability Index, higher inlet pressure would be required.

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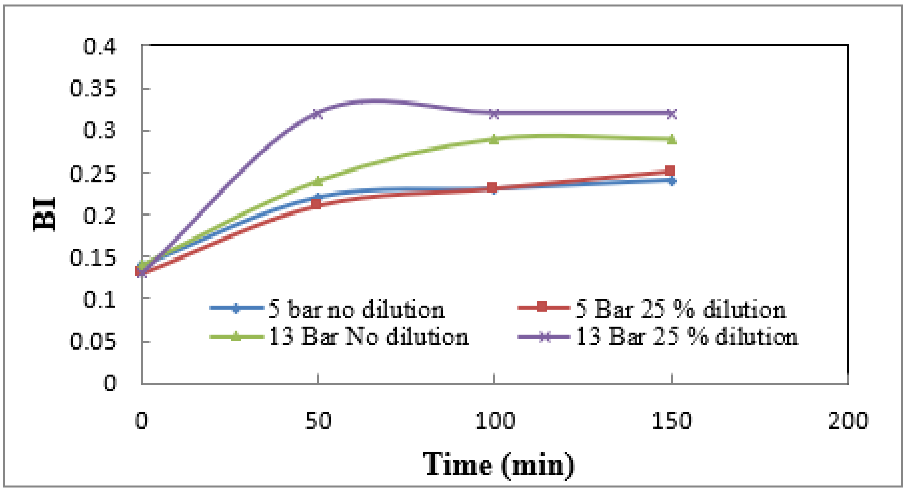

Figure 5: Effect of cavitation pretreatment on biodegradability index.

4.5 Effect of Temperature by using an oxidizing agent:

The treatment on molasses-based distillery wastewater using ozone as an oxidizing agent. The temperature increases for both the combined application of ozone + cavitation, and cavitation alone, but no changes in temperature were observed with the application of ozone alone as shown in figure 6.

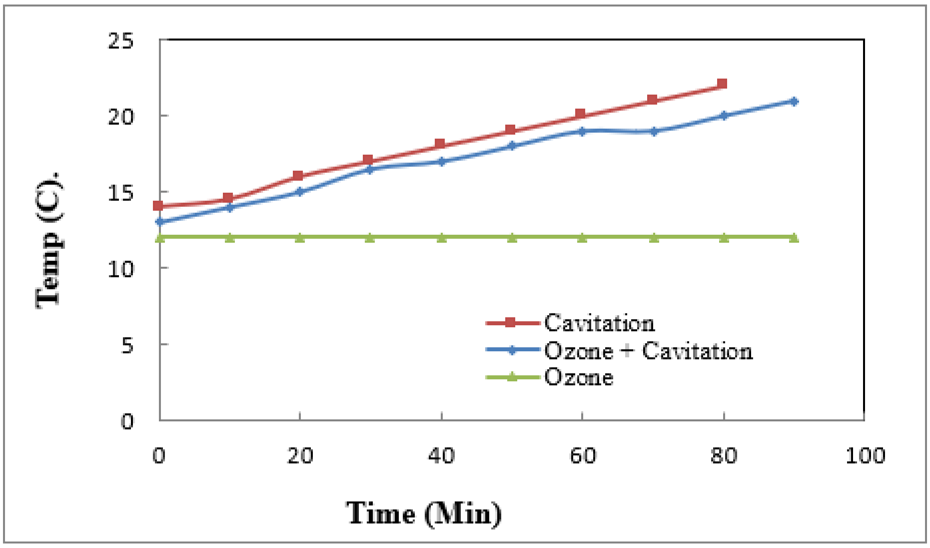

Figure 6: Effect of Temperature

Conclusion:

The hydrodynamic cavitation process can be effectively utilized for enhancing the reduction of toxicity as well as increases in Biodegradability Index of the molasses-based distillery wastewater.

1. For the reduction in toxicity of distillery wastewater, the lower inlet pressure (5Bar) is suitable and for enhancement of the Biodegradability Index, the higher inlet pressure (13 Bar) is suitable.
2. The hydrodynamic cavitation process can be serving as a cost-effective option, and which can be used as an individual or in combination with other conventional treatment technique.

Nomenclature:

1. BI - Biodegradability Index
2. BOD- Biochemical Oxygen Demand
3. COD- Chemical Oxygen Demand
4. TOC- Total Organic Carbon
5. AD- Anaerobic Digestion
6. MBR- Membrane Bioreactor
7. HC- Hydrodynamic Cavitation.

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