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Sustainable Wastewater Treatment with Ultrasound Approach

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Peer Review Information	Abstract
<p><i>Submission: 21 Oct 2025</i></p> <p><i>Revision: 18 Nov 2025</i></p> <p><i>Acceptance: 05 Dec 2025</i></p>	<p>The change in environmental conditions are because of global warming, misuse of natural resources which further stresses on conservation of conventional sources and lead to optimize the usage of natural resources. The industrial effluent waste generated in the distillery analyser column is termed as Spent Wash is also listed amongst highest polluting industry. And therefore stringent norms against environmental protection also ask for recycling of industrial effluent. Traditionally, spentwash was treated with aerobic, anaerobic, incineration etc. processes. Recently AOPs gain a popularity in waste water treatment, such as photocatalysis, fenton process, ultrafiltration etc. in this article ultrasonication treatment was studied for the treatment of spentwash by varying parameters such as pH & concentration. It is found that this technique is efficient for the wastewater treatment.</p>
<p>Keywords</p> <p><i>Cavitation, Ultrasound, Waste water, Spentwash</i></p>	

Introduction

The wastewater discharged from numerous industries, considering the large quantities of effluent, is a concern for the environment. The chemical pollutants present in effluents such as dyes, heavy metals, pesticides, solvents, pharmaceutical drugs, aromatic compounds etc. are key threats to water quality. And if these pollutants are discharged into the atmosphere then water as well soil gets contaminated and becomes difficult to treat. Therefore, it is necessary to treat the waste water at source i.e. at industry or in the common effluent treatment plants. The conventional techniques are not converting these pollutants to degrade. Thus, there is an urgent need to introduce efficient processes to degrade these pollutants so as to comply with the environmental laws.[1]

The aqueous distillery effluent known as spentwash is a dark brown highly organic effluent. Hence, this effluent requires treatment before discharging to the environment. The alcohol to spentwash ratio is generally obtained as - 1:8-15. Traditionally spentwash was used as manure to fertile soil. It is observed that

spentwash is the most complex, troublesome and strongest organic effluent with high BOD and COD amount. Recently water contamination caused by organic compounds has become a serious concern around the globe. In this project removal of TDS, COD and BOD using efficient advanced treatment techniques is the objective. The experiments are to be performed in laboratory scale and consist of batch tests. Wastewater quality analysis is to be carried out using GC, UV-Vis Spectrophotometer. In addition to evaluating the design parameters of sonochemical reactor & capability, recovery ability is tested and evaluated. This is an adaptable technique in various applications.

Many industries apply ultrasound approaches in production processes but it has wide application in wastewater treatment also. It has been proved to be useful for many chemical, pharmaceutical, dyes & pesticides etc. industries wastewater treatment.[5] When liquid pressure is below the vapour pressure, vaporisation of liquid takes place. Due to this phenomenon bubbles form in low pressure regions and at high pressure regions these bubbles collapse. Due to

continuous formation & collapse of bubbles, temperature increases at water, which leads to thermal decomposition as well as damage of materials. During cavitation, water decomposes and oxidizing and reducing radicals are formed. That's why this condition is suitable for the degradation of many pollutants in water, wastewater[7].

Literature Review

The author combined hydrodynamic cavitation with different oxidants such as H₂O₂, ozone and persulphate to reduce COD of real effluent. The COD reduced to 7.9% using Hydrodynamic Cavitation alone whereas with the combination of H₂O₂ the COD reduction increased up to 40.3%. Further combination of Hydrodynamic Cavitation + H₂O₂ + O₃ showed COD reduction about 60.8%. This result of the Hydrodynamic Cavitation was compared with the result of ultrasonic reactors. It is concluded that COD reduction using US horn was higher than the hydrodynamic cavitation. Considering this analysis of power, yield, it concluded that HC reactors gives realistic potential for immediate commercial applications.[1]

Here the authors work focused on scientometric analysis for wastewater treatment with hydrodynamic and ultrasonic cavitation. The Cavitation method on wastewater treatments will have environmental friendly applications and also green, sustainable approaches towards increasing water pollution problems. Compared to other AOPs such as Fenton Process, Hydrogen Peroxide and Ultraviolet Radiation, Photocatalysts etc. the conventional hydrodynamic cavitation methods do not use additional chemicals. And hydrodynamic cavitation utilises a lower amount of energy than these AOPs, this represents potential application for industrial use. In ultrasonic cavitation formation of bubbles is due to pressure gradients by ultrasonic waves inside the liquid further those bubbles collapse to form the effect of cavitation. The range of frequencies from 16 kHz to 2 MHz results in cavities. Furthermore, pressure variations also produce hydroxyl radicals i.e. the reaction of water vapor with oxygen.[2]

Experiments were studied on the distillery spentwash samples. This study showed the effect of ultrasound on the effluent to analyse the biodegradability of the effluent. The results were compared for the pre-treated and untreated samples and the ultrasound increases the conventional aerobic oxidation process. The pre-treated effluent is further degraded by the microorganisms. Studies also presented that characteristics of the stored effluent were

changed and therefore the efficacy was decreased compared with the fresh sample. This US technique may be considered as the pre-oxidation step for the conventional aerobic oxidation technique applied for distillery wastewater treatment.[3]

Photocatalysis is usually 315-400nm & with Catalyst TiO₂, ZnO etc used. And in sonocatalysis ultrasonication with TiO₂ catalysis is done. In sonophotocatalysis sono ultrasonication & UV irradiation with catalyst is taken. Factors considered are ultrasonic frequency, intensity of radiation, radius of the bubble of the effect of acoustic cavitation.

Small intensity & more ultrasonic frequencies gives better degree of Mineralization of organic pollutants. The main parameters determining ultrasonic degradation of wastewater are, pH, temp., initial concentration, ultrasonic frequency. The efficiencies raised in processes were combining sonolysis with photolysis, Catalytic photolysis etc. were there. The advantage of an ultrasonic field is no extra additional pollution is generated.[5]

Over conventional wastewater treatment processes ultrasonic treatment is more efficient as well as time saving ultrasound is effective in degradation of many refractory organic pollutants. Author, mentioned three pathways by ultrasonic cavitation phenomena for degradation of organic compounds. i.e. At high temp pyrolysis, the second one is free radical oxidation in the region of high temp. & pressure & the is Supercritical oxidation reaction of water as at transition zone water is in a supercritical state having lower viscosity, diffusion coeff. same as gas & density as liquid. And this condition organic matter reacts & oxidizes to form peroxide ROOH, further it decomposes to water & CO₂ leading to complete degradation.

This review paper also listed factors affecting the ultrasonic degradation process as ultrasonic frequency, intensity, such as dissolved gas, pH value, Temp. Further combined other techniques with ultrasound were discussed. In ultrasound catalyst method. TiO₂, NaCl, Fenton Reagents, H₂O₂, MnO₂ may be used as catalysts. Ultrasonic technology for organic pollutants in water treatment applied for organic dyes, pesticides, aromatic hydrocarbons, and the alcohol industry. Refractory organic pollutants degradation by ultrasound technology developed in recent years. Technology combines characteristics application of incineration, supercritical oxidation & advanced oxidation technology & other ultrasound technology improves degradation efficiency. combination with other techniques makes treatment more

economically feasible. Overall the degradation of mixed, organic compounds broaden the scope of Sonochemistry application.[8]

Physico-chemical & biological treatments generally used to treat dyes from textile wastewater. Dyes are complex in nature & these methods do not eliminate completely the dyes elements. Hence traditional methods are very costly & it only converts primary pollutants to secondary pollutants with concentrated sludge. Therefore advanced treatments are needed to remove such pollutants without creating contamination. Such as AOPs & cavitation technology. This review paper includes two cavitation methods i.e. hydrodynamic & ultrasound. Cavitation reactors showed effective & economic options for textile wastewater. Various parameters optimisation is necessary for both hydrodynamic & sonochemical reactor.[9]

A laboratory scale reactor ultrasonic bath & ultrasonic horn carefully studied with limited range of operating parameters. The cavitation effect can be improved with additives which increase cavitation events or the intensity. The distribution of cavitation activity in reactor, strongly dependent on configuration of reactor in w.r.t. transducers number & geometry.[10]

METHODOLOGY

Ultrasonic waves as useful instrument for water purification is well known. Effective application of the ultrasonic purification process requires consideration of a number of parameters, while time, temperature and chemical nature of the particle remain important in ultrasonic as they are in other purification technologies, there are other factors which must be considered to maximize the effectiveness of the process. Especially important are those variables which affect the intensity of ultrasonic cavitation in the liquid. For maximizing the cavitation very important is to precisely manage the temperature which is the most important single parameter to be considered in maximizing cavitation intensity.[11]

Experimentation

The effluent collected from industry was filtered to separate the suspended solids, and used for further study. The pH of the raw effluent was 3.8-3.9. Sonicator had a fixed frequency of 20 kHz. The body of sonicator was made of steel with one transducer attached. A sonicator is depicted in Fig. 1.

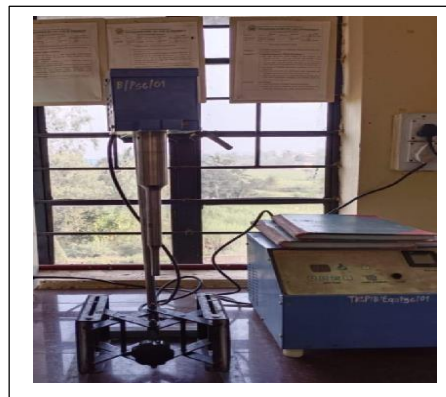


Figure 1: Sonicator Setup

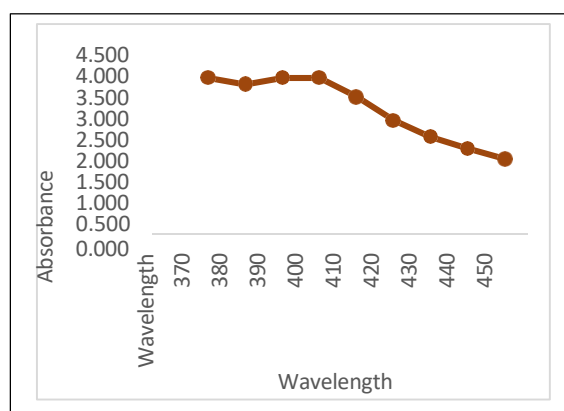


Figure 2: Absorbance vs. Wavelength

The effluent was studied for different Concentration & pH. Different ppm solution of filtered spentwash was prepared first to find out the wavelength of the solution. Concentration vs absorbance curve were obtained with 10 ppm to 100 ppm solution. Also 2 pH to 10 pH samples were prepared by adding dosage of 1N HCL & NaOH solution to get variation in pH. This sample were allowed in sonicator for treatment for each 2 mins. After that the absorbance were taken through use of spectrophotometer.

Result And Discussion

Initially the experiment was carried out to finalize wavelength of the effluent. 400nm wavelength were finalised. Latter on absorbance were recorded for different concentration to fix the standard plot of absorbance vs. concentration. Same was represented in following figures. Similarly, the result of experiment of pH is 6.

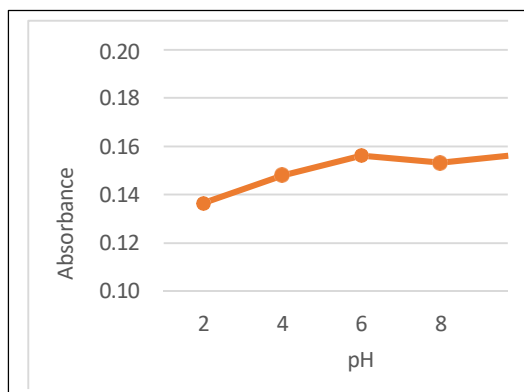


Figure 3: Absorbance vs pH.

Conclusion

The work demonstrated the effective use of sonication oxidation processes for the treatment of industrial effluent. Literature review summarises the important of waste treatment, new techniques for the same. Further studies with the distillery industrial effluent using ultra sonication have been presented and speaks about the broad scope and application on waste water treatment.

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