

Hydrodynamic cavitation for the degradation of Methyl orange dye

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Highlights

- The study of decolorization of dyes through hydrodynamic cavitation was performed.
- A comparative study between a Venturi tube and an orifice plate was described.
- The optimal values of operating conditions were addressed.
- Under optimal conditions almost 100% decolorization yields were obtained.

1. Introduction

Industrial wastewater coming from the textile industry contains a series of toxic compounds, as for example dyes. These spent solutions cannot be discharged in the sewer without any processing. It is estimated that around 10-20% of the total dyes used during the production processes of the textile and paper industries is released into the environment [1]. The colored wastewaters cause significant damage to the environment as eutrophication and problems to the aquatic environment. Usually, physical and chemical processes (as flocculation, flotation, membrane filtration, ion-exchange, coagulation precipitation, ozonation and adsorption using also activated carbon) combined with biological ones are used to treat dye wastewaters. These treatments present good removal efficiency but in some cases the degradation of dye appears very difficult for the presence at high concentration of some types of colour pigments. An alternative to the traditional processes is represented by the advanced oxidation processes (AOPs) as Fenton's treatment, photocatalytic oxidation and sonolysis. More recent are the research activities focused on the degradation of dyes using hydrodynamic cavitation (HC). In the latter process, Venturi tubes or orifice plates are used to produce radical $\text{OH}\cdot$: as the aqueous solution passes through the holes, it causes a substantial pressure reduction that generates bubble cavities. In some cavities (called hot -spots) local drastic conditions could be reached, 100 MPa of pressure and 5000 K of temperature. These conditions cause the collapse of the bubbles and the production of $\text{OH}\cdot$ due to the decomposing water vapor and non-condensable gases inside the bubbles [2-4]. In the present work, the degradation of dyes (such as methyl orange) has been investigated by using hydrodynamic cavitation. Two different experimental devices were used: a Venturi tube and an orifice plate. The effect of some parameters such as inlet pressure, pH of solution and hydrogen peroxide concentration as a function of time were studied to define the best configuration and the optimal experimental conditions for dye decolorization.

2. Methods

Methyl orange dye (molecular weight: 327.33 g/mol; molecular formula: $\text{C}_{14}\text{H}_{14}\text{N}_3\text{NaO}_3\text{S}$) was used to perform hydrodynamic cavitation tests. The solutions of dyes were prepared using distilled water for all the experiments. Hydrogen peroxide (30% v/v, Carlo Erba), sodium hydroxide (Fluka Chemika, >97%) and sulphuric acid (CARLO ERBA, 96%) were used for adjusting of the pH solution. The equipment systems used in the lab experiments is constituted by a reactor with a recycling line, as shown in Figure 1. The maximum diameter of the Venturi (Figure 2) was 12 mm as piping diameter, while the minimum was 2 mm. The divergence angle value is 5.74° [5]. The orifice plate has a diameter of 12 mm, with four orifices with a diameter of 2 mm each as shown in Figure 2. The cavitating devices materials are in photopolymer resin, while pipeline and mechanical components are in rilsan polyamide and stainless steel, respectively.

3. Results and discussion

The results of the experimental tests showed pH values seemed to have the most important effect on decolorization efficiency: acidic medium highly enhanced the process of degradation of dye.

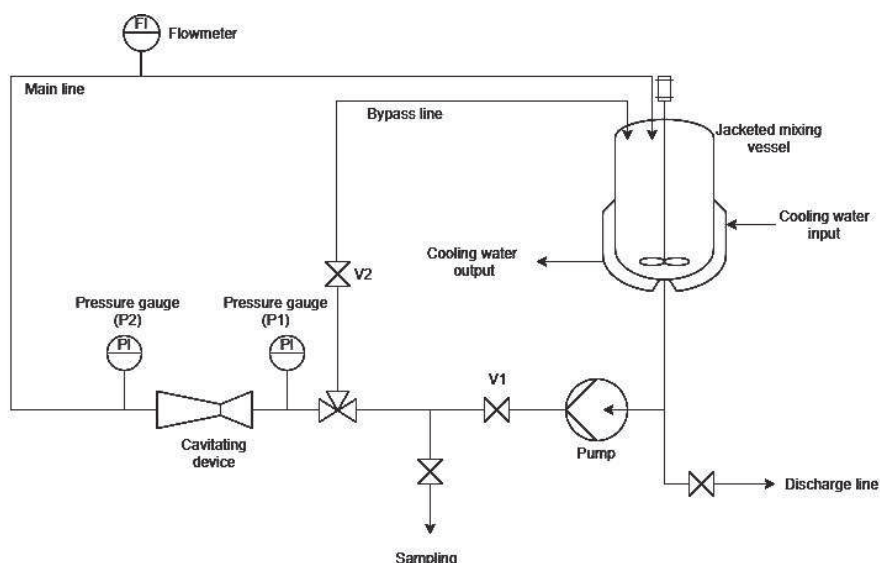


Figure 1. Layout of the experimental apparatus used for the hydrodynamic cavitation tests



Figure 2. Pictures of the Venturi tube and orifice plate devices used for the experiments

The addition of hydrogen peroxide increased the effect of the decolourization and almost complete colour removal were obtained under the tested conditions.

4. Conclusions

The present work demonstrates the efficiency of the hydrodynamic cavitation process for the degradation of dyes (Methyl orange). Further developments of the present research will be to test different experimental conditions to up-scale the process for a possible real industrial application.

References

- [1] U.G. Akpan, B.H. Hameed, Parameters affecting the photocatalytic degradation of dyes using TiO_2 – based photocatalysts: a review, *J. Hazard. Mater.* 170 (2009) 520-529.
- [2] P. Li, M. Takahashi, K. Chiba, Enhanced free-radical generation by shrinking microbubbles using a copper catalyst, *Chemosphere* 77 (2009) 1157-1160.
- [3] M. Sivakumar, A.B. Pandit, Wastewater treatment: a novel energy efficient hydrodynamic cavitation technique, *Ultrason. Sonochem.* 9 (2002) 123-131.
- [4] R.K. Joshi, P.R. Gogate, Degradation of dichlorvos using hydrodynamic cavitation based treatment strategies, *Ultrason. Sonochem.* 19 (2012) 532-539.
- [5] M. Capocelli, M. Prisciandaro, A. Lancia, D. Musmarra, Hydrodynamic cavitation of p-nitrophenol: a theoretical and experimental insight, *Chem. Eng. J.* 254 (2014) 1-8.

Keywords

Hydrodynamic cavitation; Decolorization; Dyes; Venturi tube; Orifice plates.

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D.O.B 24/06/1984
Actual position Post doc fellowship. August 2017- July 2018
Department of Industrial Engineering, Information and Economy
University of L'Aquila - Italy

Academic Education and Qualifications

University of L'Aquila
October 2010 - 2013

PhD in Innovative Chemical and biotechnological processes
Discussion of thesis (April 2014)
Thesis title: *Experimental and process analysis of the recovery of metal values from WEEE, spent batteries and accumulators: from the lab-scale research stage to industrial pilot plant scale*
Supervisor: Prof. Eng. Francesco Vegliò
Coordinator of the PhD course: Prof. Eng. Gabriele DI Giacomo

University of L'Aquila
July 28, 2010

Master degree in Chemical Engineering (110/110), (specialisation in Chemical Processes)
Title of thesis: *Hydrometallurgical treatment for recycling of alkaline and zinc carbons spent batteries using citric acid as reducing agent: experimental and process analysis*
Supervisor: Prof. Eng. Francesco Vegliò

University of L'Aquila
July 20, 2007

Bachelor's degree Chemical Engineering (101/110)
Title thesis: *Risk analysis applied to chemical treatment of process water*
Supervisor: Prof. Eng. Giuseppe Fumarola

Istituto Tecnico Industriale, "Amedeo di Savoia Duca D'Aosta", L'Aquila

High school diploma (94/100)

Research and Professional Experience

Dompè Phar.ma
L'Aquila, 2007

Pre-graduate period. Training at Dompè phar.ma in L'Aquila (Italy).
Main activity: study of the wastewater treatment plant; study of the potential hazards and application of the risk analysis of the plant.

Spin off BME srl, L'Aquila
February/July 2011

Winner of FIXO scholarship – Formazione e Innovazione per l'occupazione – Fase 2
Title of the project work: *Development of innovative know-how to be marketed in the field of base metal recovery*

Supervisor: Prof. Eng. Francesco Vegliò

Department of Chemistry, Chemical
Engineering and Materials
University of L'Aquila
August 2011 /September 2012

Winner of scholarship - Regione Abruzzo, Progetto Multiasse P.O.
FSE Abruzzo, Reti per l'alta formazione
Title of the project work: *Recovery of rare earths from fluorescent
powders of cathode ray tubes (CRT), lamps and industrial catalysts*
Supervisor: Prof. Eng. Francesco Vegliò
Supervisor: Eng. Bernd Kopacek, coordinator of the European
project Hydrowee/Hydrowee demo

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
March 2013 – February 2014

Fellowship founded by European project HYDROWEEE DEMO n°
308549

Title of the project: *Recovery process of rare earths, base and
precious metals from WEEE, minerals and industrial waste*
Tutor: Prof. Eng. Francesco Vegliò

Reporting of HydroWEEE demo project (01/10/2012- 31/03/2014)

- 2 M/U, WP2, Activity: Design of the industrial,
demonstration mobile plant for the recovery of metals
from industrial and electronic waste
- 5 M/U, WP3, Activity: Optimization of the process for
the treatment of fluorescent lamps, cathode ray
tubes, spent FCC catalysts and other wastes.
- 1.5 M/U, WP6, Activity: Participation in congresses,
meeting and workshop. Publication of scientific
articles on international journals (as Waste
Management, Hydrometallurgy, ..)

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
July 2014 – June 2015

Fellowship part- founded by European project HYDROWEEE
DEMO n° 308549

Title of the project: *Process for the recovery of base metals, rare
earths and precious metals from electronic waste, spent batteries
and catalysts and wastewater treatment*
Tutor: Prof. Eng. Francesco Vegliò

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
August 2015- July 2016

Fellowship part- founded by Smart Clean Air City L'Aquila project
ISTECH project

Title of the project: *Environmental technologies in the treatment of
wastewaters containing atmospheric pollutants by integrated
coagulation processes: process analysis and pilot plant design.*
Tutor: Prof. Eng. Marina Prisciandaro

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
August 2016 - July 2017

Fellowship part- founded by Life Bitmaps
Title of the project: *Environmental technologies in the treatment of wastewaters containing atmospheric pollutants by integrated coagulation processes: process analysis and pilot plant design.*
Tutor: Prof. Eng. Marina Prisciandaro

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
August 2017 - July 2018

Fellowship part- founded by Life Bitmaps
Title of the project: *Environmental technologies in the treatment of wastewaters containing atmospheric pollutants by integrated coagulation processes: process analysis and pilot plant design.*
Tutor: Prof. Eng. Marina Prisciandaro

Scientific activity

During the PhD course the activities were performed within the European projects HydroWEE (2008-2012) and HydroWEEE demo (2012-2016). The work was focused on the development of processes for the recovery of metals and critical materials as the rare earths from several types of waste (fluorescent lamps, cathode ray tubes, spent FCC catalysts and other wastes). In the first phase the activities were conducted on the laboratory scale, and subsequently the hydrometallurgical processes were tested in the pilot and industrial plants realized during the projects. Two industrial plants were designed and realized, one mobile and one stationary plants constructed in Relight Srl (Rho, Milano, Italy). The candidate actively participated for the design of the industrial plants and for the conduction of experimental tests in the pilot and industrial scale.

Moreover, software for the simulation of the processes (Chemcad, SuperPro Designer) were used in order to define the technical and economic feasibility of the developed processes.

In the second phase the research activities were performed within Smart Clean Air City L'Aquila project.

The activity had as its object the development of integrated processes in the treatment of wastewater obtained in the abatement of atmospheric pollutants by APA process (a particular scrubber designed by ISTECH srl). The elimination of atmospheric pollutants allowed the water reuse in a sustainable way. The main goal of the project was the design of a mobile pilot plant to treat these kinds of wastewaters. (August 2015- July 2016).

In the last period the research activities were performed within Life Bitmaps project "Pilot technology for aerobic Biodegradation of spent TMAH Photoresist solution in Semiconductor industries". The main activity of the candidate is the design of the pilot plant for the wastewater treatment. The experimental activities on laboratory scale are instead focused on the removal of metals and other substances from industrial wastewater using MEUF technique and hydrodynamic cavitation (August 2016- to present).

Teaching experience: Professor assistant

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
Academic year 2012/2013

Biochemical, Industrial and Environmental Plants
Total: 34 hours, ING-IND 26, Prof. Eng. Francesco Vegliò

Department of Industrial Engineering,

Information and Economy
Department of Clinical Medicine, Public
Health, Life Sciences and the
Environment
University of L'Aquila
Academic year 2013/2014

Industrial Production of Bio-medicines
Total 8 hours, B0451, Prof. Eng. Francesco Vegliò

Theory of the Development of Chemical Processes
Total 12 hours, ING-IND 26, Prof. Eng. Francesco Vegliò

Laboratory of Chemical Engineering
Total 9 hours

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
Academic year 2014/2015

Safety in the design of chemical plants
Total 35 hours, ING-IND 25, Prof. Eng. Giuseppe Fumarola

Chemical plants II
Total 22 hours, ING-IND 25 Prof. Eng. Marina Prisciandaro

Chemical plants I
Total 32 hours, ING-IND 25 Prof. Eng. Marina Prisciandaro

Theory of the Development of Chemical Processes
Total 30 hours, ING-IND 26, Prof. Eng. Francesco Vegliò

Laboratory of Chemical Engineering
Total 9 hours

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
Academic year 2015/2016

Chemical plants II
Total 18 hours, ING-IND 25 Prof. Eng. Marina Prisciandaro

Biochemical, Industrial and Environmental Plants
Total 9 hours, ING-IND 26, Prof. Eng. Francesco Vegliò

Chemical plants I
Total 19 hours, ING-IND 25 Prof. Eng. Marina Prisciandaro

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
Academic year 2016/2017

Chemical plants II
Total 18 hours, ING-IND 25 Prof. Eng. Marina Prisciandaro

Chemical plants I
Total 21 hours, ING-IND 25 Prof. Eng. Marina Prisciandaro

Teaching experience: Professor (responsible for courses)

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
Academic year 2015/2016

Safety in the design of process plants
Total 90 hours, ING-IND 25

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
Academic year 2016/2017

Safety in the design of process plants
Total 90 hours, ING-IND 25

Academic experience as thesis advisor

Department of Industrial Engineering,
Information and Economy
University of L'Aquila
From 2011 – 2017

Co – tutor for thesis (> 25) bachelor and master thesis for students of Chemical Engineering and Engineering of the Environment and the Territory

Tutor of thesis (n. 1) Storage of LPG: Incidental sequences after release, estimates of the consequences and safety systems.

Laboratory support and assistance for tests performed by students in their experimental activities.

Scientific publication

H Index Scopus = 7 dal 2010-2017 (scopus)

Co-authors = 15

Citations = 159

1. F. Ferella, I. De Michelis, F. Beolchini, **V. Innocenzi**, F. Vegliò, 2010. Extraction of Zinc and Manganese from Alkaline and Zinc-Carbon Spent Batteries by Citric-Sulphuric Acid Solution. International Journal of Chemical Engineering, Volume **2010**, Article ID 659434, 13 pages.
2. **V. Innocenzi**, F. Vegliò, **2012**. Recovery of rare earths and base metals from spent nickel-metal hydride batteries by sequential sulphuric acid leaching and selective precipitations. Journal of Power Sources 211, 184-191
3. **V. Innocenzi**, F. Vegliò, **2012**. Separation of manganese, zinc and nickel from leaching solution of nickel-metal hydride spent batteries by solvent extraction. Hydrometallurgy 129/130, 50-58
4. **V. Innocenzi**, I. De Michelis, F. Ferella, F. Beolchini, B. Kopacek, F. Veglio', **2013**. Recovery of yttrium from fluorescent powder of cathode ray tube, CRT: Zn removal by sulphide precipitation. Waste Management 33, 2364-2371
5. **V. Innocenzi**, I. De Michelis, F. Ferella, F. Vegliò, **2013**. Experimental results and economic simulations for the processes of recovery of yttrium from fluorescent powders of cathode ray tubes and lamps. Waste management 33, 2390-2396.
6. F. Beolchini, L. Rocchetti, P. Altimari, I. De Michelis, L. Toro, F. Pagnanelli, E. Moscardini, B. Kopacek, B. Ferrari, **V. Innocenzi**, F. Vegliò, **2013**. Urban mining: a successful experience of the EU-FP7 HydroWEEE project. Environmental Engineering and Management Journal 12, 69-72

7. **V. Innocenzi**, I. De Michelis, B. Kopacek, F. Vegliò, **2014**. Yttrium recovery from primary and secondary sources: a review of main hydrometallurgical processes. *Waste Management* 34, 1237-1250
8. **V. Innocenzi**, F. Ferella, I. De Michelis, F. Vegliò, **2015**. Treatment of fluid catalytic cracking spent catalysts to recover lanthanum and cerium: comparison between selective precipitation and solvent extraction. *Journal of Industrial and Engineering Chemistry*, 24, 92-97.
9. F. Ferella, **V. Innocenzi**, F. Maggiore, **2016**. Oil refining spent catalysts. A review of possible recycling technologies. *Resources, Conservation and Recycling* 108, 10-20.
10. F. Tortora, **V. Innocenzi**, M. Prisciandaro, G. Mazziotti di Celso, F. Vegliò, **2016**. Analysis of membrane performance in Ni and Co removal from liquid wastes by means of micellar-enhanced ultrafiltration. *Desalination and Water Treatment* 57, 22860-22867.
11. F. Tortora, **V. Innocenzi**, M. Prisciandaro, G. Mazziotti di Celso, F. Vegliò, **2016**. Heavy metal removal from liquid wastes by using Micellar Enhanced Ultrafiltration, *Water, Air & Soil Pollution*, 227-Article number 240.
12. **V. Innocenzi**, I. De Michelis, F. Ferella, F. Vegliò, **2016**. Rare earths from secondary sources: profitability study, *Advances in Environmental Research*, Vol. 5, No.2, 125-140.
13. **V. Innocenzi**, N.M. Ippolito, I. De Michelis, F. Medici, F. Vegliò, **2016**. A hydrometallurgical process for the recovery of rare earths from fluorescent lamps: experimental design, optimization of terbium acid leaching process and process analysis, *Journal of Environmental Management* 184, 552-559.
14. **V. Innocenzi**, F. Tortora, M. Prisciandaro, G. Mazziotti di Celso, F. Vegliò, **2017**. Zinc and chromium removal from liquid wastes by using Micellar Enhanced Ultrafiltration, *Desalination and Water Treatment* 61, 250-256.
15. N.M. Ippolito, **V. Innocenzi**, I. De Michelis, F. Medici, F. Vegliò, **2017**. Rare earth elements recovery from fluorescent lamps: A new thermal pretreatment to improve the efficiency of the hydrometallurgical process. *Journal of Cleaner Production* 153, 287-298.
16. F. Tortora, **V. Innocenzi**, M. Prisciandaro, I. De Michelis, F. Vegliò, G. Mazziotti di Celso, **2017**. Removal of tetramethyl ammonium hydroxide from synthetic liquid wastes of electronic industry through micellar enhanced ultrafiltration. *Journal of Dispersion Science and Technology*, 1-7.
17. **V. Innocenzi**, N.M. Ippolito, I. De Michelis, M. Prisciandaro, F. Medici, F. Vegliò, **2017**. A review of the processes and lab-scale techniques for the treatment of spent rechargeable NiMH batteries. *Journal of Power Sources* 362, 202-218.
18. F. Tortora, **V. Innocenzi**, I. De Michelis, F. Vegliò, G. Mazziotti Di Celso, M Prisciandaro. Recovery of anionic surfactant through acidification / ultrafiltration in a micellar enhanced ultrafiltration process for cobalt removal from wastewaters. *Environmental Engineering Science*, **in press**.
19. **V. Innocenzi**, I. De Michelis, F. Vegliò. Design and Construction of an Industrial Mobile Plant for WEEE treatment: investigation on the treatment of fluorescent powders and economic evaluation compared to other e-wastes. *Journal of the Taiwan Institute of Chemical Engineers*, **in press**.
20. **V. Innocenzi**, I. De Michelis, F. Ferella, F. Vegliò. Leaching of yttrium from cathode ray tube fluorescent powder: kinetic study and empirical models. *International Journal of Mineral Processing*, **in press**.
21. **V. Innocenzi**, I. De Michelis, F. Ferella, F. Vegliò. Secondary yttrium from spent fluorescent lamps: recovery by leaching and solvent extraction. *International Journal of Mineral Processing*, **in press**.

Patents

Patent WO2014020626 A: Processing for recovering rare earth metals

Patent 102016000121178: Processo per la rimozione di azoto da liquami di allevamento e digestato liquido". (Process for nitrogen removal from animals' sewage)

Patent 102017000003185: Processo ed impianto per la rimozione di TMAH ed altri inquinanti da soluzioni reflue dell'industria elettronica (Process and plant for TMAH and other compounds removal from electronic industries wastewater)

Conferences

1. SUM 2012 Symposium on Urban Mining, Bergamo, Marzo 2012.

Recovery of yttrium from fluorescent powder of cathode ray tube, CRT: Zn removal by sulphide precipitation.

Autori: **V. Innocenzi**, I. De Michelis, F. Beolchini, B. Kopacek, F. Vegliò

2. Conference and school GRICU, 2012, Settembre 2012.

Recovery of rare earth metals and base NiMH batteries exhausted and spent catalysts of the petrochemical industry

Autori: **V. Innocenzi**, F. Ferella, I. De Michelis, F. Vegliò

3. Conference and school GRICU, 2012, Settembre 2012.

Extraction and recovery of rare earths from waste electrical and electronic equipment.

Autori: B. Bianco, P. Macolino, I. De Michelis, **V. Innocenzi**, F. Beolchini, F. Vegliò, B. Kopacek

4. Final conferences RE.TAFO, Ottobre 2012.

Recovery of rare earths from fluorescent powders of cathode ray tubes (CRT), lamps and industrial catalysts.

Autore: **V. Innocenzi**. Tutor: Prof. Francesco Vegliò. Coordinatore del corso di dottorato: Prof. Gabriele Di Giacomo. Tutor estero: Dr. Bernd Kopacek

5. Sardinia 2013, 14° International waste management and landfill symposium, Ottobre 2013.

Elementi critici per l'Unione Europea: panoramica dei processi idrometallurgici per il recupero di terre rare da RAEE e rifiuti industriali

Autori: **V. Innocenzi**, I. De Michelis, F. Vegliò

Critical elements for the European Union: Overview of the processes for the recovery of rare earths from WEEE and industrial waste full

Autori: **V. Innocenzi**, I. De Michelis, F. Vegliò

6. Sum 2014, Bergamo, 19-21 Maggio 2014

Rare earths from secondary sources: hydrometallurgical process to recover yttrium from fluorescent powders of spent lamps using solvent extraction. Economical feasibility study.

Autori: **V. Innocenzi**, I. De Michelis, F. Vegliò

7. Industrial Academic networks in cooperation activities for pharmaceutical, chemical and food fields, L'Aquila, 17-18 Settembre 2014

Mobile plant: a new frontier in the treatment of WEEE

Autori: **V. Innocenzi**, I. Birloaga, I. De Michelis, B. Kopacek, F. Vegliò

8. 18th International Trade Show For Material And Energy Recovery And Sustainable Development, ECOMONDO, Rimini, - 5-8 Novembre 2014

Progettazione, realizzazione e start-up di un impianto mobile per il trattamento di rae

Autori: I. De Michelis, **V. Innocenzi**, I. Birloaga, F. Vegliò

9. Going Green, Care Innovation 2014, Vienna, 17-20 Novembre 2014

Hydrometallurgical processes for the recovery of precious and critical metals from spent lamps and cathode ray tubes

Autori: **V. Innocenzi**, I. De Michelis, M. Centofanti, F. Vegliò

10. Going Green, Care Innovation 2014, Vienna, 17-20 Novembre 2014

Hydrometallurgical processes for the recovery of precious and critical metals from catalysts

Autori: I. De Michelis, **V. Innocenzi**, F. Ferrante, F. Vegliò

11. Euromed 2015, Desalination for clean water and energy, Palermo, 10-14 Maggio 2015

Removal of nickel and cobalt from liquid wastes aimed at surfactant and metal recovery

Autori: F. Tortora, **V. Innocenzi**, M. Prisciandato, F. Vegliò

12. Euromed 2015, Desalination for clean water and energy, Palermo, 10-14 Maggio 2015

Heavy metal removal from liquid wastes by using Micellar Enhanced Ultra Filtration

Autori: **V. Innocenzi**, F. Tortora, M. Prisciandaro, F. Vegliò, 2015.

13. 2nd International congress "Industrial and academic cooperation in food, chemical and pharmaceutical industries, Voronezh State University of Engineering Technologies, Voronezh, Russia, 24-26 June 2015

An opportunity for SMEs: critical and precious metal recovery from electronic and industrial waste, The challenge of the European HydroWEEE projects

Autori: **V. Innocenzi**, I. Birloaga, I. De Michelis, M. Centofanti, F. Vegliò

14. 15th International waste management and landfill symposium, Resource recovery and recycling, S. Margherita di Pula, Cagliari 5 – 9 Ottobre 2015

An overview on the last decade technologies for rare materials extraction from feedstock of “Urban Mine” Industry.

Autori: I. Birloaga, I. De Michelis, **V. Innocenzi**, F. Vegliò

15. Desalination for the Environment: clean water and energy, Roma 22-26 Maggio 2016

Recovery of anionic surfactant by ultrafiltration

Autori: F. Tortora, **V. Innocenzi**, I. De Michelis, F. Vegliò, M. Prisciandaro

16. 13th International Conference on Protection and Restoration of the Environment Pre XIII, Mykonos 3-8 Luglio 2016

Purification of residual leach liquors from hydrometallurgical process of NiMH spent batteries through Micellar Enhanced Ultra Filtration

Autori: **V. Innocenzi**, F. Tortora, M. Prisciandaro, F. Vegliò

17. Electronics Goes Green 2016 +, Berlino 7-9 Settembre 2016

Recovery of critical metals from lamps and CRTs

Autori: **V. Innocenzi**, I. De Michelis, S. Sgarioto, D. Gotta, B. Kopacek, F. Vegliò

18. Electronics Goes Green 2016 +, Berlino 7-9 Settembre 2016

Recovery of base and precious metals from waste printed circuit boards and spent catalysts by hydrometallurgical processes

Autori: I. Birloaga, **V. Innocenzi**, I. De Michelis, B. Kopacek, F. Vegliò

19. Conference and school GRICU, 2016, Anacapri Settembre 2016

Recycling of fluorescent exhausted lamps: process development for the recovery of high grade earth oxides

Autori: N.M. Ippolito, **V. Innocenzi**, F. Medici, F. Vegliò

20. Conference and school GRICU, 2016, Anacapri Settembre 2016

Treatment of microelectronic wastewaters with Meuf: recovery of surfactant

Autori: M. Prisciandaro, F. Tortora, **V. Innocenzi**, F. Vegliò

21. Congresso MEMDES 3rd IC Desalination Using Membrane Technology, Las Palmas, Gran Canaria, aprile 2017.

Application of micellar-enhanced ultrafiltration in the pre-treatment of seawater for boron removal,

Autori: F. Tortora, **V. Innocenzi**, M. Prisciandaro, F. Vegliò, V. Piemonte, M. Capocelli

22. CEMEPE AND SECOTOX CONFERENCE 2017 Salonicco giugno 2017.

Treatment of TMAH solutions from microelectronic industry: a combined process scheme.

Autori: M. Prisciandaro, **V. Innocenzi**, I. De Michelis, F. Tortora, G. Mazziotti di Celso, F. Vegliò

Fellowship founded by European and Italian projects

March 2013 – February 2014

Project HydroWEE demo 305489

July 2014 – June 2015

Project HydroWEE demo 305489

August 2015 - July 2016

Smart Clean Air City L'Aquila

August 2016 - July

Life Bitmaps

August 2017 - July 2018

Life Bitmaps

Other information

Reviewer for:

Hydrometallurgy, Industrial & Engineering Chemistry Research, Waste Management, Environmental Technology, Journal of Environmental and Occupational Science.

Activities in Austria. October, December 2011 and March 2012. Activities performed at SAT (Austrian Society for Systems Engineering and Automation) in Wien. The activities were performed within HydroWEE project with the aim to develop hydrometallurgical processes for the recovery critical materials and base metals from industrial and electronic wastes.

Partner with 5% of the spin off SMART WASTE ENGINEERING SRL. The company, established in February 2016, is involved in the develop and design of the sustainable and innovative environmental processes.

Lessons for the course training in GSA srl and VETERES srl, site in Civita Castellana (Piano di formazione GSA 2015):

- Buone prassi per lavorare in sicurezza (28/11/2015 - 29/04/2016) - tot. 12 hours
- Formazione avanzata riciclo dei fanghi (20/10/2015 - 27/04/2016)– tot. 32 hours

FIRMA

A handwritten signature in black ink, appearing to read 'Vale M.', located below the 'FIRMA' label.