Available online at www.sciencedirect.com

ScienceDirect

www.journals.elsevier.com/journal-of-environmental-sciences

JOURNAL OF ENVIRONMENTAL SCIENCES
www.jesc.ac.cn

Invited article

# An executive review of sludge pretreatment by sonication

*Ngoc Tuan Le*[1,2,*], *Carine Julcour-Lebigue*[2], *Henri Delmas*[2]

1. *University of Science, Vietnam National University, Ho Chi Minh City, Viet Nam. E-mail: ltuan@hcmus.edu.vn*
2. *Université de Toulouse, Laboratoire de Génie Chimique, INP-ENSIACET, France*

ARTICLE INFO

*Article history:*
Received 9 December 2014
Revised 4 May 2015
Accepted 15 May 2015
Available online 4 November 2015

*Keywords:*
Ultrasonic pretreatment
Waste activated sludge
Sludge disintegration
Acoustic frequency
Intensity effect
Pressure effect

ABSTRACT

Ultrasonication (US), which creates hydro-mechanical shear forces in cavitation, is an advanced technology in sludge pretreatment. However, there are many factors affecting the efficacy of cavitation and ultrasonication disintegration of sludge as a consequence. The objective of this work is to present an extensive review of evaluation approaches of sludge US pretreatment efficiency. Besides, optimization methodologies of related parameters, the differences of optimum values and the similarities of affecting trends on cavitation and sludge pretreatment efficiency were specifically pointed out, including ambient conditions, ultrasonic properties, and sludge characteristics. The research is a prerequisite for optimization of sludge US pretreatment efficiency in lab-scale and practical application. There is not-yet a comprehensive method to evaluate the efficiency of sludge US pretreatment, but some main parameters commonly used for this purpose are degree of sludge disintegration, proteins, particle size reduction, *etc.* Regarding US parameters, power input $P_{US}$, intensity $I_{US}$, and frequency $F_S$ seem to have significant effects. However, the magnitude of the effect of $P_{US}$ and probe size in terms of $I_{US}$ has not been clearly detailed. Investigating very low $F_S$ seems interesting but has not yet been taken into consideration. In addition, static pressure effect has been marginally studied only and investigation on the effect of pH prior to US process has been restricted. Their effects therefore should be varied separately and simultaneously with other related parameters, *i.e.* process conditions, ultrasonic properties, and sludge characteristics, to optimize sludge US pretreatment process.



## Introduction

Anaerobic digestion of sludge, an efficient technology for sludge treatment, facilitating mass reduction, odor removal, pathogen decrease, and energy recovery in the form of methane, is a complex and slow process. Hydrolysis is known as the rate-limiting step, and thus requires a pretreatment of sludge which ruptures the cell wall and facilitates the release of intracellular matter into the aqueous phase to improve biodegradability and enhance anaerobic digestion.

There are some very popular techniques used in sludge pretreatment, such as biological, thermal, mechanical, chemical, and electrical methods (Carrère et al., 2010; Kopplow et al., 2004; Rittmann et al., 2008; Salerno et al., 2009; Keles et al., 2010; Mahmoud et al., 2010; Pham, 2011; Rynkiewicz, 2011). In their review, Pilli et al. (2011) claimed ultrasonication (US) to be a

* *Corresponding author at: University of Science, Vietnam National University, Ho Chi Minh City, Viet Nam.*
E-mail address: ltuan@hcmus.edu.vn (N.T. Le).

http://dx.doi.org/10.1016/j.jes.2015.05.031
1001-0742/

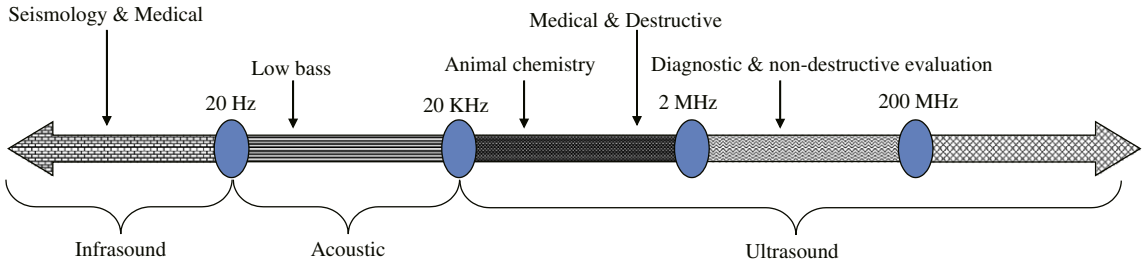


**Fig. 1 – Diagram of sonication range (Pilli et al., 2011).**

feasible and promising mechanical disruption technique for sludge disintegration and microorganism lysis according to the treatment time and power, equating to specific energy input (ES). Some positive characteristics of this method are efficient sludge disintegration (Pilli et al., 2011), improvement in biodegradability and bio-solid quality (Khanal et al., 2007), increase in biogas/methane production (Onyeche et al., 2002; Barber, 2005; Khanal et al., 2007), no need for chemical additives (Mao et al., 2004), less sludge retention time (Tiehm et al., 1997), and sludge reduction (Onyeche et al., 2002).

This article presents an extensive review of sludge pretreatment by sonication, including sludge types and properties, brief background of sonication, evaluation approaches of sludge US pretreatment efficiency, and optimization of ultrasonic pretreatment of sludge.

## 1. Sludge types

### 1.1. Primary sludge

Primary sludge was produced through the mechanical wastewater treatment process, is decayable and must be stabilized before being disposed of (Liu and Liptak, 1999). Primary sludge is easily biodegradable since it consists of more easily digestible carbohydrates and fats. Biogas therefore is more easily produced but the methane content of the gas is lower.

### 1.2. Waste activated sludge (WAS)

WAS coming from the secondary wastewater treatment, consists largely of biological mass and large amount of pathogens, causes odor problems, and thus must be stabilized (Lin et al., 1999). Activated sludge is more difficult to digest than primary sludge.

### 1.3. Digested sludge

The residual product after anaerobic digestion of primary and activated sludge, is reduced in mass, less odorous, and safer in the aspect of pathogens and easier dewatered than the primary and activated sludge types (Liu and Liptak, 1999).

## 2. Brief background of sonication

The diagram of sonication range is presented in Fig. 1. When propagating in a solution, ultrasound waves generate compressions and rarefactions. If a sufficiently large negative pressure is applied during rarefaction, acoustic cavitation will

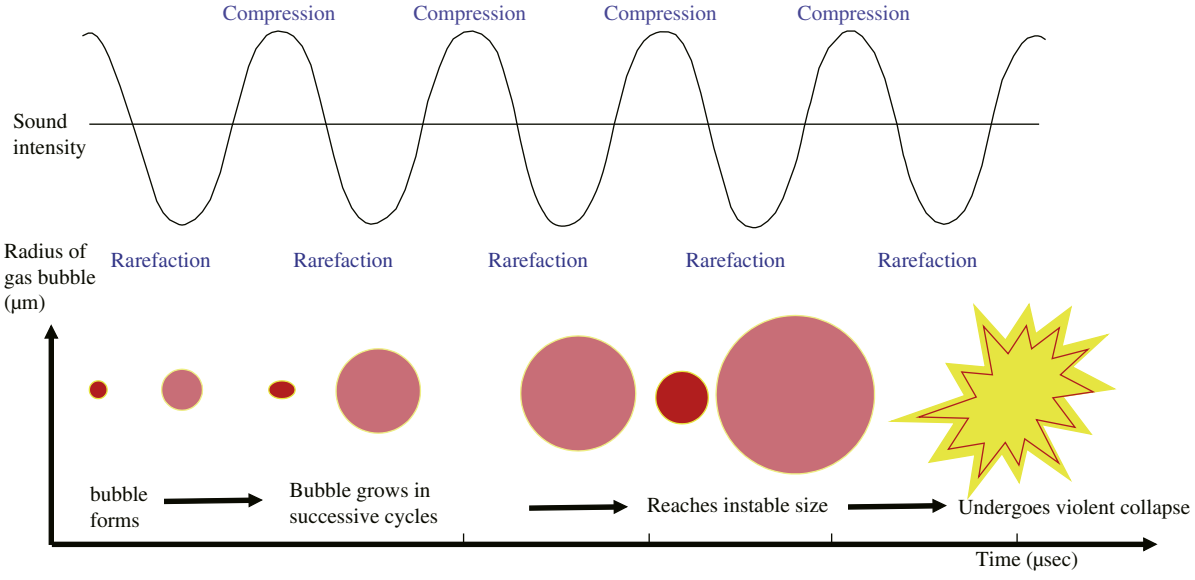


**Fig. 2 – Formation and collapse press of a cavity.**