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Review on the recent improvements in sonochemical and combined sonochemical oxidation processes – A powerful tool for destruction of environmental contaminants

Panneerselvam Sathishkumar [a,b,*], Ramalinga Viswanathan Mangalaraja [a,**], Sambandam Anandan [c]

[a] Advanced Ceramics and Nanotechnology Laboratory, Department of Materials Engineering, Faculty of Engineering, University of Concepcion, Concepcion 407-0409, Chile
[b] Department of Chemistry, Periyar Maniammai University, Vallam, Thanjavur 613403, Tamil Nadu, India
[c] Nanomaterials and Solar Energy Conversion Lab, Department of Chemistry, National Institute of Technology, Trichy 620015, India

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ABSTRACT

The last two decades research demonstrate that the presence of organic contaminants in drinking water has increased every year and the increasing demand for the technology to reclaim the water from the effluents released by the industries has persuaded us to write the review in this topic. The combination of advanced oxidation processes (AOPs) namely photocatalysis, Fenton and ozonolysis combined with sonolysis harvests the degradation of wide spectrum of organic contaminants. The various parameters including the geometry of the sonochemical reactors influencing the sonochemical reactions have been discussed. The combination of sonolysis with photocatalysis, Fenton and ozonolysis enhances the production of non-selective radicals to improve the degradation process thus avoiding the secondary pollution. The economical and technical feasibilities of the AOPs are very essential for the initialization of the combined AOPs for the degradation of environmental contaminants. The review envisions to improve our understanding and outline directions for future research.

Contents

1. Introduction

In the forthcoming years, worldwide crisis may arise for energy, food and water; however, the three are inter-connected and water is essential for all social and economic developments among the nations [1]. During the past two decades, considerable increase in the concentration of organic contaminants in surface water has been observed [2,3]. On the other hand diseases spread through

* Corresponding author at: Advanced Ceramics and Nanotechnology Laboratory, Department of Materials Engineering, Faculty of Engineering, University of Concepcion, Concepcion 407-0409, Chile. Tel.: +56 41 2207389; fax: +56 41 2203391.
** Corresponding author. Tel.: +56 41 2207389; fax: +56 41 2203391.
E-mail addresses: sathish_panner2001@yahoo.com (P. Sathishkumar), mangal@udec.cl (R.V. Mangalaraja).

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Table 1
Some reactions involved in advanced oxidation processes [19,20].

Advanced oxidation process	Reaction steps
Sonolysis	$H_2O+)))\rightarrow {}^{\bullet}OH+OH^-$ $H_2O+)))\rightarrow(1/2)H_2+(1/2)H_2O_2$
Semiconductor photocatalysis (TiO_2-semiconductor)	$TiO_2+h\nu\rightarrow TiO_2^-+{}^{\bullet}OH$ (or TiO_2^+) $TiO_2^-+O_2+H^+\rightarrow TiO_2+{}^{\bullet}OH+H_2O$ $TiO_2^-+2H^+\rightarrow TiO_2+{}^{\bullet}H_2$ $H^++H_2O\rightarrow {}^{\bullet}OH+H^+$
Fenton reactions	$Fe^{2+}+H_2O_2\rightarrow Fe^{3+}+{}^{\bullet}OH+OH^-$
Ozonolyis	$O_3^{\bullet}+H_2O\rightarrow 2HOO^{\bullet}$ $O_3+2HOO^{\bullet}\rightarrow {}^{\bullet}OH+2O_2$
Sonophotocatalysis (with H_2O_2)	
(i) **Water sonolysis**	$H_2O+)))\rightarrow {}^{\bullet}OH+OH^-$ $H_2O+)))\rightarrow ½H_2+½H_2O_2$
(ii) **Reaction of H_2O_2 with H atoms (formed from water sonolysis)**	$H_2O_2+H^{\bullet}\rightarrow H_2O+{}^{\bullet}OH$
(iii) **Photolytic dissociation of H_2O_2**	$H_2O_2+h\nu\rightarrow 2{}^{\bullet}OH$
(iv) **Reaction of H_2O_2 with superoxides (formed in the presence of TiO_2 and under UV irradiation)**	$H_2O_2+O_2^{\bullet-}\rightarrow {}^{\bullet}OH+OH^-+O_2$
(v) **Reaction of H_2O_2 with electrons (conduction band electrons are generated from semi-conductor photocatalyst under UV irradiation**	$H_2O_2+e^-\rightarrow {}^{\bullet}OH+OH^-$
UV+hydrogen peroxide+ozone	$O_3+OH^-\rightarrow {}^{\bullet}OH$ $3O_3+h\nu\rightarrow 2{}^{\bullet}OH$ $H_2O_2+h\nu\rightarrow 2{}^{\bullet}OH$ $H_2O_2+O_3\rightarrow 2{}^{\bullet}OH$
Ozone+sonolysis	$H_2O+)))\rightarrow {}^{\bullet}OH+OH^-$ $H_2O+)))\rightarrow ½H_2+½H_2O_2$ $O_3+)))\rightarrow O_2$ (g)$+O$ (^3P) (g) O (^3P) (g)$+H_2O$ (g)$\rightarrow 2{}^{\bullet}OH$

water which is not suitable for usage in day to day life of human beings. As a result of the usage of polluted water, water borne diseases spread throughout the world and in the worst case it causes the mortality of children [4,5]. Naturally available drinking water is rare and limited nonetheless it is needed for all domestic and commercial applications which clearly illustrates how even a small shortage of water could become a threat to mankind. In day to day life, the environmental pollution is appears to be very much responsible for the negative consequences in the lives of all beings on the earth. The ingestion of chemical substances into the water bodies by the consumers destroys the quality of water continuously, which is called aquatic pollution. The contaminating (foreign) substances are generally classified into organic and non-organic contaminants, while Adewuyi classifies the contaminating pollutants into various categories [6]. The discharge of the un-mineralized contaminants, for example effluents released from the textile industries, pulp and paper industries, pharmaceutical industries etc., into the water resources causes environmental pollution. Similarly, non-organic substances, for example, excessive addition of agricultural chemicals causes water as well as land pollution [7]. The release of these un-neutralized pollutants into the environment creates detrimental effects and adulteration of these chemicals into the water bodies not only creates health hazards to the human beings but also affects the aquatic organisms. For example the presence of 4-nonylphenol (endocrine disrupter) in sewage disposal plants creates the feminizing effects in fishes which is a serious problem in terms of ecological conservation [8–10].

To avoid the hazardous effects created by the presence of these chemicals, many methodologies such as adsorption [11], biodegradation [12,13], photocatalysis [14] and ozonation [15] are proposed one by one from the early 1970s for the initiation of degradation of environmental pollutants [16–18]. As a result of these innovations, some awareness has been created among the public by the researchers about environmental pollutants. Many research groups have started working towards the complete removal of these pollutants from the environment by proposing, developing and adopting the new technologies for the degradation

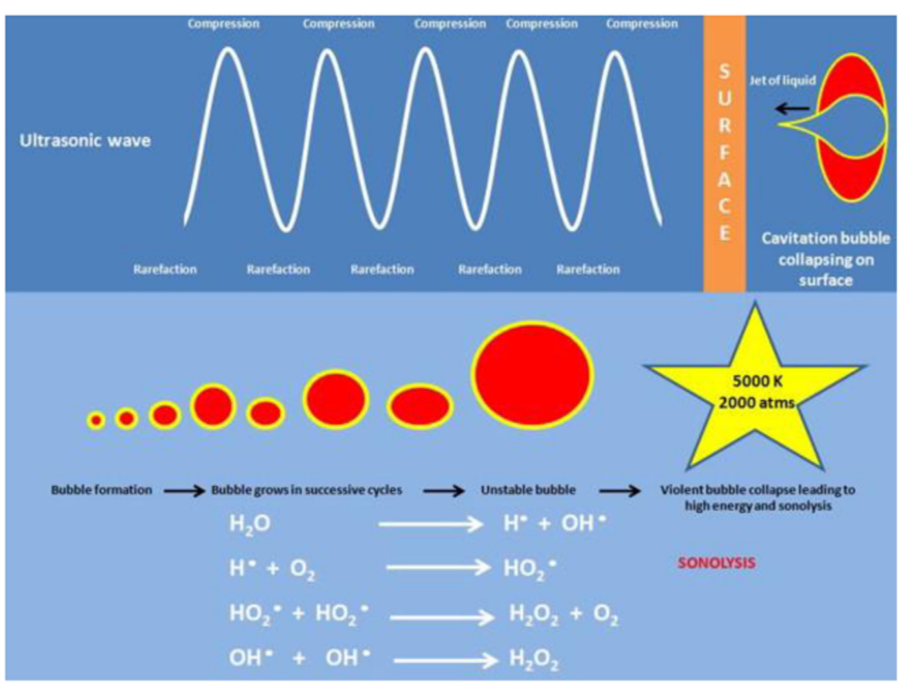

Fig. 1. Generation of an acoustic bubble [39].