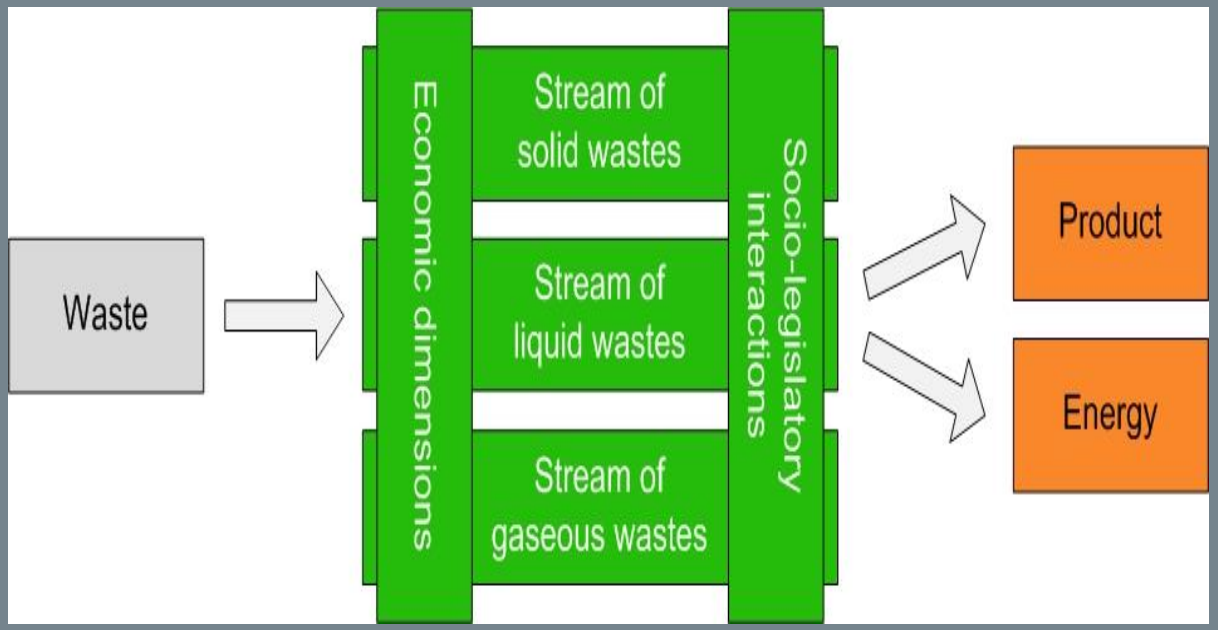
UNIVERSITY OF PATRAS
Department Of Chemical Engineering
ChemEngUP

Environmental Biotechnology – Waste Valorization and Sustainable Management of Natural Resources

Michael KORNAROS

Structure

Network on Sustainable Management of Resources and Waste Valorisation (WASTEVALOR)



Prof. G.N. Angelopoulos
Coordinator

http://wastevalor.upatras.gr

General description of the Research Area

Waste
potential by-product=resource

↓

Target
valorisation, minimisation of wastes, conservation of raw materials

↓

Via
integrated interdisciplinary approach
scientific, technological and managerial skills

↓

Advantages
rational management of recourses
sustainable growth
environmental prevention and protection

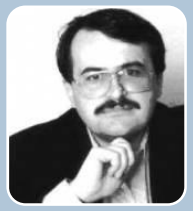
Research Groups

George Angelopoulos

- Professor
- Solid inorganic wastes valorization

Michael Kornaros

- Assistant Professor
- Environmental Biotechnology & Organic Waste Valorization



Petros Koutsoukos

- Professor
- Crystal growth processes

Dionissios Mantzavinos

- Professor
- Advanced oxidation processes in H_2O/WWT

Ioannis Kookos

- Assistant Professor
- Design, Optimization & Techno-economic analysis

Christakis Paraskeva

- Assistant Professor
- Separation processes in WWT

Victor Stivanakis

- Lecturer
- Exploitation of inorganic wastes

Dimitrios Petroutsos

- Lecturer (Appointment Pending)
- Biotechnological exploitation of photosynthesis

Panagiotis Nikolopoulos

- Professor Emeritus
- Ceramic and composite materials

Industrial solid wastes and by-products valorization

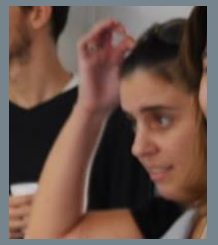
George N. ANGELOPOULOS, Professor

METLAB research group

Professor George N. Angelopoulos
High temperature Processes of Materials
Technology of Materials

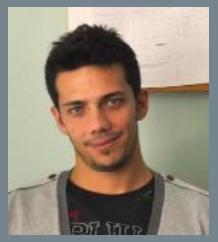
Dr. A. Christogerou

Dr. N. Marazioti



MSc. D. Koumpouri

Konstantinos Pittas



Valorization of industrial by-products

Valorization of metallurgical slags, red mud, boron wastes, fly ash, bottom ash etc. in:

- Cements
- Ceramics, heavy clay ceramics
- Light weight aggregates
- Absorbents, gas cleaning

Development of new materials:

- Low energy, low carbon cements (belite, sulfo-ferro-aluminate cements)
- Ceramic Tiles with Photocatalytic properties
- Ceramic porous materials from wastes
- Geopolymers from wastes

Valorization of industrial by-products

- Seek for high added value applications
- Seek for high volume process

Ideally…

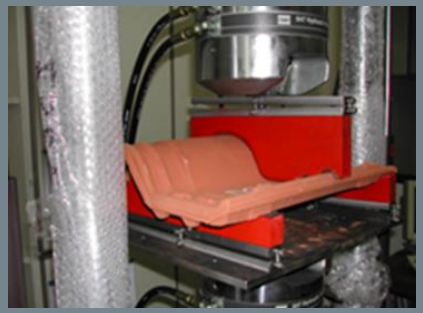
- Introduce in existing industrial process with no changes in the production cycle
- Final product comparable in quality with the currently produced one (physicochemical, mechanical properties and environmental behaviour)

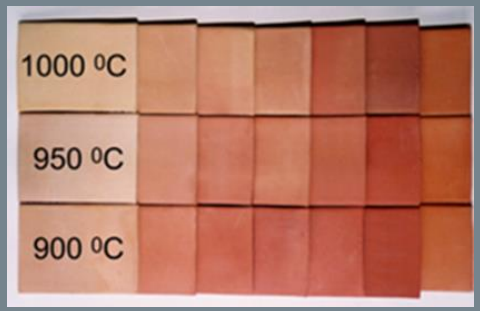
Cement	Lightweight aggregates	Heavy clay ceramics

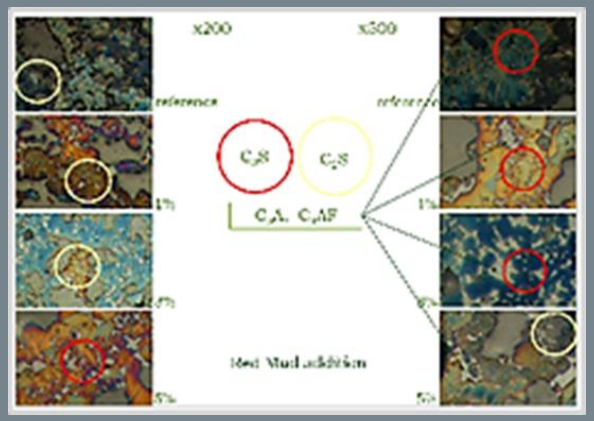
Industrial applications

Installation of filter presses at Aluminum of Greece. (*Total Investment of installation: 12,000,000 €, Al-Hellas*)
Since 2012 red mud is stockpiled and not dumped in Corinthian Gulf with subsequent environmental and economic benefits

Heavy clay products (roofing tiles, bricks) with RM addition
Panagiotopoulos SA







Portland cement with red mud addition

Main industrial partners

ERF slag: 2,3 x 10^6t/y dumped in Evoikos gulf, Greece

EAF Slag: 98,000t/y, Greece

Red Mud: 700.000t/y dumped in Corinthian gulf, Greece

Boron Wastes: 400.000t/y Turkey

Research activities

NETWORK

- "WasteValor" intra-university network. 15 faculty members from 3 departments are participating and 3 local industries are endorsing

RESEARCH INFRASTRUCTURE APPLICATION

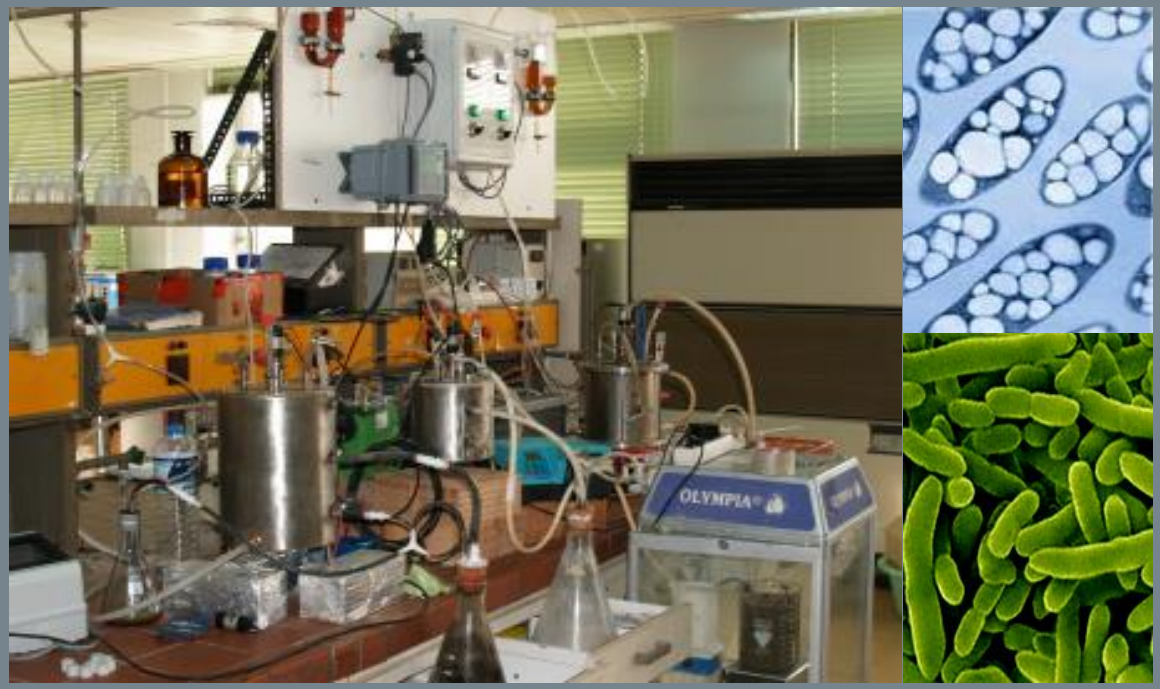
- "INVALOR" Institute of Waste Valorization and Sustainable Management of Resources with vision of the foundation of a "knowledge society group" on the concept that by-products should be considered as Resources. More than 45 faculty members from 7 national Universities and 1 research institute are participating. More than 50 industries are endorsing the proposal

RESEARCH PROJECTS (INDICATIVE)

- Valorization of red mud in the cement and ceramic industries, General Secretariat of Research and Technology (GSRT) Greece, EPAN 12252/19-11-02, 2003-2007, 1.811.246€, with Aluminium of Greece, TITAN, AGET Heracles (Lafarge), Panagiotopoulos SA.
- Energy Conservation and Environmental Protection in iron recycling. ESPA 2007-2013, GSRT 2011-2013, (780,00 EURO), UP, SOVEL, ELKEME

PATENT

- "Process for the Production of Structural ceramics from Bayer's process Bauxite Residue" Patent 20070100393/19.06.2007



Environmental Biotechnology and Valorization of Organic Wastes

Michael KORNAROS, Assist. Professor

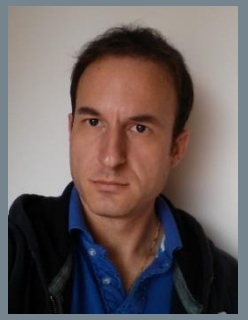
LBEET research group

Dr. K. Vavouraki, Postdoc Researcher

M. Dareioti, PhD student

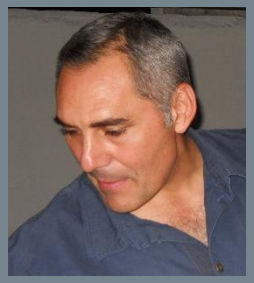
K. Stavropoulos, MSc student

M. Zakoura, MSc student

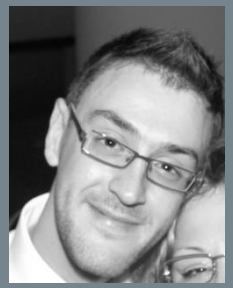


G. Raptis, MSc student

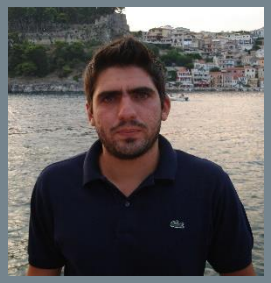
A. Kophahelis (MSc), Researcher



V. Manos, MSc student



C. Karavas, MSc student

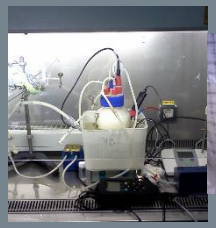


T. Vgenis, Research Associate

I. Paschaki, Research Associate

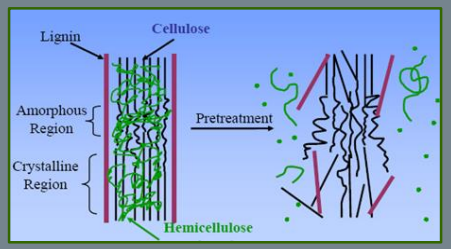
- Undergraduate Students: **6**

Research Activities

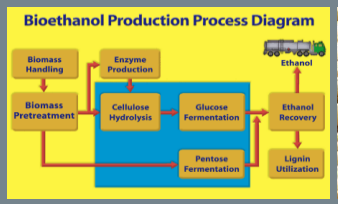


- Exploitation of agroindustrial wastes, organic residues and energy crops via anaerobic co-digestion for the production of gaseous biofuels (H_2 and CH_4). Studies at laboratory and pilot scale.
- High-rate anaerobic reactors (UASB reactors) for the treatment of wastewater rich in soluble organic compounds (mainly industrial liquid streams).
- Valorization of olive mill wastewaters for the production of biopolymers (polyhydroxyalkanoates - PHAs) using pure and mixed microbial cultures.
- Exploitation of waste streams for the production of Surfactants (Sophorolipids, Rhamnolipids) via biological processes.

Research Activities



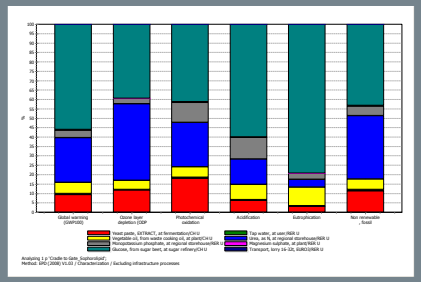
- Thermochemical pre-treatment and enzymatic hydrolysis of energy crops and food wastes (lignocellulosic and starchy biomass) for increased saccharification.



- Alcoholic fermentation of Food Wastes for Bioethanol production with the use of selected strains such as *Saccharomyces cerevisiae*.

XAD 4 XAD 16 FPx66

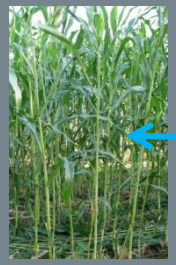
- Polyphenols recovery from olive mill wastes by physical adsorption using different Amberlite™ XAD-type polymeric adsorbents (resins).



- Application of Life-Cycle Analysis methodology for the assessment of the environmental performance of innovative environmental processes and industrial products development.

Optimized integrated management scheme for agroindustrial wastes valorization

Pilot plant capacity 10kW$_{el}$

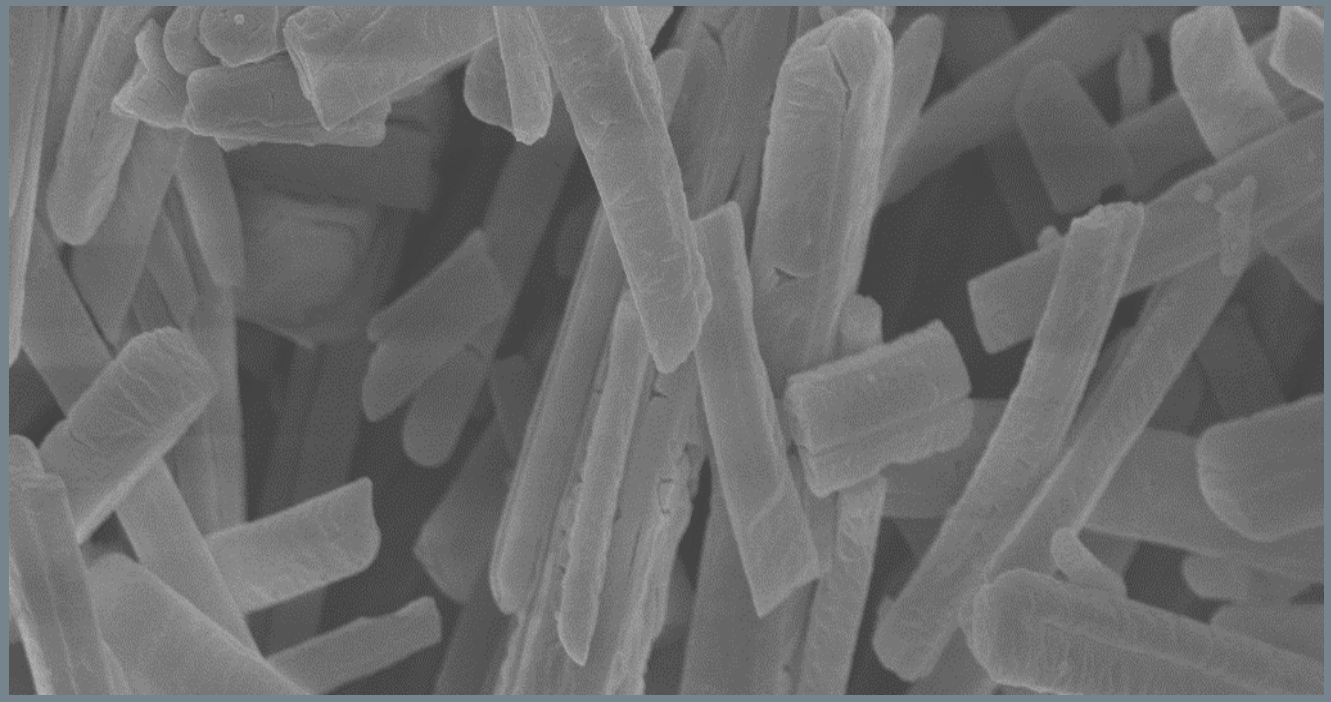


Research Projects

- *Project Title :* "Development of sustainable biogas strategies for integrated agroindustrial waste management (BIOGAIA)". *Program :* European Territorial Cooperation Programme Greece – Italy 2007-2013 (MIS Code : 902020). *Budget (LBEET) :* 410 k€. *Duration :* 30 months (2011-2014).
- *Project Title :* "Development of novel environmentally added-value surfactants and esters by biotechnological processes from fats and oils waste streams (Bio-SURFEST)". *Program :* BSG-SME-Research for the benefit of SMEs (No 286834). *Budget (LBEET) :* 148 k€. *Duration :* 24 months (2011-2013).
- *Project Title :* "Mobile Integrated Sustainable System for Treatment of Organic Wastewater (MISSTOW)".*Program :* CIP-EIP-Eco-Innovation-2010 (No 277241). *Budget (LBEET) :* 174 k€. *Duration :* 36 months (2011-2014).
- *Project Title :* "Sustainable Management via Energy Exploitation of End-Of-Life DAIRy Products In CyprUS (DAIRIUS)". *Program :* LIFE10 ENV/CY/000721. *Budget (LBEET) :* 380 k€. *Duration :* 36 months (2011-2014).
- *Project Title :* "Integrated management of agroindustrial wastes and plant biomass". *Program :* Heracleitus II (12/121/4). *Budget (LBEET) :* 45 k€. *Duration :* 36 months (2010-2013).
- *Project Title :* "Development of integrated agroindustrial waste management politics maximizing materials recovery and energy exploitation (INTEGRASTE)". *Program :* LIFE+08 ENV/GR/000578. *Budget (LBEET) :* 339 k€.*Duration :* 45 months (2010-2013).

Some Recent Publications

- Vavouraki et al., 2013. '' Optimization of thermo-chemical pretreatment and enzymatic hydrolysis of kitchen wastes''. Waste Management, in press
- *Dareioti et al., 2010. ''Exploitation of olive mill wastewater and liquid cow manure for biogas production''. Waste Management, 30 (10), 1841-1848.*
- *Dareioti et al., 2009. ''Biogas production from anaerobic co-digestion of agroindustrial wastewaters under mesophilic conditions in a two-stage process''. Desalination, 248 (1-3), 891-906.*
- *Zakoura et al. ''Assessing the performance of high-rate anaerobic reactors treating three-phase olive mill wastewater (OMW)'' oral presentation to the 13th World Congress on Anaerobic Digestion: Recovering (bio) Resources for the World, Santiago de Compostela (Spain), 25-28 June, 2013.*
- *Stavropoulos et al. ''Valorization of End-of-Life dairy products via co-digestion with agroindustrial wastes for biogas production''. 5th International Conference on Engineering for Waste and Biomass Valorization, Rio de Janeiro, Brazil, 24-28 August, 2014.*



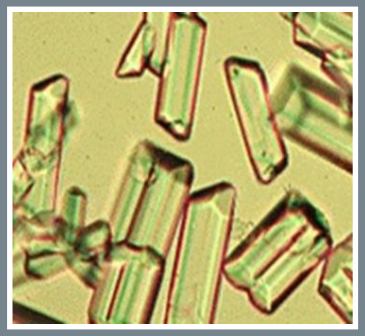
Research Group on Crystal Growth Processes

Petros G. KOUTSOUKOS, Professor

A.N.Kofina (PhD), J. Mpountas (PhD cand.), Th. Mavrikou, (MSc)

Research Activities

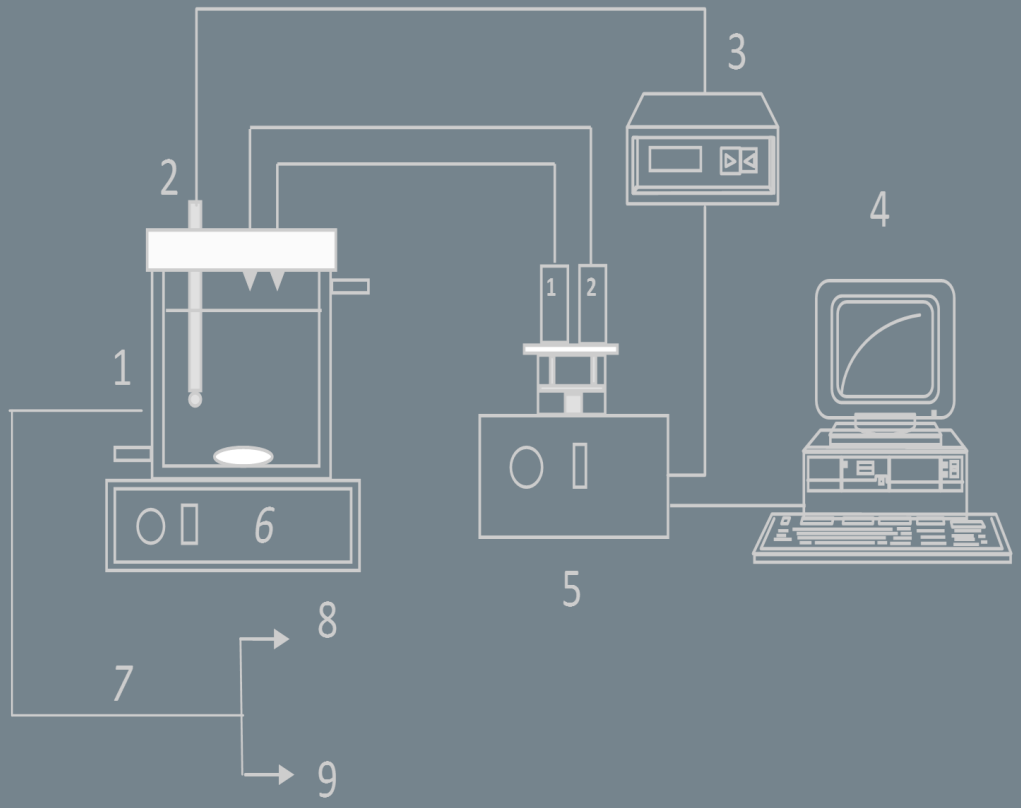
Struvite = magnesium ammonium phosphate hexahydrate, $MgNH_4PO_4 \cdot 6H_2O$

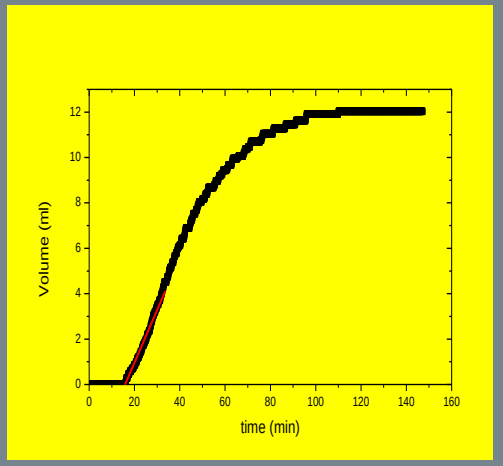


Recovery of phosphorus in municipal and other wastewaters through the direct crystallization of a fertilizer

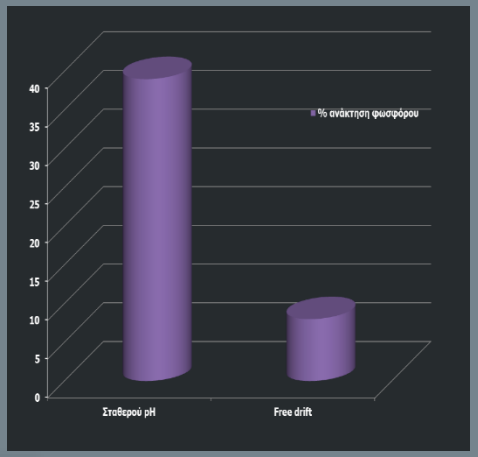
$$Mg^{+2}_{(aq)} + NH^{+1}_{4\,(aq)} + H_2\,PO^{-2}_{4\,(aq)} \leftrightarrow MgNH_4PO_4.6H_2O_{(s)}\downarrow + 2H^{+1}_{(aq)}$$

Continuous crystallizer
Continuous removal of crystalline material



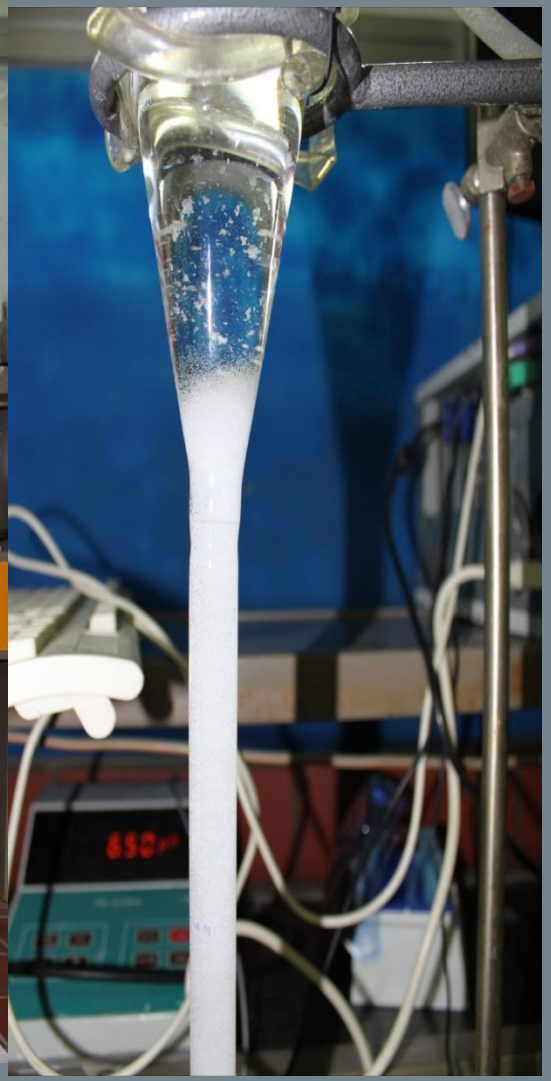


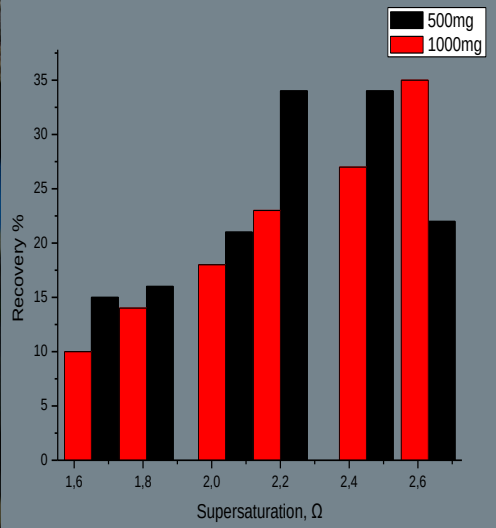
Kinetics of crystal growth



Comparison of P recovery in experiments at constant pH and free-drift experiments

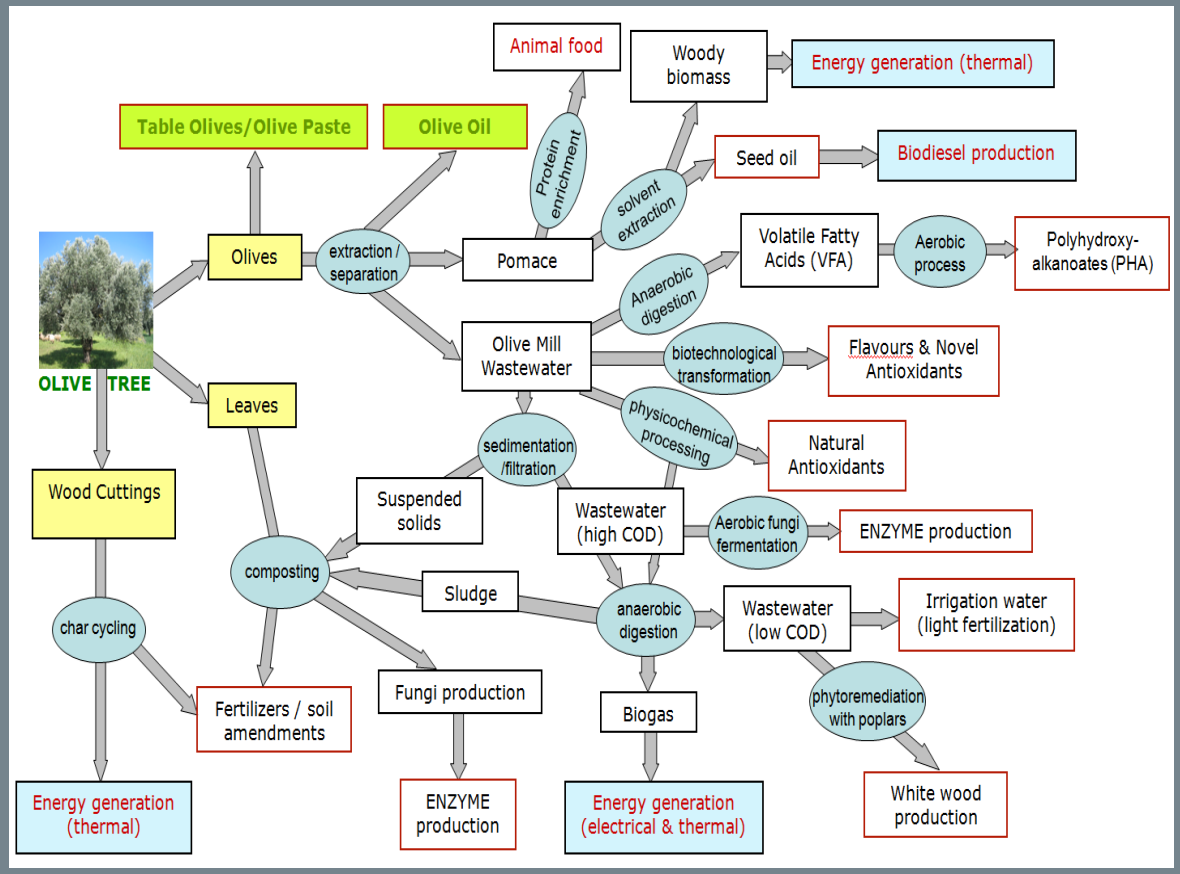
1: Thermostatted batch reactor magnetically stirred (6)
2: pH measurement electrode (glass/Ag/AgCl combination).
3: Syringe Pumps Controller (5). 4: pH for data acquisition and control. 7: Sampling 8: solid/liquid separation
9: Chemical analysis.





P recovery in the form of struvite in a FBR; Quartz particles; pH 6.50, 25 C

Fluidized bed reactor for the study of heterogeneous crystal growth of struvite



The "AOPs" Research Group

Dionissios MANTZAVINOS, Professor

Research Activities

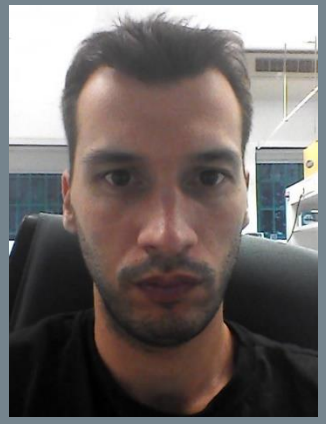
Research interests (besides or alongside AOPs)

- Sustainable management of agro-industrial effluents including valorization and post-treatment
- Waste to energy
- Effluent organic matter to re-usable water
- Life cycle analysis (LCA)
- **For other (core) activities, see next presentation**

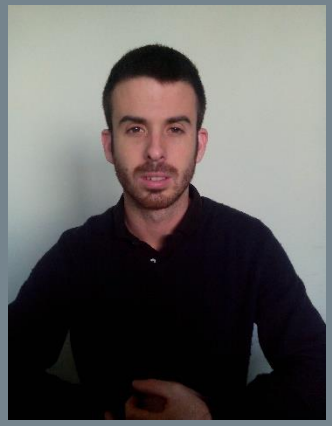
Researchers

- DM is the latest addition to the Dept (3/2013), so the group has to be reborn from its ashes (hopefully not !)

- Nonetheless…

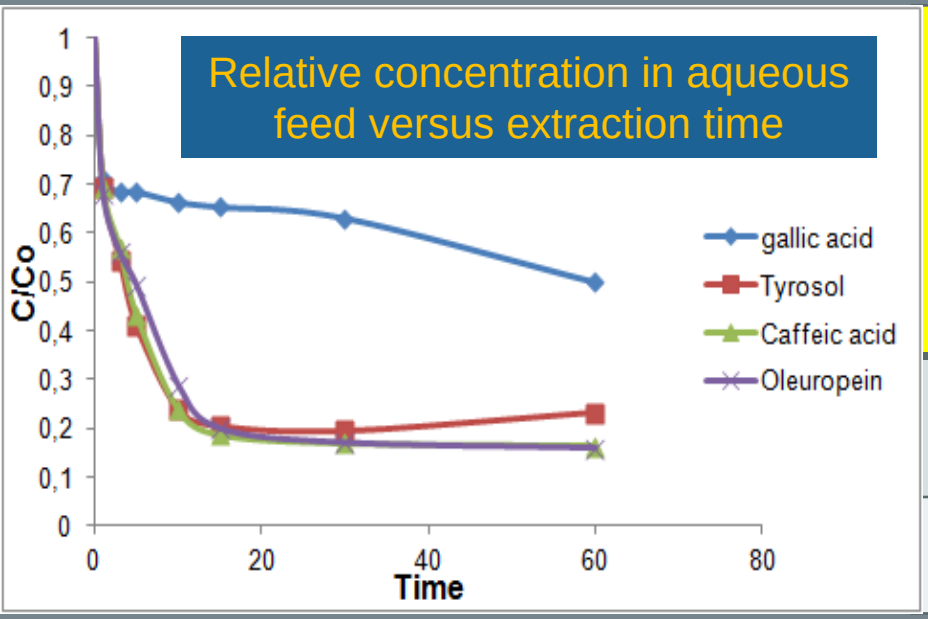


Dr Z. Frontistis
post-doc researcher



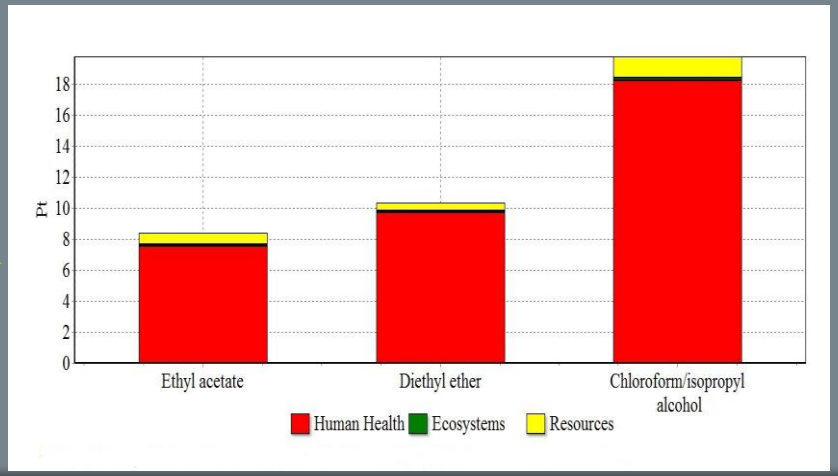
Mr E. Marti Mestres
Erasmus student
Uni. of Barcelona, Spain

L-L and Membrane Extraction for OMW Phenols



Chloroform/ Isopro-panol (70/30)	% Reco-very T	OE	GA	CA
Conventional Liquid-Liquid	74	73	15	74
Membrane Solvent	80	82	36	83

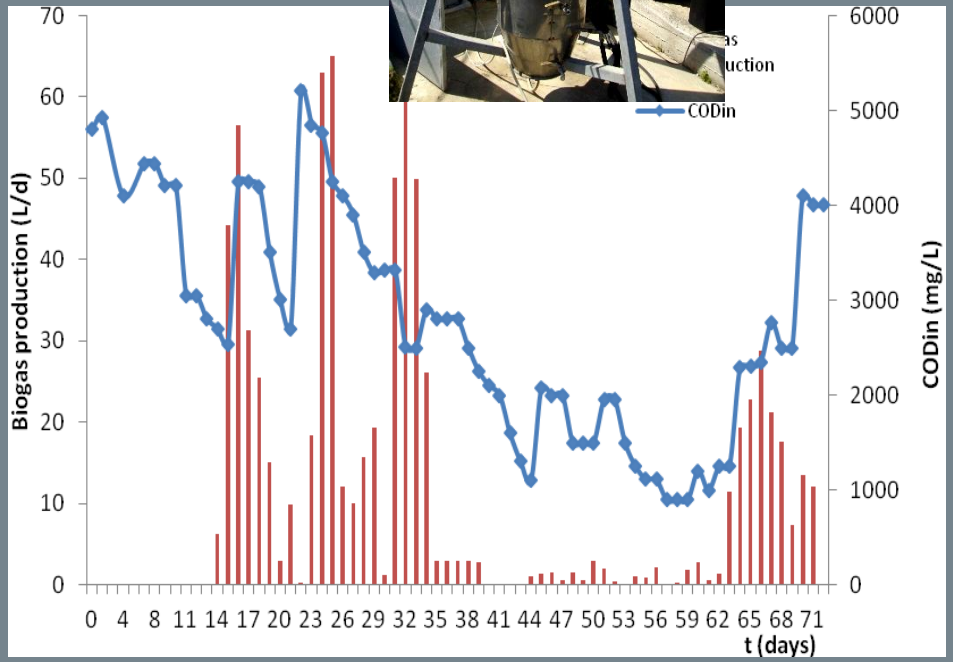
Impact assessment of damage categories for the L-L extraction of tyrosol from OMW

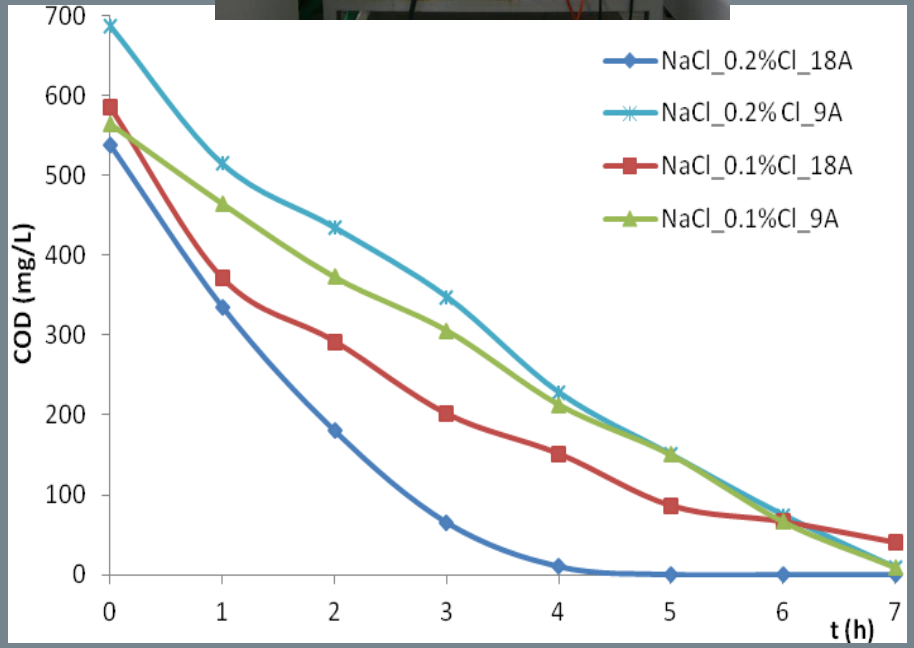


Waste to Energy: Treatment of Olive Pomace Leachate

Pilot UASB reactor

Electro-chemical oxidation reactor





Sequential UASB treatment and electrochemical oxidation of olive pomace leachate

Publications - Projects

- N.Kalogerakis et al, Recovery of antioxidants from olive mill wastewaters: A viable solution that promotes their overall sustainable management, *Journal of Environmental Management*, **128**, (2013), 749-758.
- P.C. Papaphilippou et al, Sequential coagulation-flocculation, solvent extraction and solar-Fenton oxidation for the valorization and treatment of olive mill effluent, *Chemical Engineering Journal*, **224**, (2013), 82-88.
- E.Chatzisymeon et al, Life cycle assessment of advanced oxidation processes for olive mill wastewater treatment, *Journal of Cleaner Production*, **54**, (2013), 229-234.
- A. Katson et al, Cheese whey treatment by sequential anaerobic digestion in a pilot scale upflow sludge blanket reactor and electrochemical oxidation, In *Proceed. 3rd European Conference on Environmental Applications of Advanced Oxidation Processes*, Almeria, Spain, October 2013.
- F.Federici et al, Valorisation of agro-industrial by-products, effluents and waste: concept, opportunities and the case of olive mill wastewaters, *Journal of Chemical Technology & Biotechnology*, **84(6)**, (2009), 895-900.
- PAVET, 385 k€, under evaluation: Co-processing of red mud and olive mill wastewaters for the production of novel high-added value products (Aluminium SA, NTUA, other colleagues from UP)

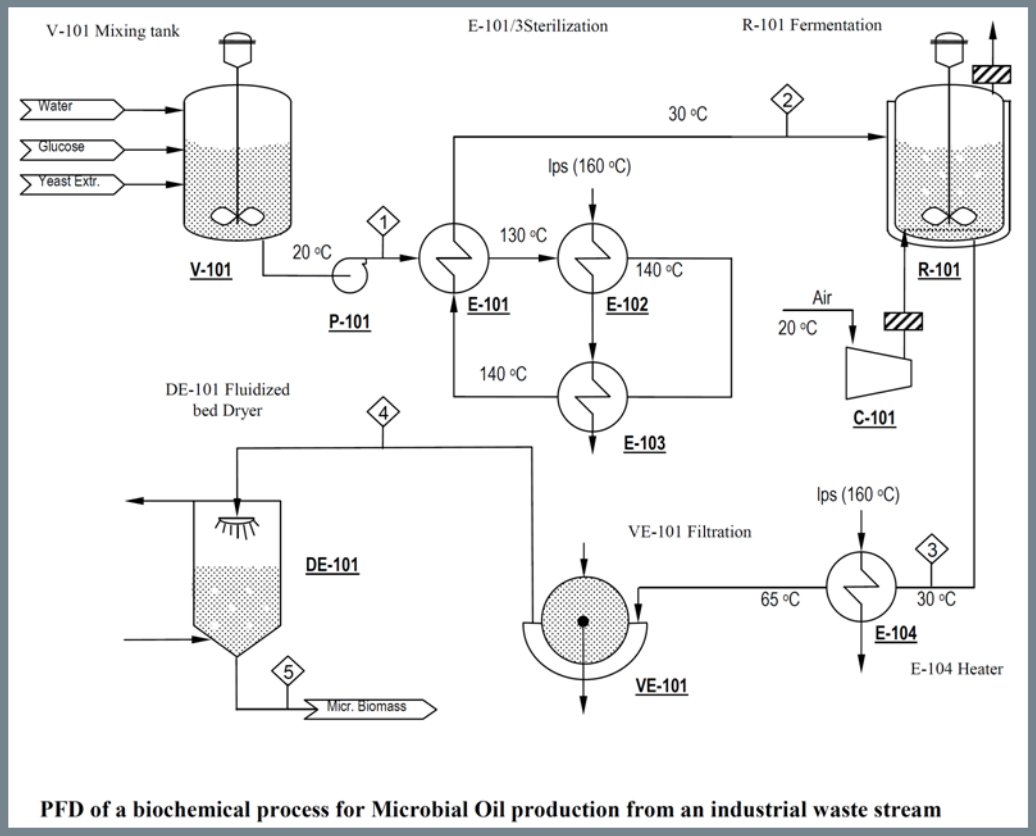
Design, Optimization and Techno-economic analysis of Chemical & Biochemical Systems

Ioannis K. KOOKOS, Assist. Professor

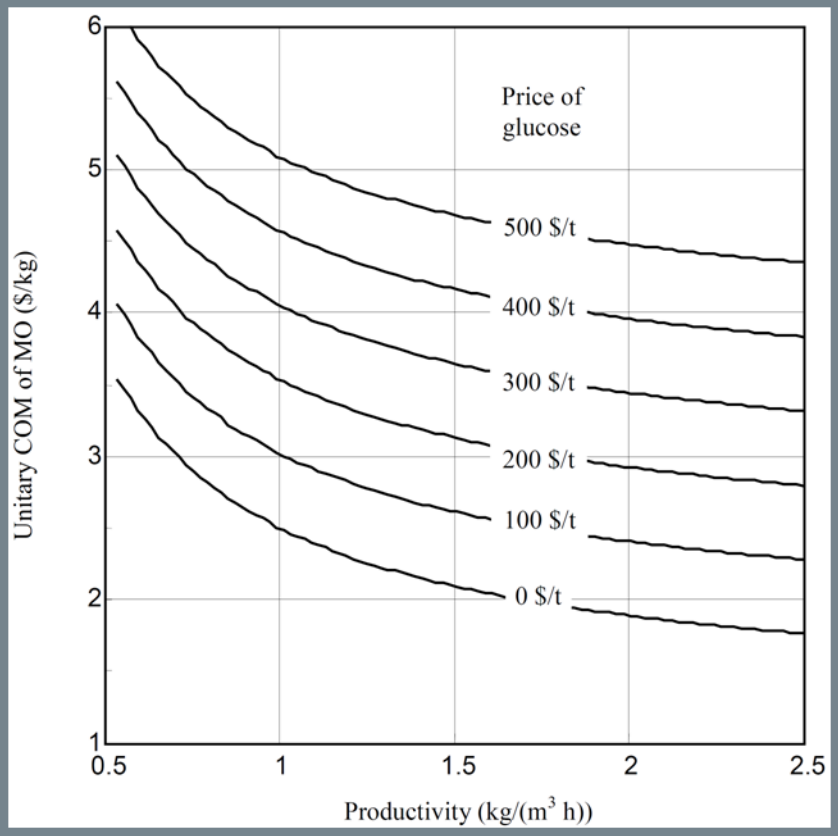
A. Psaltis PhD student & C. Charalabidou MSc student.

Research Activities

- **Economic and environmental analysis of chemical and biochemical systems**



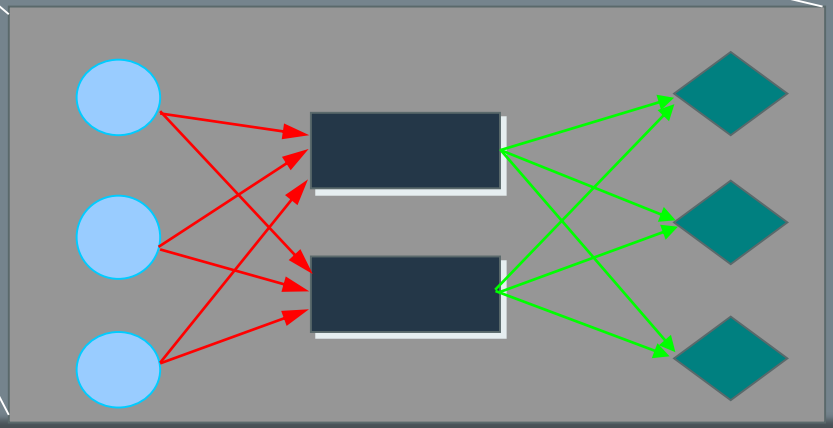
PFD of a biochemical process for Microbial Oil production from an industrial waste stream



Research Activities

- **Development of High Fidelity Models and Optimization of Energy Systems**

Application : development of Linear Programming models for the use of alternative fuels or raw materials in cement production



A combined coagulation/flocculation and membrane filtration process for the treatment of industrial wastewaters

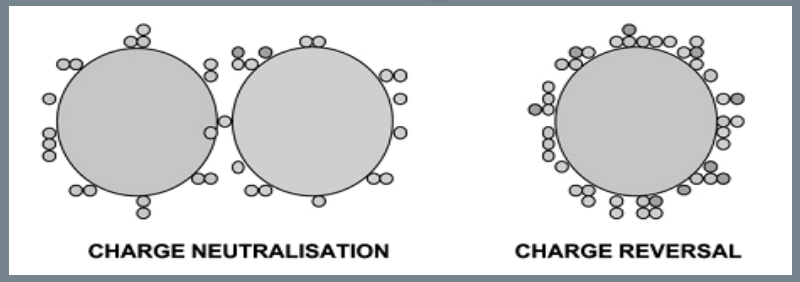
Christakis PARASKEVA, Assist. Professor

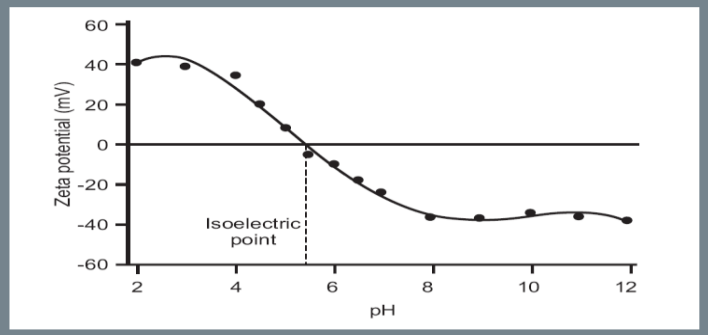
D. Zagklis, PhD cand., S. Kontos, I. Iakovides, E. Pavlakou. Graduate students

Research Activities

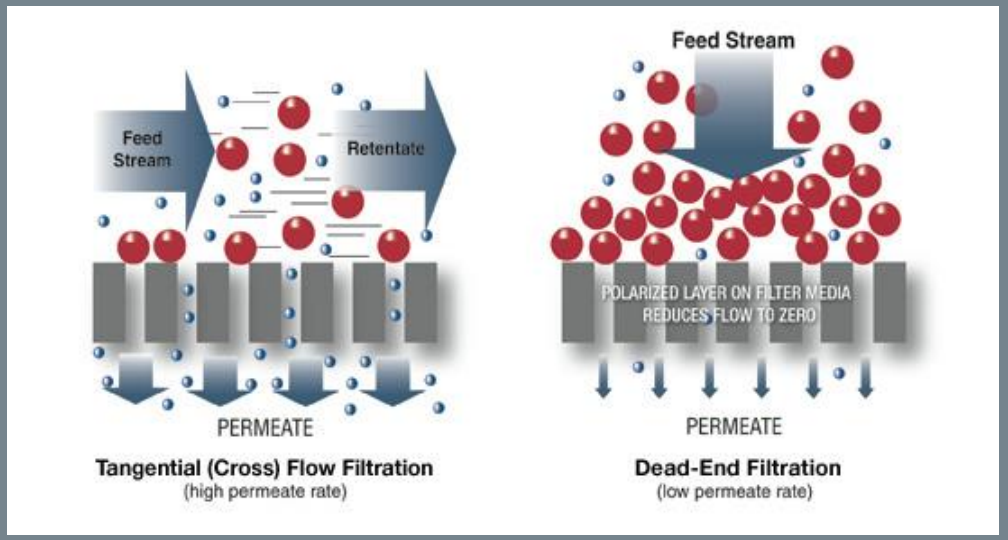
- **Scope and objective**
  - The treatment of industrial wastewaters by physicochemical methods
    - ***Flocculation/Coagulation***
    - ***Membrane Filtration***
  - ***Recycling of treated water***

Flocculation/Coagulation



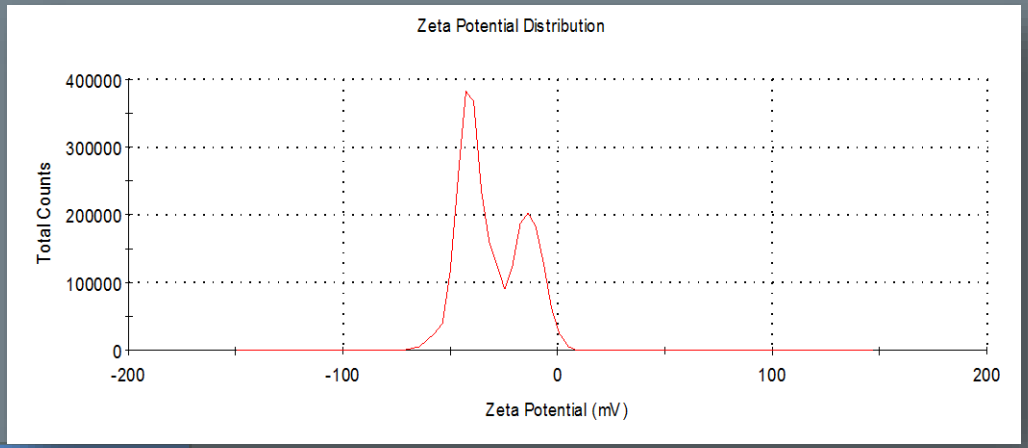


Membrane filtration



Results

- The wastes consisted of organic polymers of polyvinyl acetate, polyacrylic esters and traces of monomer, etc

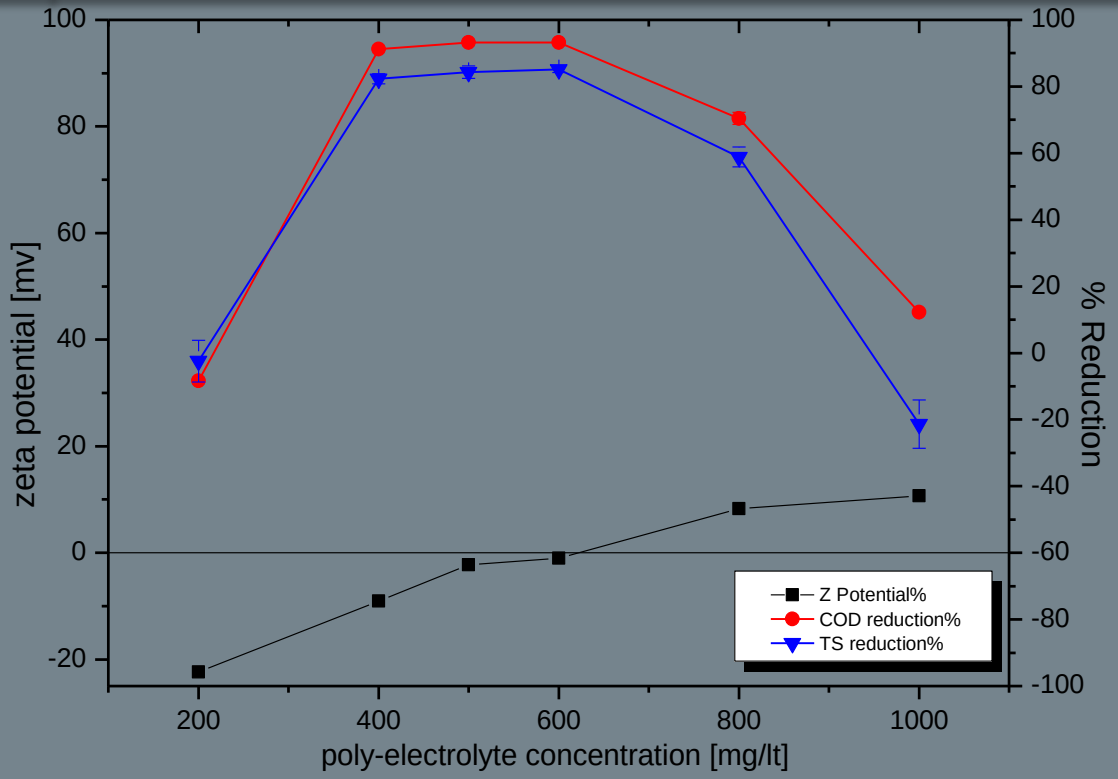


Parameters	Sample 1	Sample 2	Sample 3
COD (mg/l)	16710±280	19887±70	960±212
TS (g/l)	11.55±0.01	10.21 ±0.61	5.64±0.08
Zeta potential (mV)	-1.02mV	-30.7mV	-2.52mV
Particle size (nm)	3797 (82%) 285 (18%)	187 (100%)	83 (100%)

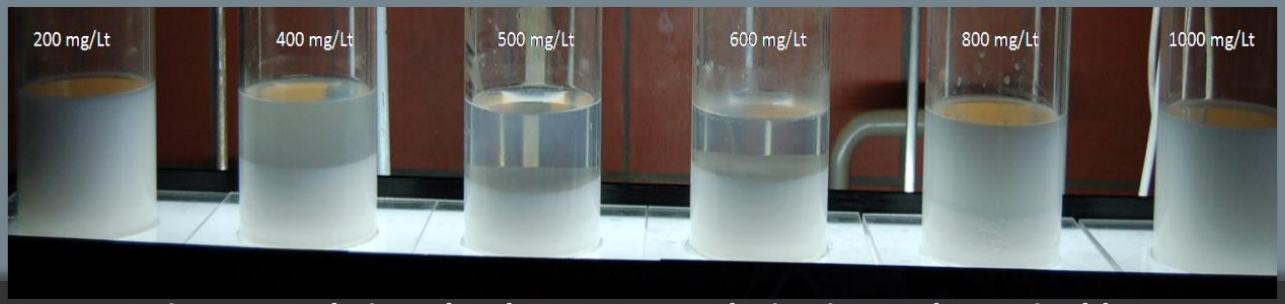
Tested polyelectrolytes

- Poly(Diallyldimethyl ammonium chloride)
- Poly(Ethylenimine)
- Poly(Allylamine)

Results [Experiments with Poly diallyldimethylammonium chloride]



- Reduction COD 95%.
- TS reduction over 80%
- Better performance in the container with concentration of 500 mg / l.



Results- Relevant Projects

Other tested industrial wastewaters

- Bar boiled rice process
- Red mud wastes
- Pulp paper wastes

Relevant Projects

- STInno - Sustainable Innovations and Treatment in Industrial Waste Water Clusters, 2 009
- Innovation coupons, GSRT (Innovation Coupons for SMEs), 2009
- SWAM - Increasing the regional competitiveness and economic growth through the RTD&I on sustainable water management, 2010
- Development of new polymeric membranes with carbon nanotubes for the treatment of aqueous wastewaters' MEKKA-SYNERGASIA, GSET, 2010
- Tempus IV, Noria: 'Strengthening Innovation Strategy and Improving the Technology Transfer in the Water Technology Sector of Morocco, 2012

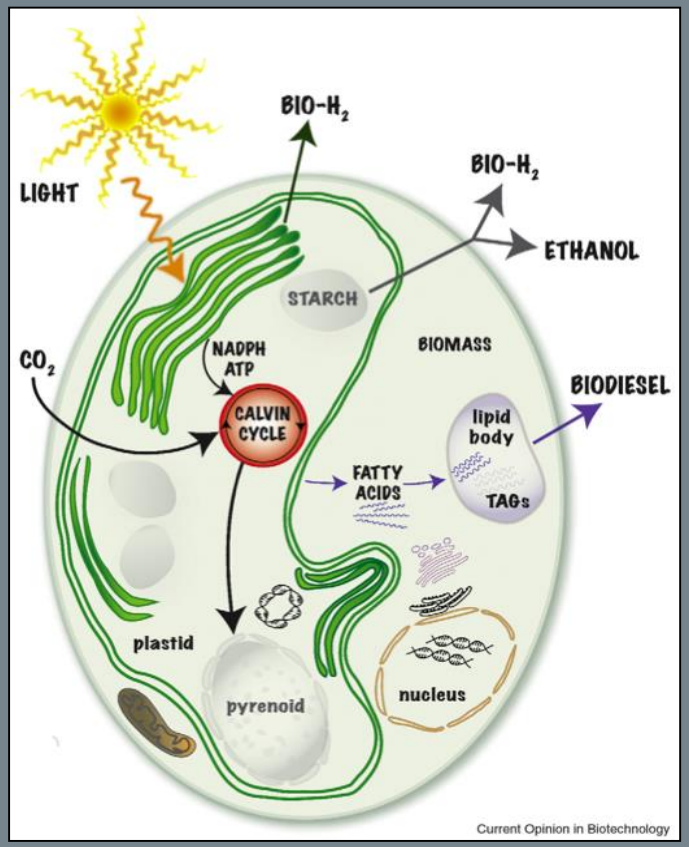
Algae Biology and Biotechnology

Coupling basic research with applied science in the field of photosynthesis

Dimitris PETROUTSOS, lecturer (appointment pending)

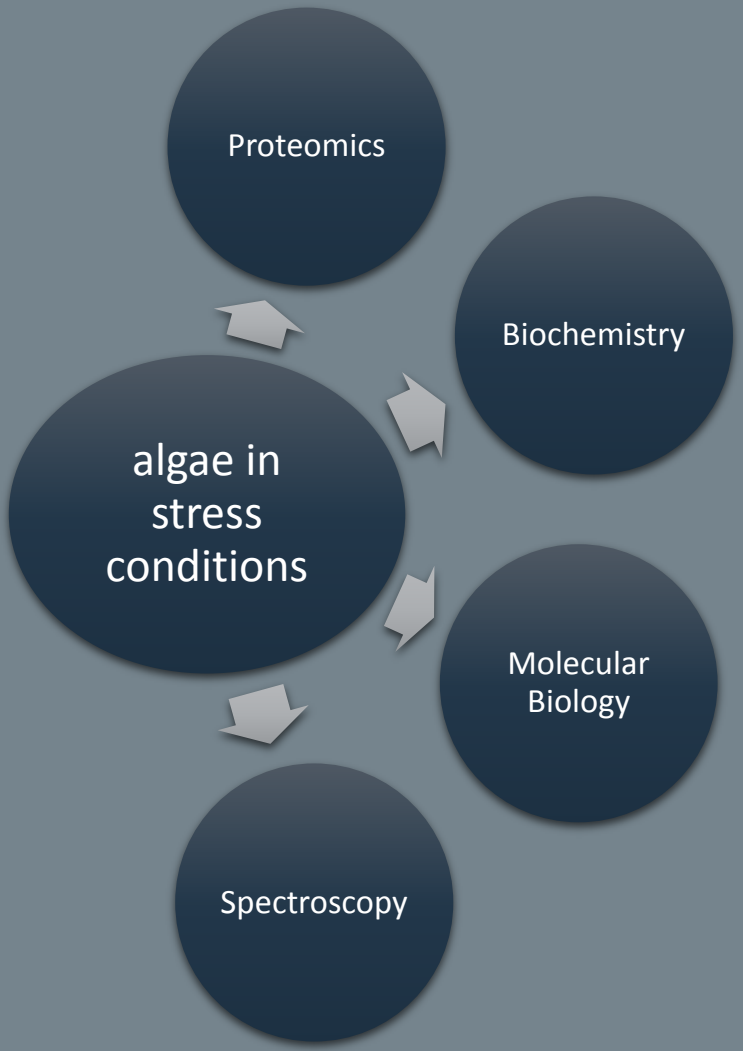
current position: CEA Grenoble, France, Laboratory of Plant Cell Physiology

Research line



- Unicellular algae are powerful cell factories with high potential for biotechnological exploitation.
- In depth understanding of algae biology is prerequisite for sustainable biotechnological applications.
- We focus in studying the acclimation of algae to stress conditions that favor formation of high added value products (ie –N and high light induce **lipid production**, -O_2 induces **H_2 production**).

Research approach



Discovery of unknown function proteins

Discovery of novel acclimation mechanisms

Identification of target proteins of biotechnological interest

Major findings

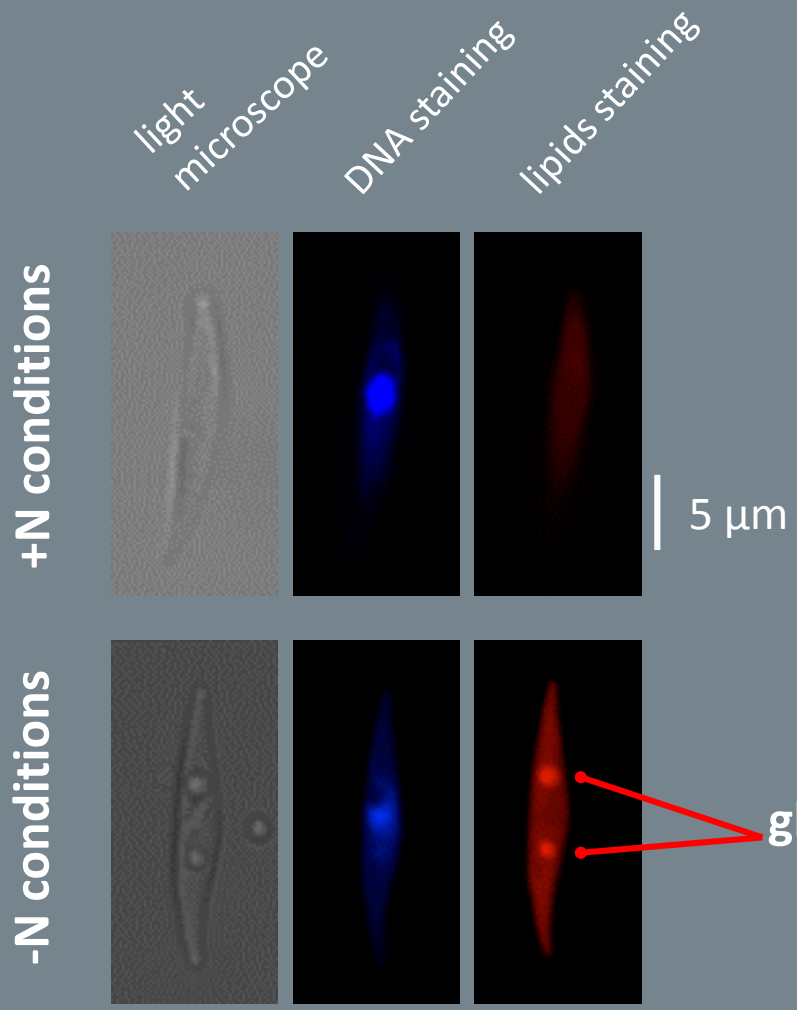
A Ca^{2+}-binding protein localized in the chloroplasts is essential for photoprotection in the green algae *Chlamydomonas*, via a Ca^{2+} signaling cascade (Plant Cell 2011, PNAS 2012).

A Fe-binding protein named PGRL1, localized in the chloroplasts, is crucial for acclimation of *Chlamydomonas* to anaerobic conditions and to iron deficiency (JBC 2009).

Down-regulation of the protein PGRL1 enhances dramatically the H_2 production in this algae, under anaerobic conditions (Plant Cell 2011).

In progress and future directions

Production of lipids from the marine algae *Phaeodactylum*




Thank you for your attention