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Critical View of Ultrasonic Removal Applied to Industrial Effluents

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ABSTRACT—*The work aims to bring together, across disciplines, some knowledge in the development of new clean technologies for the disposal of industrial contaminants, which are difficult to remove by conventional methods, using an ultrasound cavitation bubbles generator. The main aim of this study is to show that the efficiency of the application of sonic waves depends on the types of equipment used. Laboratory tests have shown that phenols and organochlorines compounds can be destroyed by ultrasonic technique aiming at its implementation of these compounds in industrial effluents.*

Keywords — Ultrasonic, effluents, clean technologies, laboratory tests**.**

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1. INTRODUCTION

Currently, the world order converges towards the establishment of environmental protection, mainly on the basis of the definition of environment, which does not put humans as an outside party to that medium, but as an integral and fundamental part of current and future decisions. Consequently, rigor was increased with regard to control of the quality of the environment as a factor that is essential to the maintenance of ecological balance.

However, from the viewpoint of Mainier et al. [1], production systems, knowing the risks of their industrial manufacturing processes and seeming not to care about the present or the future, continue to exert strong pressure on the environment, imposing or masking obsolete technologies that encompass waste, packaging, recycling and hazardous waste, which are themes that often get confused.

The large industrial complexes are most often interested in their commercial gains, showing little concern about man and the environment.

With regard to wastewater treatment, the companies adopt two types of technological routes: the treatment of waste at the end of the process (end-of-pipe) and the development of clean technologies (clean technology) that are applied to treatment and develop along the way.

The first technology is conventional and traditional. It incorporates the concentration and controlled disposal and treatment of waste in specific areas, with waste treatment policies that are deemed acceptable by national and international environmental agencies. The photographic sequence presented in Figure 1 shows a reasonable distance between several factories and wastewater treatment units, following the philosophy of "end-of-pipe".

Based on critical environmental vision, the following questions can be posed to the designers and engineers of these industries:

- Why are the effluent treatment units so far from the industrial plants?
- Is there an obscure intent to hide this from organized society?
- Will odors exhaled by those units contribute to this fact?
- During the professional training of engineers, was there the premise that the waste must always be at the end of an industrial process?
- Will the inhabitants of the area neighboring the effluent treatment plant, who are often poor, find the area permanently contaminated by odors from these plants?

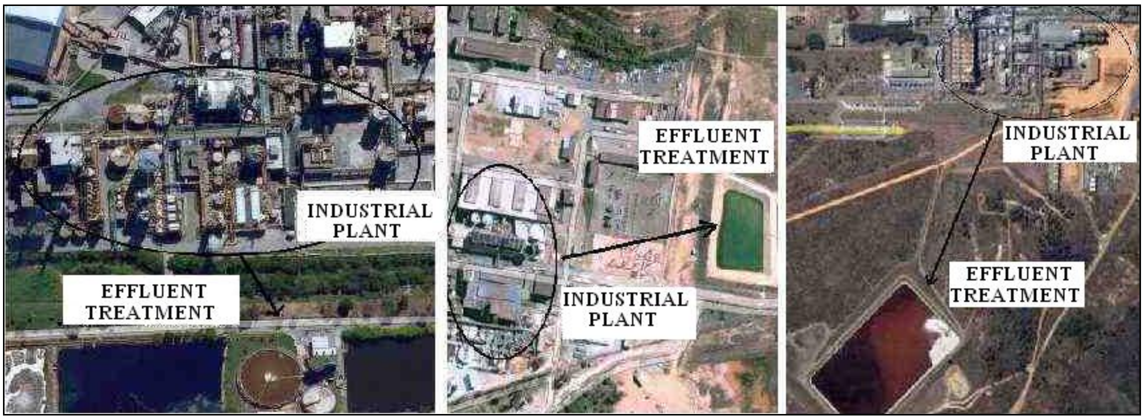

Figure 1: Image of factories and their effluent treatment units.
Source: Google maps.

These are tough questions which need to be answered by considering the evidence of some of the aerial photos of industrial units presented in this article.

Clean technologies make traditional technologies obsolete and can be defined as the set of methods and techniques that are aimed at the minimization of waste and energy with the central aim of preservation of the environment; therefore, adopting environmental management standards is essential.

The raw materials and energy needed to proceed should be optimized and integrated with the production and consumption cycle, in such a way as to minimize the environmental impact. In addition, the segregation of chemical processes provides a more direct treatment in a lower proportion.

It has been shown that the effluent treatments must be performed at the source of pollution. What we have observed is usually the need for great effort with a high cost in order to treat the final contaminated system, when, in fact, most of the analyses show that one should treat the effluent contaminant at its source rather than at the end of the process.

There is no doubt that the development of chemical products in the modern world to develop pharmaceuticals, personal care products, food additives, plastics and pesticides, among others, have brought, directly or indirectly, a countless amount of benefits the society. However, on the other hand, emissions as a result of these products in the environment have created a number of concerns, both in the springs, as well as in soils and water provided for people [2, 3].

More and more researchers have devoted efforts toward environmental protection, and have sought new methods and technological innovations to be applied to the treatment of industrial waste. Research into the use of sound waves for environmental protection has received prominent attention for various reasons. A large number of researchers have studied the effect of ultrasonic waves, based on the phenomenon of cavitation, for the destruction of chemical and biological pollutants in water [4].

Studies on the elimination of chemical pollutants by means of ultrasound involve multidisciplinary knowledge, mainly in the areas of engineering such as transport phenomena, electricity, electronics, physics, chemistry, materials, etc. [5, 6, 7].

In the area of sonochemistry, in which ultrasound is the basis of the transformation process, its application in the environment has been based on the changes in the chemical structures involved. The use of ultrasonic waves can be highlighted in several processes of environmental protection. Another important application of cavitation resulting in a performance effect of ultrasound waves is the removal of chemical contamination; for example, the direct oxidation of chemical waste and pesticides in combination with other techniques such as using ozone, electrolysis and ultraviolet (UV) light.

For the development in this technology, the importance of developing the construction of ever more efficient equipment that can perfect the technique of sonochemistry in liquid systems remediation processes is noted [8].

2. METHODOLOGY

The work in question, an interdisciplinary approach, brought together some of the necessary and fundamental knowledge in the development of ultrasound technology for application to the reduction and/or elimination of contaminants in industrial effluent.

This concept was developed from a study of literature on the issue of environmental contamination, incorporating books, journal, articles, legislation, and national and international standards. Research was also carried out with chemicals that can be destroyed by the technique of ultrasound based initially held at laboratory mounting. The results, which show promise, are focused on the process of the reduction of industrial contaminants such as phenol and other organochlorine chemicals, which are often used in certain agrochemical formulations.

Based on these facts, the objectives of this study are: first, to show that the technology of ultrasound is promising enough to eliminate or reduce toxic contaminants present in industrial effluents; secondly to draw the attention of professionals, HSE (health, safety and environment) consultants, public and private managers, to the need for understanding the toxic and corrosive effects of industrial contaminants; and thirdly, search for techniques appropriate for the preservation of industrial facilities, human health and the environment using the philosophy of clean technologies.

3. ULTRASONIC TECHNIQUE APPLIED TO THE REMOVAL AND/OR REDUCTION OF THE LEVELS OF CONTAMINANTS IN INDUSTRIAL EFFLUENTS

According to the papers of Mason & Lorimer [9] and Lickiss [10], ultrasound can be defined as the emission of more than 16 kHz of sound, which is not recognized by the human ear. Figure 2 shows the range of sound waves in cycles per second (hertz-Hz), where some sound samples are issued by mosquitoes, grasshoppers and bats.

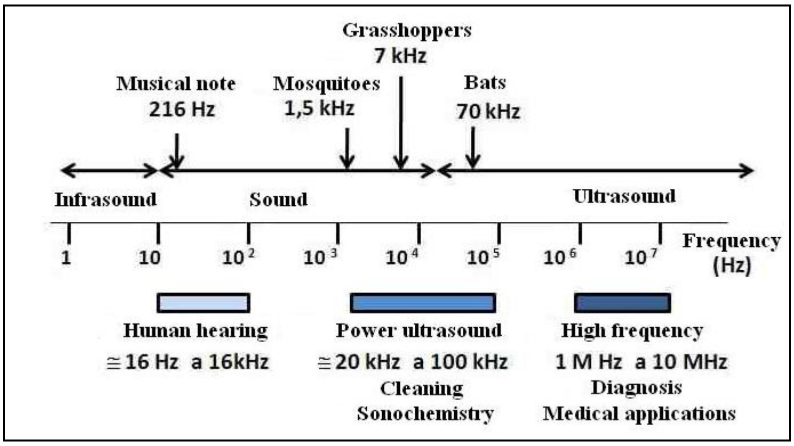

Figure 2 – Spectrum of sound waves.
Source: Lickiss [10].

High frequency is used for medical applications aiding in diagnosis, the evaluation of faults in materials (metallic and non-metallic) and is even used in submarine sonar. In medical diagnostics, sonic high frequency is used in the range of 1 to 10-MHz (low power), as at this frequency there is little possibility of physical and chemical changes that affect the patients' health.

Sonochemistry is defined as the physical-chemical interaction of ultrasound. Is held in a low frequency sonic in 20-100 kHz range and high power. Still, according to Lickiss [10], there is no direct interaction between molecular vibrations and sound waves; however, low-frequency ultrasound generates micro-bubbles or cavities in aqueous solutions. The growth and collapse of these micro-bubbles in the solution instantly generate very high temperatures and pressures.

On the point of collapse, that is, the steam inside the micro-bubble phase, the temperature can reach up to about 5000 °C, while the pressure in these conditions is in the order of 1000 atmospheres.

In the view of Gong & Hart [11], the intensity and the reactivity of the chemical reactions associated with high-power sonic waves are governed by the following parameters: amplitude and frequency of ultrasound, temperature, surface tension, vapor pressure, gas content in solution and geometry of the ultrasonic transducers.

According to Garbellini et al. [12], the literature report several research works aimed at the elimination of contaminants in industrial effluents and indicate that there are three areas that must be evaluated in treatment processes using an ultrasound system. In the first phase are the micro-bubbles, which instantly form cavitation due to high temperatures and pressures.

In this case, pyrolysis of the constituents can be demonstrated; also, atomic hydrogen (H) and radicals ($OH^{\bullet}$, $HOO^{\bullet}$) can also occur, which assist in the destruction of organic contaminants. In the second region is the limit where the temperature is lower. In this region, thermal decomposition of the contaminant can occur, while in the third region, reactions occur between the contaminants and the radicals formed by the high-power sonic waves. Even in small amounts, for example a few parts per million, phenol and its derivatives cause unpleasant odors and toxicity in water.

Phenol has been listed as the main pollutant in the list of US Environmental Protection Agency and the allowable concentration of phenol in effluent is less than 1 ppm. The degradation of phenol to low levels, called activated sludge, is not possible in conventional biological processes. Derivatives also receive special attention, for example p-nitrophenol [13].

Works published by Mason & Lorimer [9] show the reduction of phenol in water using low-frequency ultrasound and high-power, as shown in Figure 3. The graph shows that the total destruction of phenol occurs after 100 minutes of exposure and also shows that, initially, a small amount of phenol itself turns into two intermediate products: hydroquinone and catechol.

Later, after 190 minutes, these two intermediates are completely destroyed. Total destruction reactions of phenol are presented, showing the formation of CO_2, CO and HCOOH. Ideally, this process transforms the phenol (C_6H_5OH) into CO_2 and H_2O; however, this only occurs with the addition of ozone (O_3) to ultrasonic reduction [9].

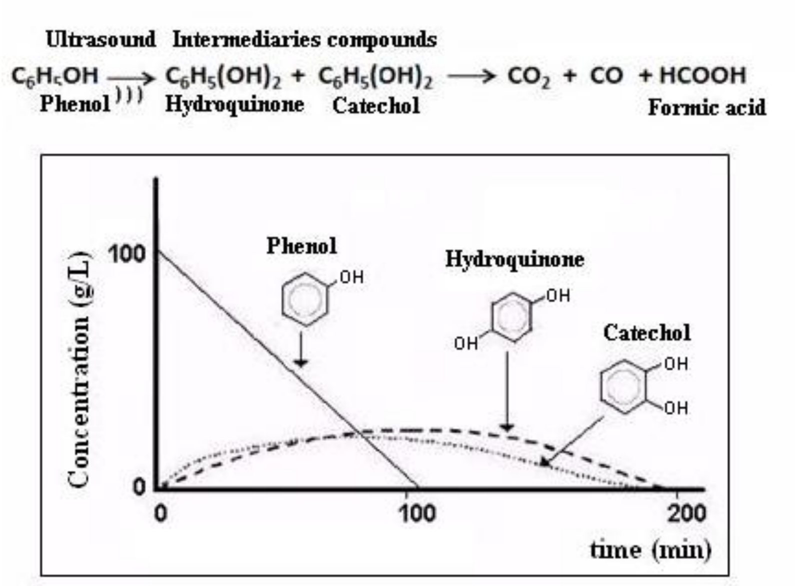

Figure 3 – Graph of the destruction of phenol by ultrasound.
Source: Mason & Lorimer [9].

Lately, interest in the application of advanced oxidation processes for the removal of phenol from wastewater has increased. Sonication for the degradation of phenol has been shown to be an attractive process for operating in normal conditions of operation and at a low cost. The direct action of ultrasonic waves has shown in some cases to result in low yield; however, the use of additives such as sodium chloride, sodium bicarbonate, carbon tetrachloride and ozone increases the yield of the process [14, 15].

Most studies on the degradation of phenol and phenolic substituents by sonochemistry indicate that phenol degradation is greater when the frequency is higher (> 500 kHz). However, phenol can be degraded at lower frequencies (22 kHz) under more prolonged high-intensity radiation (75 W/cm²).

4. LABORATORY EXPERIMENTS

According to Mason & Lorimer [9], the laboratory equipment that is currently available for use in the treatment of industrial effluents comprises two main types. The first type, shown in Figure 4, consists of a stainless steel container with ultrasonic transducers placed at the bottom of the container. When the sonic power is applied, the spread of sonic waves occurs through the water surrounding the sample which is inside the glass Erlenmeyer flask. The chemical transformations that occur in the sample are a function of time, the physicochemical characteristics of molecule and the possible association with other chemical contaminants, such as those formed by the use of ozone and/or electrolysis.

The second type of ultrasound refers a high-power titanium cell that can be inserted directly into the sample, as shown in figures 5 and 6.

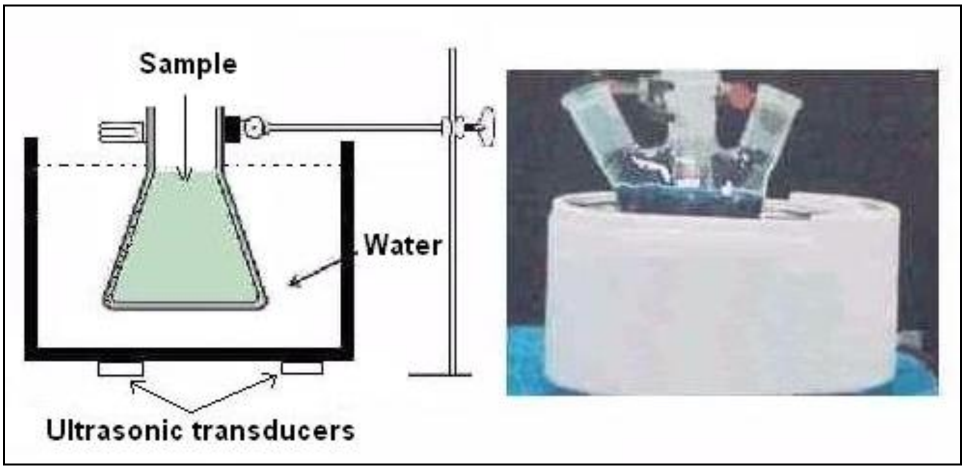

Figure 4 - Laboratory ultrasonic bath.
Source: Lickiss [10].

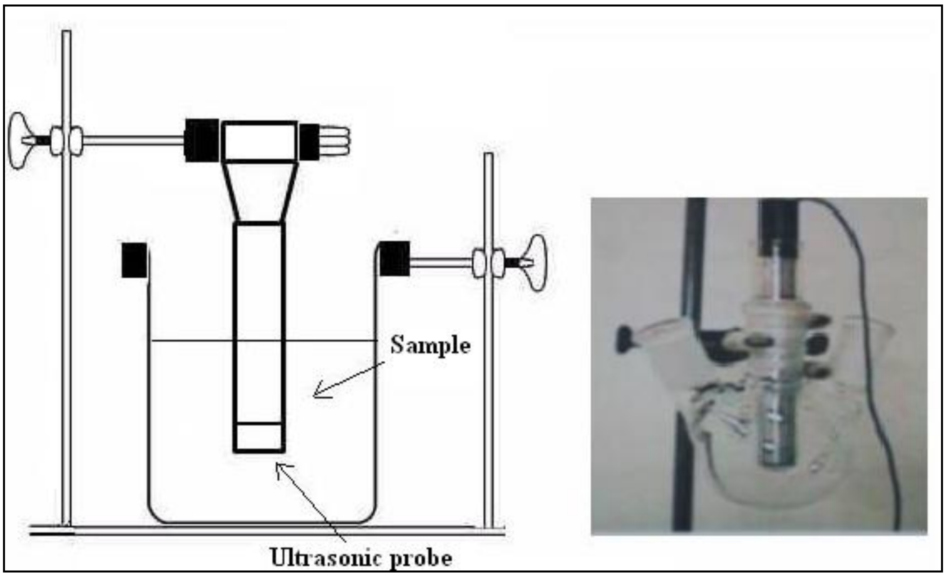

Figure 5 – Ultrasonic laboratory Cell for direct placement in the sample.
Source: Lickiss [10].

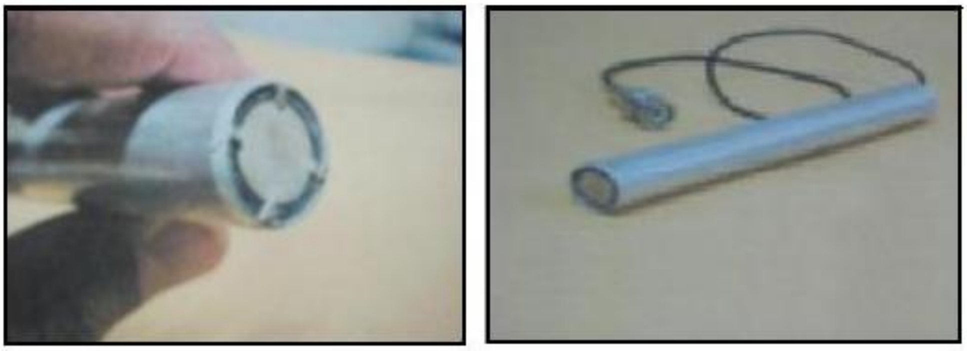

Figure 6 – Ultrasonic laboratory probe for direct placement in the sample.

The ultrasonic probe has a kind of megaphone that is capable of amplifying the vibrations of the transducer, whereas the pads used in piezoelectric ceramics emit sonic waves with slight variations. So that they can be used directly in the samples, the ultrasound system is encapsulated in a tube of titanium or other alloys with greater resistance to corrosion. The high temperature generated in these probes results in the need for a constant cooling.

5. TESTS RESULTS

The results of the laboratory tests with ultrasound using phenols and organochlorides are still incipient; however, qualitatively, these techniques have presented promising results for contaminant reduction of phenols and some organochlorine products. The various types of probes and static ultrasound baths show the possibility for use on an industrial scale.

6. CONCLUSIONS

Based on the literature search and the results of fledgling laboratories, it can be concluded that:

- It is essential to develop new techniques and technologies targeted at destroying and/or reducing toxic contaminants in industrial effluents; adaptation of these technique is still experimental in the segregation of products in existing industrial plants;
- The use of ultrasonic waves for the treatment of industrial effluents, which was previously difficult, shows the possibility for new techniques to be identified to solve this problem;
- Once developed, an ultrasound probe can be used to build equipment with continuous reactors; these reactors may have different frequency values arranged;
- By analyzing the information found in the specialized literature, it appears that this form of high-energy transmission has a very characteristic set of interdisciplinary;
- It is necessary to re-evaluate and restructure the industrial projects in such a mode that the environmental effects of social, economic and political processes can be identified in the planning phase of the project, before deployment decisions are adopted.

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