

CENTERS OF RESEARCH

Nireas, International Water Research Center (Nireas-IWRC) of the University of Cyprus

***Corresponding author:**

Despo Fatta-Kassinou
Nireas-IWRC
School of Engineering
University of Cyprus
P.O. Box 20537
1678 Nicosia, Cyprus
Tel. +35722893515

E-mail: dfatta@ucy.ac.cy

Symeon Christodoulou, Costas Michael, Konstantinos Kostarelou, Stavros Kassinou, Dionysios Dionysiou, Despo Fatta-Kassinou*

Nireas- IWRC, School of Engineering, University of Cyprus, P.O. Box 20537, 1678 Nicosia, Cyprus



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Summary. The Nireas International Water Research Center (Nireas-IWRC) was established in 2011 with the vision of reaching out to the wider scientific community to exchange knowledge and best practices, to advance the state-of-the-art in water-related scientific research and technologies, and to strengthen public awareness on water-related issues. The Center's mission is twofold: to conduct research of high international caliber, while at the same time serving the research needs of Cypriot society, economy, and industry. Among the Center's many research, social, and dissemination activities, of particular note are its efforts in the thematic research areas of: (i) Water Quality, Monitoring and Treatment; (ii) Water Supply and Urban Water Management; and (iii) Socioeconomic Analysis of Water-Related Issues. Nireas-IWRC researchers have already secured significant national, EU, and international funding, and their research results have widely been disseminated in peer-reviewed journals, international conferences, technical reports, and technical workshops. [Contrib Sci 10:221-228 (2014)]

Introduction

The Nireas International Water Research Center (Nireas-IWRC) (Fig. 1) is a research organization devoted to the study and advancement of scientific research in water-related issues.

Keywords: water research centers · water-related research · Cyprus water research



Fig. 1. Logo of the International Water Research Center (Nireas).

The creation of the Center, in January 2011, is the culmination of research efforts and a successful research proposal by the Center's Board of Directors. The Center is currently co-financed by the European Regional Development Fund and the Republic of Cyprus through the Research Promotion Foundation and the University of Cyprus. It is named after Nireas (Nereus), one of the most important water deities of Greek mythology, known for his truthfulness and virtue, and most often referred to as the "old man of the sea" (Fig. 2). In the Greek language, the word "Nireas" connotes flowing water.

Water is, of course, one of the most important issues that humanity will have to deal with in the 21st century, and Nireas-IWRC was created with the vision of reaching out to the wider scientific community to exchange knowledge and best practices, to advance the state-of-the-art in water-related scientific research and technologies, and to strengthen public awareness on water-related issues. The objective of Nireas-IWRC as a new Research Center is to conduct research of high international caliber, while at the same time serving the research needs of Cypriot society, economy, and industry.

From Cyprus, to the Mediterranean, to Europe and beyond

Cyprus is the third largest island in the Mediterranean Sea, with a population of approximately 840,000. Water shortage has been one of the most serious issues that Cyprus has to face, with low levels of precipitation and varying periods of drought, spanning 2–3 years at a time.

For Cyprus, water scarcity has historically been the source of challenges and hardships, to both the population and the country's economy, with several extended drought periods recorded through the years. In modern times, Cyprus has responded to the water scarcity problem with the creation of a network of fresh-water reservoirs; in recent years the fresh-water supply was supplemented by a network of desalination plants and wastewater re-use schemes to strengthen the island's water balance and to prolong national water reserves.

These large infrastructures have made the problem of water scarcity in modern Cyprus less urgent, but have at the same time created a number of other issues, regarding water quality and the side effects on the surrounding ecosystem, must be confronted. Among the most important potential adverse effects is the release of xenobiotic compounds in the environment through wastewater re-use practices, salt-water intrusion, water loss due to evaporation, water quality issues regarding cyanobacteria, infrastructure integrity, and issues associated with small water treatment plants.

Of course, the aforementioned measures are a relatively common practice for many arid-weather Mediterranean and southern European countries, which have over the years been faced with extended periods of drought and short supplies of water. However, the case of Cyprus is of particular interest: Cyprus currently has the largest number of dams per square kilometer in Europe and the largest storage volume per capita, with over 100 dams and a total capacity of 304 million m³. Yet in 2008, after 4 years of drought and increasing water consumption, the Republic of Cyprus was forced to take drastic measures to safeguard diminishing national water reserves and to prepare for worsening drought conditions. These measures included the importation of water by ships from neighboring Greece, the enforcement of an intermittent water supply policy (city residents were provided with water through city water pipelines for about 12 h every 48 h) and the construction of several desalination plants. The intermittent water supply lasted for about 2 years (March 2008–October 2010) and put the country's water reserves (volume and quality), its residents, and its economy under enormous strain.



Fig. 2. Nireas or Nereus in ancient Greek mythology.

Nireas-IWRC was created with the vision to leverage scientific and engineering expertise in order to develop solutions to these important water-related problems in Cyprus. However, these problems are not unique to Cyprus; they are faced by almost all countries around the world. Thus, while emphasizing the resolution of local water-related problems, from the beginning Nireas-IWRC was created with an outward view, first establishing and subsequently continuously widening and strengthening international collaborations and partnerships.

Nireas-IWRC is the first water research center in Cyprus and is focused on water-related issues, such as the presence of xenobiotics in water and water quality, salt-water intrusion, water loss to evaporation, water quality issues regarding cyanobacteria, urban water distribution networks, advanced technologies for water treatment, water infrastructure integrity, water treatment and purification with low cost technologies, water reuse, water sustainability, and water problems faced by small arid islands; just to name a few.

Research in water-related issues requires innovative solutions. A multidisciplinary approach is needed to face these challenging water demands arising both from the growing population of the island and from global climate change without compromising water quality or the local ecosystem. A combination of scientific, technological, and management solutions are needed to address these issues, with the ultimate goal of improving existing methods or developing new ones for treating wastewater and drinking water resources while minimizing water supply problems. These methods should be sustainable, cost-effective, and socially acceptable. The Nireas-IWRC combines the knowledge and expertise of a wide spectrum of scientists specializing in multidisciplinary areas focusing on water.

Nireas-IWRC's overarching goals. In summary, Nireas-IWRC's aims are as follows:

- To conduct high-caliber water-related research.
- To establish the Center as a pioneer in water-related research by attracting researchers and experts.
- To establish infrastructure in support of its scientific mission, with permanent offices and state-of-the-art laboratories.
- To publicize the Center and make the name 'Nireas-IWRC' synonymous with innovation, excellence, and cutting-edge technology on water-related issues within the scientific community.

- To attract international research collaboration with renowned researchers in the field of water-related research.
- To perform research that will help address water-related issues, not only in Cyprus but also in the rest of the world.
- To secure additional funding and sustain the Center's scientific mission for future growth.

Research pillars. To support these goals, Nireas-IWRC is organized into specific Research Pillars:

Research Pillar 1: Water Quality, Monitoring and Treatment

- Advanced chemical water treatment.
- Advanced wastewater treatment through hybrid processes.
- Development and use of (nano) porous materials in water treatment applications.
- Characterization of properties of particles in waters and identification of organics adsorbed on solid surfaces.
- Environmental chemical analysis for water quality.
- Water pollutants impact assessment.
- Development of sustainable technologies for water treatment, purification, and reuse.
- Development of low-cost technologies for water management in both developed and developing countries.

Research Pillar 2: Water Supply and Urban Water Management

- Water resources.
- Groundwater resources.
- Protection of groundwater resources.
- Groundwater recharge.
- Development of mitigation techniques for evaporative loss from freshwater reservoirs.
- Reservoir sedimentation monitoring and management.
- Surface reservoir integrity.
- Water supply and urban water management.
- Automatic meter reading and ad-hoc wireless sensor networks for leak detection.
- Numerical modeling, prediction, and monitoring of salt-water intrusion on coastal aquifers.

Research Pillar 3: Socioeconomic Analysis of Water-Related Issues

- Virtual water and water pricing.
- Socioeconomic studies.
- Intermittent water supply.
- Public awareness.

The Nireas-IWRC's facilities

Nireas-IWRC's central office and laboratories are state-of-the-art facilities that adopt the latest in research and learning technologies and encourage greater innovation and collaboration, whilst supporting individual scholarship. They also enhance the vital relationships with industry and various national and international research centers by providing space for joint research activities and for exhibitions. Even though Nireas-IWRC's permanent facilities are still in development and will eventually be housed within the School of Engineering of the University of Cyprus, the Center currently operates a fully equipped laboratory and has office spaces in close proximity to the University campus.

Through Nireas-IWRC, several research laboratories and office facilities are, physically and scientifically, integrated into a single Research Center and their research efforts are directed at the achievement of the common and shared vision of Nireas-IWRC. The state-of-the-art laboratories of the Nireas-IWRC are clustered in the following lab complexes:

Gaia: Laboratory of Environmental Engineering.

SRL: Subsurface Research Laboratory.

Eupalinos: Construction Engineering and Water Networks Management Laboratory.

UCY-CompSci: Computational Science Laboratory.

The laboratories are complemented with additional research facilities managed by members of the Center's Board of Directors and related to environmental engineering, advanced oxidation technologies and nanotechnologies, urban water distribution networks environmental geomechanics, subsurface research, computational simulations, and virtual reality.

The equipment housed at the Center includes analytical equipment (UPLC-MS/MS, HPLC, GCs, TOC analyzer, ion chromatography); microbiological equipment (microbiological safety cabinets, microscope, filtration system for bacteria enumeration, ToxKit incubator, etc.); bench-scale reactors (photochemical, ozonation, sonolysis); pilot-scale reactors (coagulation/flocculation [90 l], membrane bioreactor [10 m³/d], moving bed biofilm reactor [90 l]); ultrafiltration unit (0.03 μm, 1 m³/d), microfiltration unit (0.2 μm, 160 l); solar compound parabolic collector pilot plants (100 and 250 l) for the treatment of urban wastewater and wastewater produced from wineries and olive mills; working water distribution network scaled models; and two computer clusters that are used for running large-scale production jobs with in-house codes that do not need frequent library

updates. In addition, Center members have access to a variety of other advanced scientific instrumentation, including for water quality analysis, the detection of contaminants of emerging concern, and the characterization of (nano) materials, located in various institutes in Cyprus and other collaborative centers outside the country, including the University of Cincinnati, which serves as Nireas's international research partner.

On-going Nireas-IWRC research

The Center has several on-going projects, covering a wide range of research topics:

ANSWER (H2020-MSCA-ITN-2015, Project coordinator). "Antibiotics and mobile resistance elements in wastewater reuse applications: risks and innovative solutions" aims to train a new generation of young researchers in the interdisciplinary technologies/frameworks required to meet the major challenges in the field of wastewater reuse and antibiotic resistance, including assessment of associated environmental and public health risks. The project will: contribute to: (i) an understanding of the fate and transmission of antibiotics, antibiotic-resistant bacteria, and antibiotic resistance genes (A&ARB&ARG) within urban wastewater, soil, ground/surface water, and crops; (ii) the validation of a suitable battery of bioassays for A&ARB&ARG effects evaluation and hazard identification; (iii) the development of a modeling framework capable of predicting the fate and assessing the risks associated with A&ARB&ARG in activated sludge, soil, waters, and crops; (iv) an assessment of the efficiency of innovative technologies to minimize A&ARB&ARG; and (v) the management and validation of the scientific and technological know-how generated in this project by academia, companies, and industries that will work together to develop relevant and feasible policy guidelines.

NEREUS COST Action ES1403 (Project coordinator). The COST Action "New and emerging challenges and opportunities in wastewater reuse" seeks answers to critical questions related to wastewater reuse with respect to the various current challenges with regard to contaminants of emerging concern, including antibiotic-resistant bacteria and genes (ARB&ARG). Other aims of the project are to provide consolidated insight into the potential effects of reuse practices regarding microcontaminants and ARB&ARG and crop uptake, to establish criteria and specifications on tech-

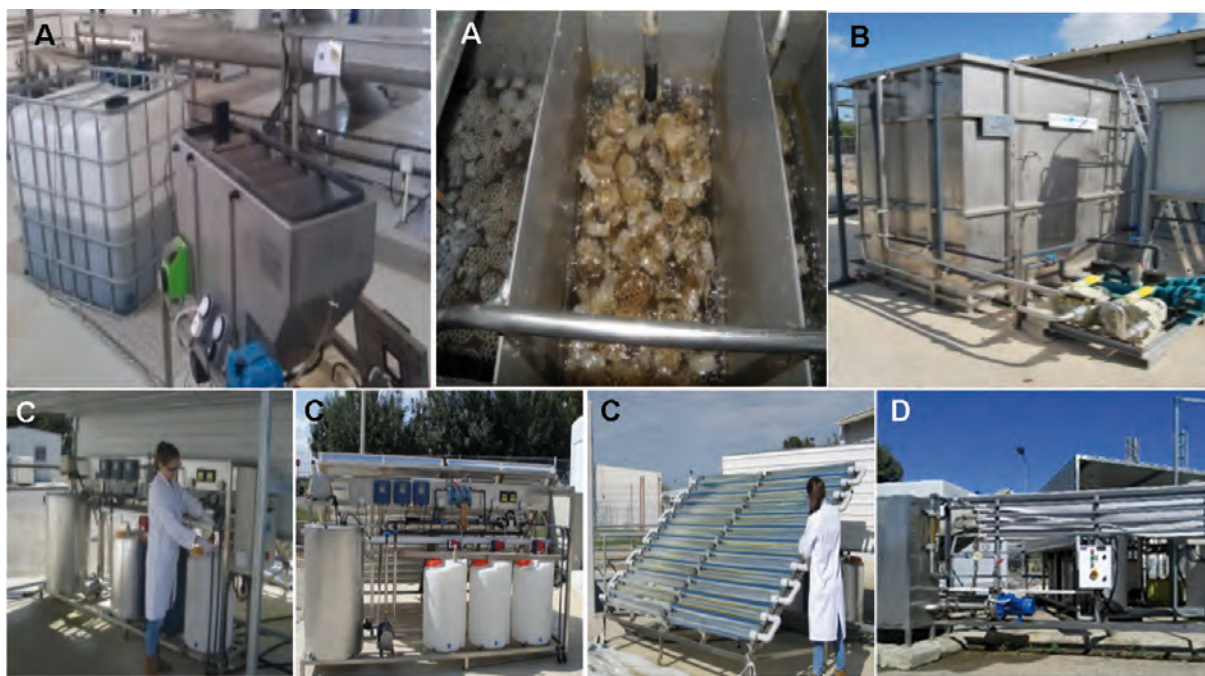


Fig. 3. (A) Pilot-scale moving bed biofilm reactor, (B) pilot-scale membrane bioreactor, (C) solar-driven pilot-scale photocatalytic reactors, (D) ultrafiltration pilot unit.

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nologies and assessment methods, and to suggest new effluent quality criteria to overcome current barriers and enhance further the reuse.

StARE. “Stopping antibiotic resistance evolution” project (EU JPI on Water Challenges) investigates a large number of European wastewater treatment plants to evaluate ARB&ARG abundance vs. chemical contamination and regional backgrounds. This project will develop guidelines for ARB&ARG monitoring in wastewater and evaluate the efficiency, impact, and cost effectiveness of advanced wastewater technologies, based on an innovative biological risk control strategy.

NEREUS (COST Action ES1403, Action Chair). The COST Action entitled “New and emerging challenges and opportunities in wastewater reuse” aims at answering critical questions related to wastewater reuse under the threat of the various current challenges with regard to contaminants of emerging concern (CEC) including antibiotic resistant bacteria and genes (ARB&ARG), and in particular to provide consolidated insight on the potential effects of the reuse practice with regard to microcontaminants and ARB&ARG, data on crops' uptake, establish criteria and specs on technologies and assessment methods, and suggest new effluent quality criteria to overcome current barriers and enhance further

the reuse. The main objective of this Action is to develop a multi-disciplinary network to provide insight into which of the current challenges related to the wastewater reuse practice, are the most concerning from both public health and environmental perspectives and how these can be overcome.

ANSWER (Marie Skłodowska-Curie Action, ETN 675530, Project Coordinator). The main objective of ANSWER “Antibiotics and mobile resistance elements in wastewater reuse applications: risks and innovative solutions” is to develop well-trained and creative Early Stage Researchers (ESRs) through innovative research projects Ph.D. projects to unravel the highly complex factors driving antibiotics and antibiotic-resistant bacteria and resistance genes (A&ARB&ARG) propagation in the framework of urban wastewater reuse, in order to assess the relevant environmental and public health risks, able to face current and future challenges and to convert knowledge and ideas into products and services for economic and social benefit. ANSWER aims to substantially contribute to the relevant EU wastewater policies, by providing valuable contributions for guidelines and recommendations for sustainable wastewater reuse.

MEDOLICO (I-B/2.1/090, Project coordinator). “A Mediterranean cooperation in the treatment and valorization of olive

mill wastewater” is a European Union project funded through an ENPI CBCMED. It brings together Cyprus, Israel, Jordan, Portugal, and Italy in a project that seeks to prevent and reduce the environmental risk presented by olive mill wastewater, by collaborating on the evaluation of various promising treatment technologies and developing uniform treatment procedures allowing the production of water for irrigation, recycling into the olive mill manufacturing process, etc., which will then be pilot tested. There will be a further evaluation of the potential for valorization of the collected by-products so that a solution can be provided that sustainably protects the environmental heritage of the Mediterranean regions while remaining cost-efficient for the olive mills.

I-WEB. “Integrating Water cycle management: building capability, capacity and impact in Education and Business” is funded by the European Commission (TEMPUS IV, grant no. 530718-TEMPUS-1-2012-1-UK-TEMPUS-JPCR) and focuses on supporting Kazakhstani organizations to work collaboratively with business, professional, and regulatory organizations at national and international levels to develop and deliver Masters and PhD programs in Integrated Water Cycle Management.

GAPS (KOULTOURA/VENS/0412/24, Project coordinator). “Closing Gaps of Knowledge with respect to Advanced Chemical Oxidation Processes for the Removal of Contaminants of Emerging Concern” is co-funded by the European Regional Development Fund and the Republic of Cyprus through the Cyprus Research Promotion Foundation). Its aims are to understand the role of natural organic matter during the application of advanced oxidation treatment for water and wastewater purification, to evaluate the efficiency of advanced chemical oxidation to remove antibiotic micropollutants, resistant bacteria, and genes from wastewater, and to investigate the role of hydroxyl and sulphate radicals during oxidation.

UCyAMR (AEIFORIA/ASTI/0609(BIE)/07, Project coordinator). “University of Cyprus Automatic Meter Reading” which is funded by the European Union’s Regional Structural Funds through the Cyprus Research Promotion Foundation, has the aim of: (i) expanding current research at the host organization on water-loss reduction; (ii) performing vulnerability assessment of lifeline systems (e.g., water, natural gas, electricity), with a focus on urban water distribution networks; (iii) developing prediction and evaluation methods for evaluating the social and economic vulnerability with a view to integrating these methods with engineering-based vulnerability

or fragility evaluation methods. The project will develop indicators of engineering, social and economic vulnerability based on a number of factors that represent engineering principles, community demographics, and socio-economic and risk perception characteristics. Additional aims are: (iv) developing a comprehensive hardware and software solution for the monitoring of piping systems with ad-hoc wireless sensors; (v) developing a comprehensive hardware and software solution for the automatic meter reading of water meters, providing online monitoring of water consumption in the network; and (vi) implementing the developed system at a pilot location.

PRODROMOS. The “Integrated platform for security, information and accessibility in intelligent multimodal transport” project is co-funded by the European Union, Greece and Cyprus, through the Greece-Cyprus Program of Transnational Cooperation (K5_03_01/16-10-2013), and deals with the creation and implementation of an integrated methodology to complement a “single window” platform for the security, information, and operation of intelligent marine transport and for the security of supply chains through seaports.

Recently completed projects

- Development of solar technology for the removal of effluent organic matter from urban wastewaters (SolTec, AEIFORIA/0308/BIE/01, 2008–2010).
- Leak detection and management in urban water networks using wireless sensors (WATERSENSE, IPE/PLYPH/0505/21).
- UWDN modeling, simulation and optimization of leakage detection via sensing technologies (UCyMSAD, PENEK/ENISX/0308/34).
- Sustainable management of agro-industrial wastes: Valorization and solar-Fenton post-treatment of olive mill effluents (SOLIVAL, AEIFORIA/FISI/0308(BE)/12, 2010–2012).
- Advanced systems for the enhancement of the environmental performance of wineries in Cyprus (WINEC-LIFE08 ENV/CY/455, 2010-2013).
- Photocatalytic removal of organic micropollutants from the aqueous phase using TiO₂ coupled with graphene as a photocatalyst (PhotoGraph, AEIFORIA/FISI/0311/(BIE)/33, 2012–2014).
- Development of novel methods for the toxicity as-



Fig. 4. World Water Monitoring Day in Cyprus.

assessment of multi-component chemical mixtures to humans and the ecosystem (TOMIXX, PENEK/0609/24, 2010–2012).

- Fate, effect and removal potential of xenobiotics present in aqueous matrices (IX-Aqua, UPGRADING/DURABLE/0308/07, 2009–2013).

Outreach activities

Besides the aforementioned research activities, the Center undertakes and/or participates in several national and international dissemination activities. Targeted and successful dissemination is a vital aim of Nireas-IWRC. Nireas-IWRC is therefore devising targeted dissemination/training modules for engineers, public agencies, SMEs, and the general public. Additional training elements include: (i) dissemination to prospective users of emerging tools, techniques, and technologies arising from the individual engineering projects; (ii) provision of comprehensive, timely, accessible, and reliable data to support and promote the developed tools, techniques, and technologies; (iii) fostering a general understanding within the target user groups of developments in engineering-focused technology tools; (iv) actively disseminating the findings of quality research evidence and promoting their use in practice and policy. Much of this activity involves raising awareness by distilling key messages from the research outputs and providing them in easily accessible formats (such as paper and electronic publications), making use of relevant scientific organizations (such as IWA and EWRA), and pro-

moting the work of the research group through peer-reviewed journal publications, conference proceedings, and presentations at conferences and workshops.

Some examples of successful workshops organized and hosted by the Research Center are:


- International Workshop on “Environmental management of wineries and olive mills –current challenges and opportunities” (19 October 2012, Hilton Hotel, Nicosia, Cyprus).
- International Workshop on the “Wastewater reuse applications and contaminants of emerging concern” (13–14 September 2012, Columbia Resort, Limassol, Cyprus). Organized within the framework of Norman network activities, DARE EU COST Action TD0803, and Nireas-IWRC.
- Workshop on the “Advanced systems for the enhancement of the environmental performance of wineries in Cyprus” (11 June 2012, Amathus Beach Hotel, Limassol).
- Workshop on the “Environmental assessment of xenobiotics released in the environment” (29 June 2011, University of Cyprus).

To date, Nireas-IWRC has been involved in many public outreach activities, local and international competitions, training seminars, public lectures, etc., including, but not limited to: Stockholm Junior Water Prize, World Water Monitoring Day, Researcher’s Night, Nireas-IWRC “When Ideas Flow” Speaker Series, Nireas-IWRC Educational Series Seminars and the Water Development Department Open Day.

A new task force led by Nireas-IWRC

A Working Group on Wastewater Reuse was recently established by the Norman Network [www.norman-network.net] in collaboration with the European COST Action TD0803 [www.cost-dare.eu], with the objective to formulate a task force to tackle the various “hot” issues related to wastewater reuse practices and contaminants of emerging concern. It is expected that the mandate of this scientifically fascinating and challenging working group will lead to the development of new knowledge within the specific research field and thus provide the basis for improving current applica-

tions and securing environmental quality and health.

The new task force aims at tackling the emerging challenges related to wastewater reuse applications. Important questions to be answered are: Which contaminants of emerging concern are relevant to wastewater reuse applications? (e.g., antibiotics and other licit and illicit drugs, transformation products, disinfection byproducts). What are the new concerns related to reuse applications? (direct and/or indirect effects). What technologies can enhance the conventional treatment by removing such contaminants? 

Competing interests. None declared.