

UNIVERSITÀ DEGLI STUDI DI UDINE  
DOTTORATO DI RICERCA IN  
TECNOLOGIE CHIMICHE ED ENERGETICHE



# EFFECT OF ULTRASOUND PRE-TREATMENT ON WASTE ACTIVATED SLUDGE ANAEROBIC DIGESTION

Dott. Michela SIMONETTI



## COMMISSION

---

Prof. Hai DO NGUYEN  
Prof. Roberto RAGA  
Prof. Alessandro TROVARELLI  
Prof. Albin PINTAR  
Dr. Antonino Salvatore ARICO'  
Prof. Daniele GOI

REVIEWER  
REVIEWER  
REFEREE  
REFEREE  
REFEREE  
SUPERVISOR

---

Prof. Alfredo SOLDATI

DIRECTOR OF PH.D. PROGRAM

Author's e-mail: michela.simonetti@uniud.it

Author's address:

Dipartimento di Chimica,  
Fisica e Ambiente  
Università degli Studi di Udine  
Via del Cotonificio, 108  
33100 Udine – Italia  
tel. +39 0432 558827  
fax. +39 0432 558803

Ai miei genitori



---

# Contents

<b>Introduction</b>	<b>1</b>
<b>1 Theory</b>	<b>5</b>
1.1 Fundamentals of ultrasound treatment . . . . .	5
1.1.1 Ultrasound disintegration mechanisms . . . . .	5
1.1.2 Factors influencing the cavitation phenomena . . . . .	6
1.1.3 Ultrasound generation . . . . .	8
1.1.4 Power and energy quantification . . . . .	11
1.1.5 Evaluation of ultrasound disintegration efficiency . . . . .	12
1.2 Fundamentals of anaerobic digestion . . . . .	17
1.2.1 Anaerobic digestion process basic theory . . . . .	18
1.2.2 Variables influencing anaerobic digestion . . . . .	18
1.2.3 BMP test . . . . .	23
1.2.4 Effect of ultrasound pretreatment on anaerobic digestion . . . . .	26
1.3 Fundamentals of respirometry . . . . .	29
1.3.1 Oxygen uptake rate (OUR) . . . . .	29
1.3.2 Classification of respirometers . . . . .	29
1.3.3 Ultrasonic treatment and anaerobic digestion test performance evaluation by respirometric techniques . . . . .	30
<b>2 Materials and Methods</b>	<b>33</b>
2.1 Sample . . . . .	33
2.2 Apparatus . . . . .	35
2.2.1 Ultrasonic disrupter . . . . .	35
2.2.2 Set up of batch anaerobic digestion system . . . . .	38
2.2.3 Set up of respirometer . . . . .	40
2.3 Parameters . . . . .	44
2.3.1 COD and soluble COD-Method 5220 D of Standard Methods . . . . .	44
2.3.2 TOC-Method 5310 B of Standard Methods- and TN . . . . .	45
2.3.3 UV254 Absorption -Method 5910 B of Standard Methods . . . . .	46
2.3.4 Nitrogen, ammonia -HACH colorimetric method adapted from Standard Method . . . . .	47
2.3.5 Phosphorus -HACH colorimetric method adapted from Standard Method . . . . .	48
2.3.6 Total and Volatile Solids -Method 2540 B and 2540 E of Standard Methods . . . . .	48
2.3.7 Carbon and Nitrogen (on dry basis) . . . . .	49

---

2.3.8	Biogas composition . . . . .	49
2.3.9	Microscopic observations . . . . .	49
2.3.10	Particle size analysis . . . . .	49
<b>3</b>	<b>Results and Discussion</b>	<b>51</b>
3.1	Ultrasound treatment results . . . . .	51
3.1.1	Physical evaluation . . . . .	51
3.1.2	Chemical evaluation . . . . .	55
3.1.3	Final considerations . . . . .	60
3.2	Batch anaerobic digestion results . . . . .	62
3.2.1	Anaerobic digestion tests at F/I = 0.5 . . . . .	62
3.2.2	Anaerobic digestion tests at F/I = 1 . . . . .	64
3.2.3	Comparison between different F/I ratio . . . . .	67
3.2.4	Energy considerations . . . . .	69
3.2.5	Final considerations . . . . .	70
3.3	Respirometric test results . . . . .	70
3.3.1	SOUR test results . . . . .	70
	<b>Conclusions</b>	<b>73</b>
	<b>Bibliography</b>	<b>77</b>