جامعـــة خليفـــة
Khalifa University

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explorer

ENSURING AN ETERNAL CYCLE

KHALIFA UNIVERSITY'S QUEST FOR SUSTAINABLE WATER SOLUTIONS

A SMART FUTURE

A PERVASIVE DIGITALIZATION STRATEGY TO SOLVE GLOBAL CHALLENGES


ANDRIY ONUFRIYENKO/ MOMENT/ GETTY IMAGES
DRIVING A SUSTAINABLE FUTURE
At Khalifa University, we're playing a pivotal role in creating a greener and more sustainable future for our community and beyond.
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ABOUT THE COVER

Flowing water nourishes the leaves of a tree branch in the form of a circle. Our cover image symbolizes water's vital role as a precious resource and emphasizes the urgent need for sustainable water management.

COVER IMAGE: ANDRIY ONUFRIYENKO/ MOMENT/ GETTY IMAGES

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Khalifa University

ABOUT KHALIFA UNIVERSITY

The internationally top-ranked Khalifa University of Science and Technology is the one university in the UAE with the research and academic programs that address the entire range of strategic, scientific and industrial challenges facing the UAE's knowledge economy transformation and our rapidly evolving world.

Its world-class faculty and state-of-the-art research facilities provide an unparalleled learning experience to students from the UAE and around the world. The university brings together the best in science, engineering and medicine in the UAE, to offer specialized degrees that can take promising high school graduates all the way to top-rated doctorate degree holders.

ABOUT KU EXPLORER

KU Explorer covers the scientific achievements of the internationally top-ranked Khalifa University of Science and Technology. The website is updated weekly with new stories on a range of topics.

Whether you're a student, academic, industry professional or simply interested in learning more about the latest scientific advancements from Khalifa University of Science and Technology, KU Explorer has something for everyone.

We invite you to join us on this journey of discovery and exploration. You can stay up to date with our latest research news by following us on social media or subscribing to our newsletter.

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CONTENTS

01 SUSTAINABLE CITIES

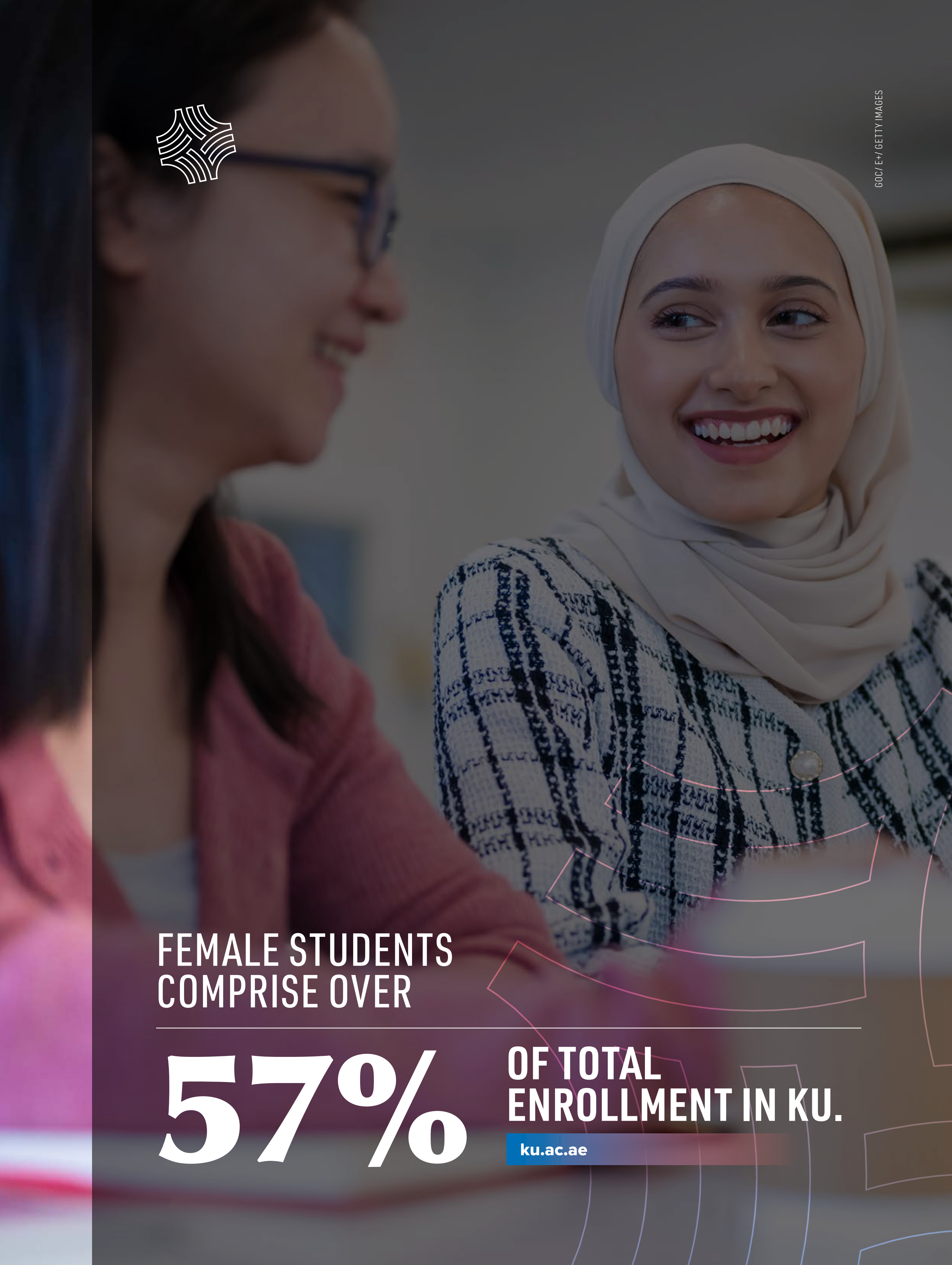
02 AI & ROBOTICS

INSIDE VIEWS

03 WATER SOLUTIONS

04 SUSTAINABLE ENERGY SOLUTIONS

05 HEALTHCARE TECHNOLOGY


FEMALE STUDENTS COMPRISE OVER
57%
OF TOTAL ENROLLMENT IN KU.
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EDITOR'S LETTER

Welcome to the second issue of KU Explorer, a journey through the cutting-edge research and groundbreaking innovations that are shaping our world.

As we face the pressing challenge of water scarcity, Khalifa University's researchers are at the forefront of developing innovative solutions. From advanced membrane technologies to harnessing the power of nature-inspired solutions, our scientists are working tirelessly to ensure a sustainable future.

Researchers at KU's Center for Membranes and Advanced Water Technology (CMAT) focus on developing resilient, energy-efficient, and cost-effective solutions. Meanwhile, the Sustainable Bioenergy Research Consortium (SBRC) has been testing the viability of the University's pioneering Seawater Energy and Agriculture System (SEAS) and its potential to transform seemingly inhospitable terrain into sustainable ecosystems generating biofuels, food and other valuable products. Inspired by nature, they're developing eco-friendly ultrafiltration membranes based on what they learned about mangrove trees.

Beyond water scarcity and pollution, KU is committed to driving innovation and developing sustainable solutions. This edition highlights the remarkable work being done by our talented researchers and the cutting-edge solutions they bring to the table, from waste-based materials to smart materials and advanced separation techniques. Their breakthroughs are not only improving water quality but also reducing environmental impact in the United Arab Emirates and beyond.

From the depths of the ocean to terra firma, we explore the realm of sustainable cities, where energy-efficient urban planning and green technologies are transforming our living environments. Researchers examine the world of energy dynamics modeling, highlighting the crucial role of building design and function in urban sustainability. Additionally, research into seawater and salt-tolerant plants offers promising potential to turn deserts into productive land.

Our researchers are also collaborating with industry, pioneering applied research and AI tools to integrate renewable energy into national power grids with real-world solutions. With AI and robotics revolutionizing industries and shaping our future, KU has rolled out a new pervasive digitalization strategy which explores the ubiquitous connected sensors, devices and networks that monitor and respond to human needs. The strategy brings together the university's expertise in robotics, artificial intelligence, data science, and information and communication technologies.

In line with Abu Dhabi's Vision 2030 for AI, robotics and healthcare, the university's Advanced Research and Innovation Center (ARIC) is harnessing generative AI and cognitive computing to propel advancements in robotics capabilities, bolster aerospace communication systems, and refine data processing and analysis.

And to cement its role as a hub for innovation, this year KU successfully hosted the International Conference on Intelligent Robots and Systems. A first in the Middle East and North Africa region, IROS 2024 highlighted the region's rapidly advancing capabilities as well as groundbreaking research and innovation in robotics and smart systems. It also served as a platform for universities, research institutions, and industry professionals to showcase their work while inspiring local talent and fostering collaboration.

We invite you to explore the pages of this issue and discover the remarkable work being done by our talented researchers. Join us on this exciting journey as we shape the future, one innovation at a time.

Advancing sustainability and security through research and teaching

Khalifa University is putting the emphasis on water and environment in its latest strategic priorities.

Soaring temperatures in the United Arab Emirates drive people to spend up to 95% of their time indoors, elevating the significance of air quality for public health compared with countries where citizens spend more time outside. Yet, understanding the factors influencing this indoor air quality—and how it relates to the conditions outside—is far from clear.

"Most of our time is indoors and little has been done about indoor air quality, which is of course affected by the outdoor air quality, but the link is not clear," says Diana Francis, an atmospheric scientist and assistant professor at the Earth Science Department at Khalifa University in Abu Dhabi. One uncertainty, for example, is the impact of desert dust particles mixed with pollutants on the lungs, and how this might be affected by climate change.

Studies suggest an alarming increase in dust storms in the Middle East, due to climate and human activities. Lakes across the region face the twin threats of drought and too much water being used by local industry and agriculture.

"Dried lakes are a very important source of atmospheric dust because the particles at the surface are not compacted and can easily be eroded," Francis says. This can increase the risk of severe health effects, as dust irritates the lungs and can trigger allergic reactions and asthma attacks. In susceptible people, these events can be serious.

> "Dried lakes are a very important source of atmospheric dust because the particles at the surface are not compacted and can easily be eroded."

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Addressing dust damage

Beyond health concerns, dust can affect the efficiency and lifetime of airplane engines. A better understanding of the different interactions at play would help in building more resilient and energy-efficient engines. Topics such as this are part of Khalifa University's refreshed academic strategy, which focuses on key priorities that affect the region.

"One of those overarching topics is sustainability and secure society, under which there will be water and environment," Francis explains. "It means this will be taken into account in the new projects, partnerships and collaborations with the private sector and with other universities."

Other strategic topics that KU academics will focus on include artificial intelligence, advanced materials, energy transition and health. Both teaching and research at the university will align with these new priorities, Francis says. "It's very important to have this clear direction from the university leadership so that attention can be directed to these different activities."

Developing a wider international reach

While the initial focus remains on regional issues, KU's research could develop a broader international impact through strategic partnerships and projects with overseas partners.

Interdisciplinary collaboration will be pivotal, particularly in areas such as climate change. For example, research on new materials used for renewable energy will depend on studies that forecast how the weather conditions will change. In return, new materials can be used to help filter air and provide clean water, which is important in environmental influences on health and, in turn, a sustainable society.

Similarly, climate change can create new hotspots for vector-borne diseases. Being able to accurately predict these changes can help safeguard the population from their spread.

"We are looking to expand horizontally with themes that run across the different strategic priorities," Francis says.

The change in emphasis is already shaping research at KU. Francis is keen to explore how climate change will affect the UAE, which as a coastal state is vulnerable to sea-level rise. She is also interested in how some environmental conditions will become more extreme, and the wider impacts this might have.

"All this research will be developed further under the umbrella of a secure society, because of course, it will help determine whether society is secure and sustainable," Francis explains.

Modelling energy dynamics for sustainable urban planning

Modelling energy supply and demand in different building types highlights how crucial built form and function are to urban sustainability.

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With cities housing almost half of the world's population and consuming two-thirds of the global energy supply, the quest for more efficient and sustainable energy solutions is critical if countries are to reach net-zero targets.

"Cities and urban settlements hold great significance in the drive for sustainability, yet previous studies often have not considered individual features of the built environment and their influence on energy demand and supply," says Ahmad Mayyas, an assistant professor of industrial and systems engineering at Khalifa University's Department of Management Science and Engineering. "Our research seeks to shed light on these important aspects of sustainable urban planning."

Mayyas and his team, including colleague Osama Mussawar, have developed a novel modelling framework[1,2] that provides planners with a nuanced understanding of the energy dynamics of different types of urban environments. By examining the form and function of each building in a given area, the model can evaluate the energy demand and supply characteristics for that specific area.

The team used an agent-based modelling approach, which is not often used for built-environment settings, to create their framework. "Agent-based modelling is used for simulating systems with many interacting components such as gas molecules in a cylinder or tracking crowds of people," says Mussawar. "Instead of mathematically describing the behavior of a system as a whole, this method models the behavior of each component individually to understand the system's overall behavior."

The team used data from local climate-zone classifications used in urban planning and transport applications, which specify the building type and use, to develop a modelling framework ap-

JON ARNOLD IMAGES LTD / ALAMY STOCK PHOTO

Masdar City is the world's first zero-carbon, car and skyscraper-free city.

"Low-rise areas show the greatest potential for developing self-sufficient energy communities and could even become areas of positive net energy."

plicable to various urban settings, whether existing or planned, and to different climates worldwide.

In the first iteration of their model[1], the team tested scenarios in which each building produced and consumed energy individually. They conducted a comparative case study of high-rise and low-rise urban areas equipped with rooftop solar photovoltaic systems. While the high-rise areas achieved 99% self-consumption of locally generated solar energy, this represented only 5% self-sufficiency due to dense population and high energy use. In contrast, low-rise areas with solar panels achieved more than 25% self-sufficiency.

"We then addressed a collaborative scenario in which all buildings in an urban area produce and consume energy collectively as a community[2]," says Mayyas. "Such energy communities are an active area of investment for governments across the world. However, understanding precisely how different building types can interact and share resources is critical to the success of such schemes."

This time, the model computed the energy supply and demand outcomes for each building and how it interacted within its community[2]. Once again, high-rise self-sufficiency remained low at less than 20%, suggesting that these urban areas have lower chances of becoming energy self-sufficient, even in an energy community setup. Mid-rise areas performed slightly better, but still relied heavily on the main power grid.

"Low-rise areas show the greatest potential for developing self-sufficient energy communities and could even become areas of positive net energy. There would be a need for local energy storage solutions to harness their full potential," says Mussawar.

The research shows that the energy performance and sustainability of urban areas are strongly influenced and conditioned by the characteristics of urban built environments including building height and compactness, and land use.

"Our findings can help in urban planning, particularly in context-specific development and deployment of energy solutions and policies," Mayyas concludes.

1. Mussawar, O., Mayyas, A., and Azar, E. Built form and function as determinants of urban energy performance: An integrated agent-based modelling approach and case study. *Sustainable Cities and Society* **96** 104660 (2023).

2. Mussawar, O., Urs, R.R., Mayyas, A., and Azar, E. Performance and prospects of urban energy communities conditioned by the built form and function: A systematic investigation using agent-based modelling. *Sustainable Cities and Society* **99** 104957 (2023).

UNVEILING EARTH'S CLIMATE CHRONICLES

Aisha Al Suwaidi, Associate Professor at the Department of Earth Science, Khalifa University.

AISHA AL SUWAIDI

Aisha Al Suwaidi's research transcends time, weaving geological insights with interdisciplinary collaboration to shed light on our planet's climate evolution. Integrating geology with numerous disciplines, her research projects have taken her and her PhD students around the world.

Tell us about the research work that your team is doing.
Our research revolves around using sedimentary rocks, found on the continents and in the ocean, to understand climatic and environmental changes. By analyzing concentration and cycling of carbon across Earth's geological epochs, we explore the cause and timing of major changes. At present, we are working on events that happened during the Triassic and Jurassic Periods 250 to 150 million years ago, in addition to analyzing more modern records of climate change in the marine sediments from the Gulf of Oman.

Is it a very interdisciplinary field?
Absolutely! My areas of research—chemostratigraphy and sedimentology—require a broad range of experts. More specifically, they integrate geology with numerous disciplines, including biology, chemistry, physics, and geography. This is unique and means that we are constantly employing an interdisciplinary approach to understand how our planet has changed over time and how it responds to disruptions.

One of Al-Suwaidi's PhD candidates is working on the continental record and impact of the Manicouagan meteorite that fell on Earth approximately 225 million years ago.

How can your research help explain the causes and effects of climate change?
Conducting fieldwork, gathering samples of rocks spanning millions of years, and performing chemical analyses on them provides crucial insights into the mechanisms driving environmental and climate shifts. Most importantly, this can help us understand how natural systems respond to changes in greenhouse gases in our atmosphere, offering perspectives on Earth's capacity to naturally correct these imbalances.

What notable discoveries have you made?
We uncovered an interesting connection between disruption in the carbon cycle and a palaeo-environmental crisis that happened 183 million years ago, when large parts of Earth's oceans were depleted of oxygen, resulting in the extinction of several marine creatures. My research has established that this disruption was truly global and not just limited to a few localities in the Northern Hemisphere, as was previously thought. The disruption can be attributed to two major, but distinct, volcanic events in South Africa and Antarctica.

How important is collaboration in your field of research?
Collaborations are very important for our field. My team is currently investigating an event that occurred around 230 million years ago, when major volcanic activity triggered a shift from an arid to an intensely wet climate. One of my PhD students, Indodeep Ghosal, is working with Calum Fox at JAMSTEC in Japan to explore this event in the paleo-Antarctic circle. Another PhD student, Marwa Painkal, is analyzing the records of the Northern Hemisphere, in collaboration with Micha Ruhl at Trinity College Dublin in Ireland and Kim Senger at the University Centre in Svalbard, Norway. These collaborations allow us to take a more holistic research approach.

Irrigated by saltwater, salt-tolerant species of Salicornia plant can generate valuable bio-resources, turning sand into rich soil.

KHALIFA UNIVERSITY

Transforming deserts into green oases using seawater

Salt-tolerant plants and microbes irrigated by seawater can generate valuable bio-resources, in a system that turns desert sands into rich soil.

At the heart of barren coastal deserts lies the potential to transform seemingly inhospitable terrain into sustainable ecosystems generating biofuels, food and other valuable products.

Over the past eight years, the viability of the pioneering Seawater Energy and Agriculture System (SEAS) has been fully demonstrated at a two-hectare pilot plant established by Khalifa University's Sustainable Bioenergy Research Consortium (SBRC).

Aquaculture, agriculture and aviation fuel

The SEAS concept of irrigating an agriculture and biofuel system with seawater depends not only on a salt-tolerant (halophytic) species of Salicornia plant, but also on the transformation of desert sand into agricultural soil. To develop and sustain the soil and nourish the Salicornia, a three-stage system has been developed. In the first stage, saltwater from the ocean is held in ponds where fish and shrimp are cultivated. The nutrient-rich wastewater from this phase irrigates the Salicornia biomass grown in phase two.

The fish and shrimp are the first valuable output of the system, followed by the plant seed oil and biomass from the second phase. Finally, in phase three the water draining from the Salicornia plots is used to irrigate wetland mangrove tree cultivation. This generates either further biomass that can be burned or otherwise processed as a bio-energy source, or young trees to support reforestation projects.

The SEAS project initially focused on producing aviation fuel from the Salicornia seeds, and was supported by major commercial aviation companies including Boeing, Honeywell, General Electric, Safran and Etihad Airways. Early success led to a commercial Etihad Airways flight, fuelled partially by biofuel from the pilot plant, flying from Abu Dhabi to Amsterdam in January 2019. The options for making valuable products from the Salicornia biomass have now been extended to include biogas and other useful chemicals.

"The project is now at an inflection point," says Alejandro Rios Galvan, SBRC Director, emphasizing the need for new investment to establish the system as a full-scale commercial operation. "We are more than halfway there in terms of the funding needed, and we now need to reach out to sustainably minded investors that understand the long-term needs but also great opportunities," says research engineer Joao Uratani, who is overseeing the business development initiatives.

Plants to products

Khalifa University's multidisciplinary personnel and scientific resources can cover the diverse needs of such an innovative and multi-phase project that requires expertise in aquaculture, agriculture, forestry, plant and microbial science, and engineering.

At the heart of the process are the halophytic plants and the waste stream generated by the aquaculture subsystem, which facilitate the conversion of desert sand into rich organic soil. Both are essential for growing plant biomass in such an unconventional environment.

Plant scientist and postdoctoral fellow at Khalifa University Houda Chelaifa explains that converting the desert sand into soil was achieved by adding organic effluent from the aquaculture ponds, stimulating the growth of a microbial community, and then incorporating the interaction with the halophyte root system and other biomass waste. "It's just amazing how we have transformed the sand," she says.

Chelaifa's research focuses on learning more about the Salicornia plants, including genome sequencing. She hopes to apply the knowledge gained to develop more effective hybrids, either by conventional plant breeding or perhaps using CRISPR gene editing to modify the plant genome directly.

"We want to identify the specific genes that make the plants able to survive in the salty environment, examine the differences between different species of Salicornia including our native species, which are different from those currently used in the pilot plant, and then perhaps develop more efficient hybrids," she says.

The SEAS project serves as a fertile early-career training ground for KU postgraduate students. M-Haidar A. Dali, for example, focused his master's research on using locally sourced biomass to enhance soil, not only at the SEAS plant but more widely across the UAE.

"Using natural polymers and fibers from food waste, we are learning how to stabilize the sandy soils typically found in the region, increase their organic content and improve their performance in carbon fixation," Dali explains. "I am really enjoying my work on the project, which is equipping me with valuable skills and experience to develop my future career plans in sustainable engineering and research."

Scaling for commercialization

Chemical engineer Rafael Gonzalez Hernandez oversees the operations across all parts of the SEAS pilot plant. Having worked through the challenges and development of the project, which has evolved substantially from its initial focus on producing aviation fuel to the current wider range of applications, he is now identifying the requirements for scale-up into real commercial operations.

SBRC established the pioneering Seawater Energy and Agriculture System in the UAE eight years ago.

The team has sourced a 200-hectare plot of land in the Western Region of Abu Dhabi, available for the first phase of commercialization. "Each of the three parts of a fully commercial operation would need to be at least the size of our entire current facility, but we have done all of the technical demonstrations needed to move up to much larger scales," Hernandez says. "The main challenge now is to get the funding, because we already have a plan in place for scaling up."

While the fish and shrimps can be used as food, and the mangroves as biomass fuel and a source of trees for reforestation, the options for making use of the Salicornia are more varied. They include use as livestock feeds, cooking oil, cosmetics products and in biogas generation, in addition to aviation fuel.

While working on research for his master's degree some years ago, Uratani contributed to the diversification of outputs by using experimental microbial ecology methods to engineer microbiomes that could flourish in salt-water conditions and generate biogas. This led to a patent for their innovative method to convert biomass into biogas using salt-tolerant microbes.

Today, Uratani is developing the business case for commercialization and looking for new investors to take that major step forward. He explains that the wider future options are somewhat out of the field of expertise and interest of the original commercial members of the SBRC, mainly focused on aviation fuels. "What we need for this next step is to engage with more traditional agriculture-oriented investors," he explains.

In terms of future potential, not just for the UAE but also worldwide, Uratani says that the amount of arid desert land around the world suitable for this technology is roughly equivalent to the world's arable land. "So, the geographical opportunities are global, and potentially immense," he says enthusiastically.

That enthusiasm is shared by everyone on the project and underscores the key challenge of spreading the word and bringing sufficient investors on board.

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Chelaifa, H. *et al.* Beyond the greenhouse: coupling environmental and salt stress response reveals unexpected global transcriptional regulatory networks in Salicornia bigelovii. *bioRxiv* (2020).

SCIENTIFIC DEFINITIONS AND FACTS

Plant to biofuel

Salicornia bigelovii is one of the most salt-tolerant plant species in the world and is a candidate plant model for studying salt stress regulation and tolerance. It has shown promise as an economical non-crop species that can be used for saline land remediation and for large-scale biofuel production.

Smart cities with advanced communication networks hold unprecedented potential.

Pervasive digitalization: Toward connectivity and a smart future

As digital technology becomes ubiquitous, Khalifa University's cross-cutting research strategy gives it the edge.

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In a world where our homes, cities, and even our clothes are becoming smarter, we stand on the brink of a new era that promises to revolutionize the way we live, work and interact with our environment. The fourth industrial revolution, which will see the fusion of digital, physical, and biological systems, holds unprecedented potential.

A strategy to solve global challenges

Khalifa University has categorized its research priorities into 'verticals' and 'horizontals'. The verticals are challenges identified as being key to both the university and the United Arab Emirates more broadly. They include a managed energy transition; a sustainable, secure society; and a route to long, healthy lives. The horizontals define the technologies and expertise that will likely be needed to address the vertical challenges.

Pervasive digitalization, the trend toward ubiquitous connected sensors, devices and networks that monitor and respond to human needs, is one such horizontal and brings together the university's expertise in robotics, artificial intelligence (AI), data science, and information and communication technologies. "We are able to work toward end-to-end solutions for pervasive digitalization using the diverse expertise of our researchers," says Mérouane Debbah, professor of computer and information engineering and Director of the university's 6G Research Center.

KU scientists across research units including the Center for Cyber-Physical Systems, the Emirates ICT Innovation Center and the Center for Autonomous Robotic Systems, as well as the 6G Research Center, are contributing to this joint mission through projects involving autonomous systems, sensing, software applications, hardware accelerators, blockchain and cyber-security.

Debbah is also a Khalifa University ambassador for 'Integrated Generative AI and Cognitive Computing,' a sub-theme of the overarching pervasive digitalization strategy. "As an ambassador, my role is to promote the ongoing work at KU in the field of pervasive digitalization, and also to support our ecosystem with solutions and use cases," he explains.

End-to-end solutions for intelligent communications

A crucial consideration for all of these technologies will be the potential for remote devices to communicate with each other. Debbah's research focuses on building the next generation wireless infrastructure for what he calls the internet of intelligence. "Intelligence is becoming massively pervasive at every part of the network, and we need a collective intelligent network that can connect different AI technologies together," he says.

Debbah has research experience in small-cell (4G), massive-MIMO (multiple-input multiple-output, 5G) and large intelligent-surface (6G) technologies. But he also has contributed to large language models (LLMs) with Falcon, distributed AI systems for networks, and most recently the development of Telecom GPT for 6G communication. "My research lies at the interface of fundamental mathematics, algorithms, statistics, information and communication sciences with a special focus on random matrix theory and learning algorithms," he explains. "KU was visionary in establishing a 6G center, the first of its kind in the region, in September 2023."

To ensure the project is a practical success, the university has begun to collaborate with other stakeholders within the UAE. This includes working with the country's telecommunication and digital regulation authority to ensure that the right frameworks are in place. "My colleagues have also put into place a cybersecurity academy together with the UAE Cyber Security Council," says Debbah. "The most important outcome will be that KU's pervasive digitalization strategy will play a role in creating the next-generation talents who will be at the heart of the UAE's transition from an oil economy to a knowledge economy."

The future of AI and robotics: insights from IROS 2024

Robotics experts discussed and shared insights about pathways to sustainable development at this year's International Conference on Intelligent Robots and Systems.

With over 4,000 global participants, IROS2024 fostered a unique exchange of insights, expertise, and collaboration. Keynote and plenary speakers shared impactful perspectives on the transformative role of robotics across industries and economic sectors.

IROS24 highlighted the region's groundbreaking research and innovation in robotics and smart systems.

Abu Dhabi is strengthening its position as a major hub for robotics experts with this year's international conference on intelligent robots and systems (IROS 2024). Held from October 14-18, the IEEE/RSJ event brought together global researchers, scientists, engineers, and industry professionals to showcase the latest advancements and innovations and discuss how these findings can ensure long-term environmentally and socially responsible growth.

"The conference was designed to offer participants cutting-edge knowledge, networking opportunities, practical applications, and hands-on experiences in robotics and AI, fostering valuable insights and collaborations," says Director of Marketing and Communication at Khalifa University Sayed Al Hashmi.

A first in the Middle East and North Africa region, the event highlighted the region's rapidly advancing capabilities as well as groundbreaking research and innovation in robotics and smart systems. It also served as a platform for universities, research institutions, and industry professionals to showcase their work while inspiring local talent and fostering collaboration.

> **"The IROS2024 conference was designed to offer participants cutting-edge knowledge, networking opportunities, practical applications, and hands-on experiences in robotics and AI, fostering valuable insights and collaborations."**

Groundbreaking research and innovation

The event featured a diverse program of keynote lectures, forums, and workshops. Distinguished experts such as Oussama Khatib from Stanford University, Magnus Egerstedt from the University of California, Irvine, and Najwa Aaraj, who runs the UAE's Technological Innovation Institute, shared insights on cutting-edge topics, including human–robot and robot–robot collaboration, interaction, and trust in various environments ranging from healthcare to biological systems. Yoshihiko Nakamura, from the UAE's Mohamed Bin Zayed University of Artificial Intelligence, also talked about AI–robotics integration.

The official opening ceremony of #IROS2024 in Abu Dhabi witnessed the attendance of esteemed officials and dignitaries, highlighting the UAE's commitment to pioneering research and innovation in robotics and AI.

Leading experts presented pioneering research on autonomous flying machines and lightweight miniature drones, which are set to play a key role in transportation, logistics, and surveillance.

Among the experts was Davide Scaramuzza from the University of Zurich, Switzerland, who specializes in drone racing, pushing the boundaries of high-speed, and agile flight in competitive environments. Giuseppe Loianno from New York University, presented his work on boosting drone performance by optimizing agility and collaboration. Naira Hovakimyan, from the University of Illinois Urbana-Champaign, addressed the critical issue of ensuring safety and reliability in autonomous systems in complex, dynamic environments, while Guido De Croon, from TU Delft, discussed integrating brain-inspired algorithms into insect-like drones working alone or in swarms, and Mirko Kovac from Imperial College, United Kingdom, spoke about developing drones to enhance monitoring and preservation efforts in fragile ecosystems.

Another key area of focus was bio-inspired robotics, which mimics physical structures and mechanisms found in living organisms to produce efficient and adaptable designs useful in fields such as healthcare and engineering. Several examples were presented during the conference, for instance, bio-robotics and computational neuroscience expert Auke Ijspeert, head of the EPFL Biorobotics Laboratory, Switzerland, highlighted how he uses insights from animal locomotion to develop highly efficient robotic systems, while Barbara Mazzolai from the Fondazione Istituto Italiano Di Tecnologia, Italy, presented her work on creating soft robots, which are made from flexible, deformable materials like silicone or rubber, inspired from natural organisms.

These robots can be useful for medical devices, wearable technologies, exploration, and even rehabilitation. Another example came from Kaspar Althoefer from Queen Mary University, United Kingdom, who focuses on translating nature's efficiency and precision into medical robotics that enhance surgical performance. Justin Werfel, Senior Research Fellow at Harvard University, in the United States, evaluates social insects to develop cooperative robotic systems capable of solving intricate tasks.

Advanced AI and machine learning

Intelligent robots are revolutionizing industries, thanks to advanced AI and machine learning algorithms. Several experts discussed how AI is driving global innovation in various domains, such as telecommunications and robotics, enabling machines to perceive, learn and adapt to complex environments.

Barbara Caputo, who leads the AI Hub at Politecnico di Torino, Italy, spoke about her work to drive the practical implementation of AI in industries to solve real-world challenges, while Merouane Debbah, director of the KU 6G Center at Khalifa University, showcased his groundbreaking work on TelecomGPT by integrating AI with next-generation telecommunication systems for smarter, more efficient networks, and Concepción Alicia Monje from University Carlos III of Madrid, Spain, outlined how she's developing AI-enabled soft robots with greater flexibility and adaptability for delicate tasks.

Cross-modal machine learning was the focus of a talk by Jianwei Zhang, from the University of Hamburg, Germany, whose work aims to teach robots to integrate and process information from multiple sensory inputs, mimicking human perception. President of Mohamed bin Zayed University of Artificial Intelligence (MBZUAI), UAE, Eric Xing, spoke about exploring next-generation foundation models that extend beyond traditional lingual and visual intelligence.

The final keynote session brought together leading experts who promote robotics through innovation, high-profile global competitions and grand challenges. A key figure in European robotics, Pedro Lima from the University of Lisbon, Portugal, is overseeing initiatives, such as the European Robotics League competitions and euROBIN Coopetitions. These initiatives are expected to strengthen European robotics capabilities, act as an educational platform by raising student awareness and understanding, as well as allowing robotics and AI teams to simultaneously collaborate and compete using robots.

Among the speakers was Timothy Chung, a program manager at the Defense Advanced Research Projects Agency (DARPA) tactical technology office, and now general manager of Autonomy and Robotics at Microsoft. Chung helped shape robotic innovation in the Americas through the DARPA Challenges. In particular, he ran the DARPA Subterranean (SubT) Challenge, which aimed to engineer autonomous robots that can navigate, map, and search in hazardous and unstructured subterranean settings, such as tunnels, caves, and urban underground spaces, by combining AI and robotics.

President of the RoboCup Federation, Ubbo Visser, from the University of Miami, demonstrated how

"IROS 2024 succeeded in driving innovation, collaboration, and economic growth in the UAE and the MENA region, positioning them at the forefront of the global robotics and AI landscape."

the federation is advancing robotics through the Robot World Cup initiative, or RoboCup, an annual international competition that fosters collaboration in AI and robotics research. Thomas McCarthy, Executive Director of ASPIRE, the technology transition arm of UAE's Advanced Technology Research Council, highlighted the grand events he manages, such as the Mohamed Bin Zayed International Robotics Challenge, which are set to accelerate the translation of robotics innovations from lab to market and real-world applications.

Networking and collaboration

IROS offered attendees opportunities to network with experts and peers and open doors for collaborations and partnerships, while hands-on workshops and tutorials offered practical experience. The conference's various forums enabled fruitful discussions on the technological and socio-economic impact of robotics on sustainability, human–robot interaction and future societies, regulation and policy, regional innovation and entrepreneurship, as well as diversity.

Technical visits and competitions were just as beneficial, providing a deeper understanding of real-world applications and inspiring creativity and innovation. Attendees had the chance to visit several facilities at Khalifa University, MBZUAI, and the applied robotics and AI research lab at Dubai Future Foundation, which feature some of the leading-edge technological capabilities in the country.

"IROS 2024 succeeded in driving innovation, collaboration, and economic growth in the UAE and the MENA region, positioning them at the forefront of the global robotics and AI landscape," Al Hashmi says.

Intelligent robots are revolutionizing industries, thanks to advanced AI and machine learning algorithms.

KHALIFA UNIVERSITY OF SCIENCE AND TECHNOLOGY

Ways AI and robotics save energy and enhance lives

With Yahya Zweiri at its helm, Khalifa University's Advanced Research and Innovation Center is harnessing robotics and AI technologies to benefit society.

In line with Abu Dhabi's Vision 2030 for AI, robotics and healthcare, the Advanced Research and Innovation Center (ARIC) at Khalifa University is transforming intellectual property into industrial solutions, startups and enterprises, enriching the emirate's economic landscape.

The only high Technology Readiness Level (TRL) center in the region, "Khalifa University's unique model allows it to make a significant impact on both industry and academia," says ARIC Director Yahya Zweiri. With a wealth of experience as a professor at the university's aerospace engineering department, Zweiri is ideally placed to run ARIC. He has led research projects in robotics and AI, securing eight patents and creating a spin-off company, DroneLeaf. The latter, a culmination of years of cutting-edge research at KU, has developed the world's most advanced AI-powered flight control software for drones, pushing the limits of performance, agility, and robustness while reducing development costs and time.

An overarching goal for the university's robotics and aerospace research is 'pervasive digitalization'. "This includes harnessing generative AI and cognitive computing to propel advancements in robotics capabilities, bolster aerospace communication systems, and refine data processing and analysis," Zweiri explains.

As part of its digitalization strategy, the university aims to develop resilient networks and cybersecurity measures to protect aerospace and healthcare systems, ensuring their reliability. Equally important is that robotic solutions are environmentally sustainable and have positive impacts on societal well-being.

An example of such beneficial applications is KU's drive to promote health longevity through innovations such as robot-assisted surgery and high-tech medical transport. Researchers at ARIC are also collaborating with Amana Healthcare, a subsidiary of regional healthcare firm Mubadala Health, in developing a customized knee exoskeleton system for rehabilitation assistance, enhancing physiotherapy sessions and assisting patients in post-surgery exercises.

A strong sustainability ethos is applied in the related area of advanced materials manufacturing, where experts are aiming to fabricate lightweight yet robust materials for spacecraft and robotics. Meanwhile, researchers are playing key roles in a wider managed energy transition;

Researchers are partnering to develop AI-powered flight control software for drones,

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employing their intelligent algorithms and innovative designs to optimize energy consumption in robotics and aerospace systems.

ARIC's technologies are already being deployed in real applications with industry partners, and Zweiri expresses enthusiasm for the many collaborations with industry that ARIC has fostered. "Through collaboration with STRATA Manufacturing, SANAD and Mubadala, ARIC is fulfilling precision engineering applications in the field of industrial manufacturing," he says. "We developed the first robot capable of fully automatic drilling processes in aeroplane structures. It features an array of sensing technologies and AI algorithms that enable it to autonomously navigate across the factory and then perform the required tasks within aerospace-grade tolerances."

The research teams have been working toward other automation solutions. These include aero-engine blade repairing, painting, sorting and inspection, enabling aerospace companies to keep up with the demands of airlines and comply with extremely rigorous safety standards.

But robots and AI are nothing without nurturing the best people, which is why ARIC is upskilling UAE nationals in key industrial technologies, "Our ongoing commitment to training UAE nationals fosters a highly skilled and proficient workforce," says Zweiri. "All our UAE nationals—senior design students, postgraduates and national service students—have found employment within three months of their time at ARIC."

Aiswarya Babu, a research associate at ARIC who works on SANAD maintenance, repair and overhaul projects, is inspired by KU's vision and its potential in the field of robotics and aerospace. "With the guidance of Prof. Yahya and support from Khalifa University, I am confident in my ability to achieve my aspirations in this field."

Khalifa University emerges as a global conference hub

Abu Dhabi's premier institution is set to host high-impact international conferences, fostering cutting-edge research and global partnerships across diverse engineering and scientific fields.

Abu Dhabi's Khalifa University is gearing up for an exciting line-up of international conferences in the coming months, solidifying its position as a global hub for research and innovation.

"International conferences are crucial because they report on the latest cutting-edge aspects in the advancement of science, engineering, and technology," says Mahmoud Al Qutayri, Professor of Computer and Information Engineering and Associate Provost for Academic Operations. "They also serve as platforms for networking across the globe and forging collaborations."

The events span a diverse range of fields, reflecting Khalifa University's commitment to interdisciplinary research. The schedule kicked off with the International Conference on Intelligent Robots and Systems (IROS) in mid-October, followed by the IEEE International Conference on Image Processing in late October. November brought the International Conference on Nanostructured Materials. Conferences on Communications and Networking, Smart Power and Internet Energy Systems, Cloud Computing Science and Technology, and Data Mining are also on the horizon.

Of particular note is the inaugural IEEE Middle East Conference on Communications and Networking, scheduled for November 2024. "We were approached by the IEEE Communications Society to organize this conference, recognizing our capability to host such events," says Al-Qutayri.

Continuing the momentum

These conferences align perfectly with Khalifa University's mission to catalyze growth in Abu Dhabi's rapidly evolving knowledge-based economy. "Our vision is to be a globally leading university that stimulates positive change and shapes the future," Al-Qutayri emphasizes.

The impact of the conferences extends throughout Khalifa University's academic community. International conferences attract world-class speakers, including Nobel laureates, university deans, prominent professors, and industry leaders from top companies. This high-profile participation not only elevates the academic discourse but also provides unparalleled networking opportunities for attendees. As a result of these interactions, Khalifa University has fostered valuable collaborations with renowned institutions such as the University of Glasgow in the UK, University of British Columbia in Canada, and Zhejiang University in China.

> "International conferences are crucial because they report on the latest cutting-edge aspects in the advancement of science, engineering, and technology."

Graduate students in particular can greatly benefit from attending and participating. "They have opportunities to submit papers, present their work, and network with international researchers and fellow students," Al-Qutayri says. "This helps them start building their own networks, which is crucial for people conducting research."

Khalifa University's high-impact conferences have drawn in delegates from all over the world.

The Abu Dhabi government, through the Department of Culture and Tourism, provides strong support for these initiatives. This partnership has been crucial in the competitive bidding process for international conferences. "We need to present a strong case not just on the technical front, but also to effectively showcase the country and the location," Al-Qutayri explains.

After successfully hosting the IEEE Global Communications Conference (GLOBECOM) in 2018, which attracted about 2,500 delegates, the university will once again host GLOBECOM in 2027.

Beyond exhibitions

Looking to the future, Khalifa University aims to expand its conference portfolio. "We're really interested in events that present the latest advancements and solutions to challenging concepts, rather than just exhibitions of products." Al-Qutayri states.

The university's strategic location helps to attract a diverse international audience. "We tend to host a large number of participants from China and South-east Asia, as well as significant attendance from Europe, North America, and even Australia," Al-Qutayri notes.

As Khalifa University continues to cement its place among the world's leading academic institutions, conferences play a vital role. They not only enhance the university's global reputation but also contribute to Abu Dhabi's vision of becoming a hub for research, development, and innovation.

Al-Qutayri concludes with an invitation to the global scientific community: "We're looking to expand more in the materials field and the energy field. Health is another area where we need to do more to attract large conferences to Abu Dhabi. We welcome organizations looking for their next conference venue to consider Khalifa University and experience the unique blend of cutting-edge facilities and warm hospitality that we offer."

Innovative ways to make water resources last

Through key collaborative efforts and innovative research, Khalifa University endeavors to offer sustainable water solutions and establish itself as a global leader in desalination technologies.

Across the world, water security and scarcity are of increasing concern, particularly in arid regions such as the United Arab Emirates. With the UAE government committing to ambitious plans to secure sustainable and effective water management, Khalifa University aims to demonstrate viable sustainable water strategies and cement its position as a world leader in membrane and water technology research.

"With rapid population growth, urbanization, and industrial development, the demand for water is increasing, placing immense pressure on existing resources," says Shadi Hasan, director of KU's Center for Membranes and Advanced Water Technology (CMAT). "The United Arab Emirates, like many countries in the Middle East, faces serious challenges related to water use."

Such issues include limited freshwater resources, high consumption rates, reliance on desalination for potable water, inefficient water management, and environmental degradation due to water pollution and depletion.

"These challenges are compounded by climate change, which impacts the availability of water resources," adds Hasan. "KU recognizes the urgency of developing sustainable water solutions to ensure water security for future generations."

Real-world solutions

"Our objectives at CMAT include enhancing water efficiency, promoting water conservation and reuse, and developing sustainable desalination technologies," says Hasan. "We also work to protect water quality, and foster interdisciplinary collaborations to resolve complex water issues."

Researchers at CMAT are developing innovative techniques and tools for water management and reuse, and fostering strategic partnerships with industry and several UAE governmental agencies to further their research and development. Current projects involve partnering with the Abu Dhabi Department of Energy (DoE), Ministry of Interior (MoI), and the Environment Agency (EAD), in addition to the Dubai Water and Electricity Authority (DEWA), among others.

"Through these practical partnerships and knowledge exchange initiatives, we can share best practices and advance our ideas through to real-world solutions more quickly," says Hasan.

Mohamed Dawoud, Senior Water Advisor at EAD, is confident the partnership with Khalifa University not only enhances the agency's ability to conserve precious and scarce water resources, but also strengthens the resilience of the UAE's ecosystems and supports the nation's long-term environmental goals.

"By combining EAD's regulatory expertise and environmental stewardship with CMAT's cutting-edge research in water reuse and desalination, we are pioneering innovative solutions that ensure sustainable water management for the UAE," Dawoud says.

Shadi Hasan, Director at the Center for Membranes and Advanced Water Technology

ELIZABETH FERNANDEZ/ MOMENT/ GETTY IMAGES - SIDDHARTH SIVA/REDUX

Many CMAT projects have secured external funding through government grant schemes and industry collaborations. These projects cover a wide range of themes, from developing sustainable desalination technologies and advanced wastewater treatment solutions to resource recovery from waste brine and water quality monitoring.

Eco-friendly and sustainable options for membrane technologies

CMAT teams are currently working on improving membrane technologies for desalination and wastewater treatment, experimenting with new materials such as graphene and MXenes. These 2D atomically thin layered materials are of particular interest for purification membranes because they can separate pollutants and salts from water.

"We are also exploring eco-friendly and sustainable options for membrane technologies, including a project developing biopolymer-based membranes for desalination pretreatment," Hasan says.

"Through practical partnerships and knowledge exchange initiatives, we can share best practices and advance our ideas through to real-world solutions more quickly."

Another interesting project lies in the integration of mangroves within the membrane matrix offering an opportunity to filter out contaminants such as heavy metals. "We are also investing in the development of efficient solar-powered desalination methods including solar photothermal-based membrane distillation systems," adds Hasan.

As a byproduct of desalination and wastewater treatment processes, it is also possible to harvest valuable compounds and metals from the water. CMAT is exploring how to recover lithium from desalination brines using 3D printed adsorption modules. The center also prioritizes extracting resources from brine, developing intelligent water monitoring systems, employing computational fluid dynamics and thermal desalination techniques, and investigating water microbiology.

A sustainable future ahead

With numerous research projects and initiatives in place, KU is looking ahead to further success in driving sustainable water solutions. "Over the next five years, we will expand our research portfolio, deepen our collaborations with industry and government partners, and enhance our impact on water sustainability," Hasan says. "We will also focus on technology commercialization and scaling up our solutions for widespread implementation, ensuring that our research translates into real-world impact."

Pushing the boundaries of water technologies

At Khalifa University's Center for Membranes and Advanced Water Technology, researchers are developing resilient, energy-efficient, and cost-effective solutions to tackle water scarcity.

In the arid landscapes of the United Arab Emirates, the challenge of securing a clean and sustainable water supply is a pressing concern. Established in 2018, the Center for Membranes and Advanced Water Technology (CMAT) at Khalifa University is a dynamic hub of innovation, focusing on advanced research to tackle water scarcity through cutting-edge technology.

Looking ahead at sustainable water solutions

Aligning with Khalifa University's overarching goal of advancing knowledge and fostering sustainable development, "CMAT's mission is to pioneer innovative membrane and water technologies that address pressing water-scarcity challenges," explains center director Shadi Hasan, an associate professor in the Department of Chemical and Petroleum Engineering.

The drive behind establishing CMAT was the urgent need for integrated water management solutions to be resilient, energy efficient, environmentally friendly, and cost effective. "We face growing water-scarcity challenges that require long-term sustainable solutions," Hasan says. "CMAT fosters innovation and technology transfer to relevant stakeholders, aiming to become a global leader in the field."

The center's research portfolio is extensive, with numerous projects breaking new ground in water technology. One of these involves integrating 2D materials, such as graphene, into membrane technology for desalination pretreatment, aiming to reduce the overall energy consumption of the seawater desalination process.

CMAT's PhD students and research staff are also developing advanced membranes capable of removing a wide range of contaminants, including polyfluoroalkyl substances, microplastics, and pharmaceuticals.

Mariam Ouda, a third-year PhD student, is developing an electro-membrane filtration system using emerging 2D materials known as MXenes. "We apply electricity to the membrane to induce various electrochemical processes," explains Ouda, whose research targets micro and nanoplastic pollutants, which are emerging challenges in water treatment.

"These membranes showed promising results in mitigating microplastic fouling while maintaining water flux. By applying electrical potentials, the membranes demonstrated improved performance," Ouda says. "Additionally, intermittent voltage application showed enhanced stability in water flux, offering a potential solution for long-term membrane operation."

Harnessing solar energy

Jehad Kharraz, a postdoctoral fellow at CMAT, is working with a team of researchers including Hanaa Hegab and two PhD students, Lobna Nassar and Ahmad Jawed, on an innovative project using solar energy in photothermal membrane distillation. "This is a cutting-edge water desalination technique that harnesses solar energy to drive the distillation process," Kharraz explains. "In this method, solar energy is absorbed by a photothermal material, which then generates heat used to

The CMAT team is developing effective solutions to tackle water scarcity.

evaporate water. The vapor is then condensed on a membrane surface, resulting in purified water."

Traditional technologies such as reverse osmosis are limited in their ability to treat highly saline water, for example reject brine, but membrane distillation can help to overcome this limitation.

"Our process reduces the energy required for desalination," Kharraz says. "It aligns with our goal of developing energy-efficient water treatment processes, which is crucial for regions such as the UAE where energy resources are precious."

"Currently, brine is treated as waste, but we aim to recover valuable resources such as magnesium and lithium… This research fits into the circular economy concept."

Developing eco-friendly membranes

Fatima Khamis, a third-year PhD student, is at the forefront of developing innovative and eco-friendly pH-responsive absorptive membranes for wastewater treatment. Her work at CMAT focuses on integrating materials from mangroves into biopolymers that effectively remove microplastics and heavy metals from wastewater.

"Our membranes can change properties in response to pH variations, enhancing the absorption and removal of these pollutants," Khamis says. This innovative approach targets

SIDDHARTH SIVA/REDUX

microplastics and heavy metals in a more sustainable water treatment solution. "By using materials that respond to environmental conditions, we can improve the efficiency and adaptability of wastewater treatment processes," she says.

Resource recovery from brine

Resource recovery from brine is another significant focus area for CMAT researchers. "Recovering valuable resources such as lithium, calcium and magnesium from brine is becoming a pivotal research area," Hasan says.

Faisal AlMarzooqi, an associate professor and deputy director of CMAT, explains that brine is currently treated as waste. "We aim to recover valuable resources such as magnesium and lithium. Magnesium is widely used in construction and electronics, while lithium is crucial for lithium-ion batteries," he says. "This research fits into the circular economy concept," AlMarzooqi adds. "By recovering and reusing these elements, we can make our processes more sustainable and economically viable."

Going green

Professor of chemical and petroleum engineering Enas Nashef's research emphasizes the replacement of harmful commercial solvents. "Most commercial solvents are volatile, toxic, and non-biodegradable," Nashef says. "We aim to replace these with green solvents including ionic liquids and deep eutectic solvents, which are non-volatile, biodegradable, and have low toxicity."

Green solvents are used for fuel purification, carbon dioxide capture, and wastewater treatment. "We have achieved great results and even filed a patent for a novel method using green solvents for water purification," Nashef reveals.

Sana Eid, a fourth-year PhD student, is tackling the challenge of removing persistent emerging pollutants known as perfluoroalkyl and polyfluoroalkyl substances (PFAS) using green solvents. "PFAS are notoriously difficult to remove from water due to their chemical stability and persistence," says Eid. "We focus on using deep eutectic solvents, which are environmentally benign, to extract these pollutants from water sources effectively."

> **"CMAT's mission is to pioneer innovative membrane and water technologies that address pressing water scarcity challenges."**

Deep eutectic solvents have low volatility, biodegradability and can dissolve a wide range of substances. "By incorporating solvents into membrane technology, we can enhance the removal efficiency of PFAS and other persistent pollutants," Eid explains. This research is crucial as it addresses the challenge of emerging contaminants that traditional water-treatment methods struggle to eliminate.

Fostering innovation

CMAT's success is underpinned by its collaborative environment, bringing together researchers, students, and industry partners. "We have over 100 people using our research facilities," Hasan says. "Our six well-established laboratories cover various specialized areas, from material synthesis to membrane fabrication, characterization and testing."

The center's commitment to fostering innovation is evident in its engagement with both national and international scholars and industries. "We are discussing potential projects with industry and governmental entities to take our pilot plants into the field for further research," Hasan adds. This collaborative approach ensures that CMAT's research not only advances scientific knowledge but also translates into practical solutions for water sustainability.

As CMAT research teams continue to push the boundaries of water technology, they remain focused on addressing the critical challenges of water scarcity and environmental sustainability. "Our vision is to become a global leader in the field, driving impactful solutions for water sustainability while nurturing a culture of excellence and collaboration," Hasan says.

Postdoc fellow Tarek Lemaoui and PhD student Anjali Goyal work with green solvents.

SIDDHARTH SIVA/REDUX

Jubail Mangrove Park in Abu Dhabi.

BN_3GEEL/ SHUTTERSTOCK.COM

Mangroves inspire membranes that can filter heavy metals from water

Khalifa University researchers have developed an eco-friendly ultrafiltration membrane using particles from mangrove trees.

Heavy metals such as copper, lead, and nickel found in water supplies pose significant health risks. Even at low concentrations they can contribute to liver damage, kidney failure, and cardiovascular disease.

Taking cues from mangrove trees, which are renowned for their ability to absorb heavy metals from soil, a team of researchers from the Center for Membranes and Advanced Water Technology (CMAT) at Khalifa University recently developed an environmentally friendly membrane that can efficiently remove harmful metals from water.

The innovative membrane, a composite material combining carbon-modified particles from the mangrove with polylactic acid (PLA) polymer, showed a pH-sensitive filtration profile and was able to almost completely remove copper, lead, and nickel ions at some pHs. Rejection levels were measured as 99.95%, 100%, and 99.95%, respectively, at a pH of 10. At pH 7, maximum absorption rates of 4.2mg/g, 6.8mg/g and 5.0mg/g respectively were seen.

"Tannins in the leaves of the Avicennia marina mangrove (AMM) are known to chelate heavy metals, influencing how the metals travel and change in estuarine mangrove wetlands," explains Hassan Arafat, Senior Director of the Research and Innovation Center for Graphene & 2D Materials (RIC2D), who works closely with CMAT. "We thought that AMM-derived materials could be used with activated carbon for enhanced absorption performance. Our membranes are efficient, biodegradable, eco-friendly, and can be re-generated readily by pH adjustment."

> "Our membranes are efficient, biodegradable, eco-friendly, and readily re-generated by pH adjustment."

The synthesized mangrove particles were analyzed using a suite of characterization techniques, including scanning electron microscopy, X-ray diffraction, Fourier-transform infrared spectroscopy, and energy-dispersive X-ray spectroscopy, to confirm their structure and properties. The pore size and water permeability of the membranes were also studied.

Team members Fatema Khamis, Hanaa Hegab, Fawzi Banat and Shadi Hasan are now exploring opportunities to exploit other natural materials. "We continue to look for novel functional materials inspired by nature to serve particular industrial objectives," Arafat says. "By mimicking how nature does its work, we are likely to stay within a safer zone than by using synthetic organic materials with known negative impacts on our health and environment."

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Renewable energy model turns water desalination green

Incentivizing industries to actively manage their power consumption could lead to more efficient usage of renewable energy.

Although renewable energy sources such as solar are abundant in the United Arab Emirates, there are inevitably large fluctuations in power output over time. Such fluctuations pose substantial challenges for power-hungry infrastructure such as water desalination plants.

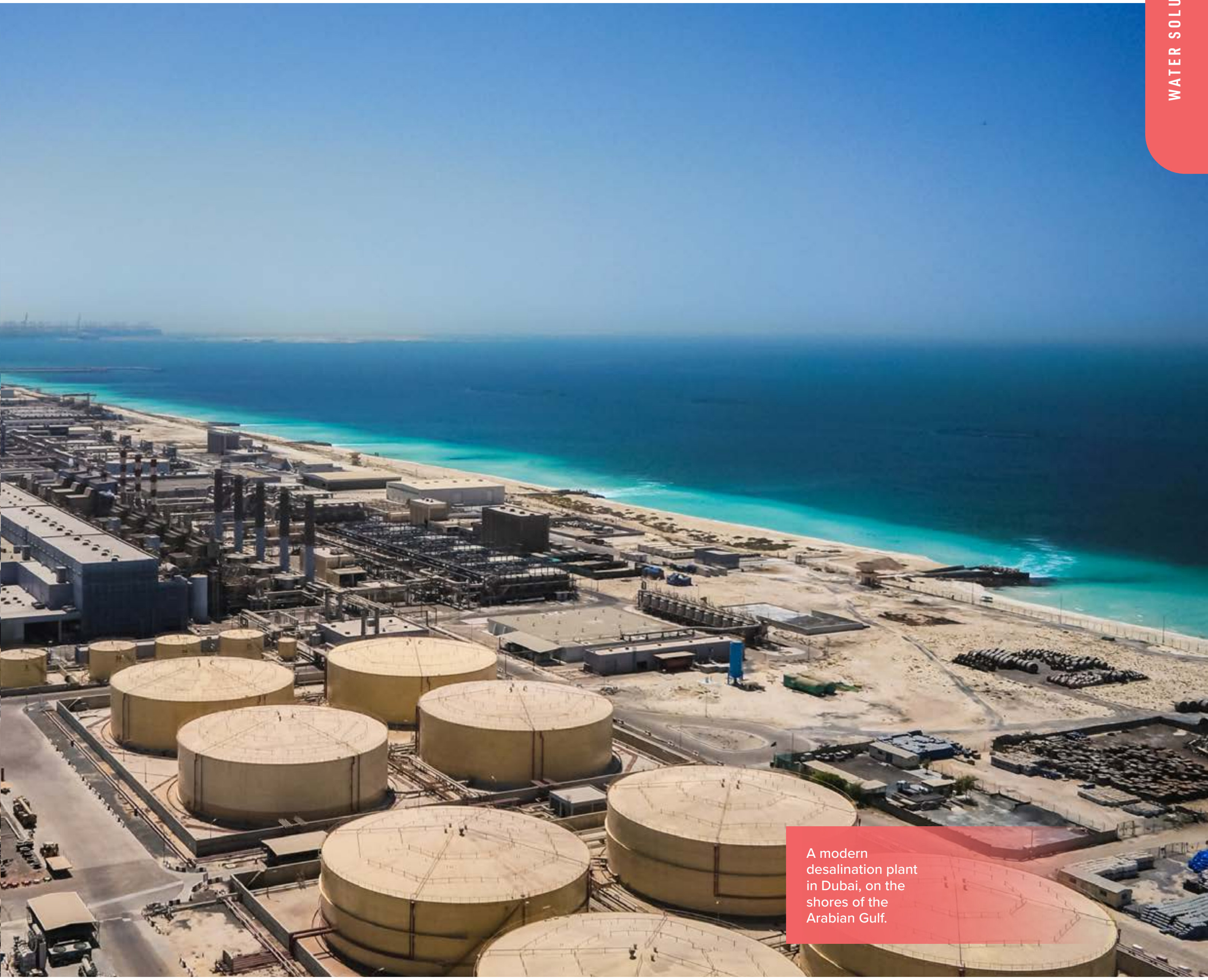
Ameena Al-Sumaiti and her team at Khalifa University's Advanced Power and Energy Center have developed a sophisticated model that coordinates the operation of desalination plants with renewable-rich power grids.

Al-Sumaiti's model encourages desalination plant operators to adjust electricity demand to align with periods of ample electricity supply, reducing power fluctuations and yielding substantial cost saving for all stakeholders.

"The UAE relies heavily on desalination due to limited natural water resources. Given the growing concerns over environmental impact, there is a push to integrate desalination plants with renewable energy sources," Al-Sumaiti says.

In addition to being energy intensive, desalination processes such as reverse osmosis are vulnerable to temperature variations that affect membrane activity, water flux, and quality. To address these challenges during operations, the system must use temperature correction factors to adapt to renewable energy fluctuations. Al-Sumaiti's newly developed model gives consumers the ability to manage these technical challenges while optimizing their energy consumption through a system called demand response.

"A demand-response model is built on the premise of encouraging consumers to engage with electricity markets and willingly modify their consumption behaviors, within a tight bidding framework," explains Al-Sumaiti. In the model, customers are offered financial incentives to adjust their loads and engage in various



A modern desalination plant in Dubai, on the shores of the Arabian Gulf.

STANISLAV71/ SHUTTERSTOCK.COM

demand-response options, including scheduling times when they may curtail or shift their loads, or investing in energy-storage technologies such as batteries or hydrogen storage.

"This range of options enables customers to select strategies that align with their technical capabilities and financial preferences," says Al-Sumaiti. "Additionally, our model emphasizes clear incentives, real-time feedback, and flexible options to further encourage consumers to alter their electricity consumption patterns willingly."

The team's simulations show that their optimization strategy could cut the smart-grid operations cost by up to 7% and effectively reduce electricity price volatility, leading to more stable pricing structures for consumers. The strategy also ensures that excess demands can be met by renewable energy.

Looking ahead, the researchers plan to collaborate with industry partners and utilities to gather real-world data, which can be used to validate the models and tailor them to industry needs. "By optimizing energy resource allocation and reducing reliance on conventional fossil fuels, our study contributes to mitigating climate change, enhancing energy security, and promoting economic prosperity," says Al-Sumaiti.

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Elsir, M., Al-Sumaiti, A.S., El Moursi, M.S., & Al-Awami, A.T. Coordinating the day-ahead operation scheduling for demand response and water desalination plants in smart grid. *Applied Energy* **335** 120770 (2023).

A specialist collects and tests water samples with the help of a mobile laboratory.

ALEKSEY KURGUZOV/ SHUTTERSTOCK.COM

Bio-composite material tackles emerging water contaminants

Researchers at Khalifa University have found a novel way to remove potentially toxic chemicals from wastewater.

Paracetamol, a widely used painkiller, often finds its way into wastewater where it's hard to remove or treat using conventional means, and it ends up in rivers and streams. In recent years, many have voiced concern about such pollution from drugs and other chemicals, and warned that it could have toxic effects on human and aquatic life.

Research at Khalifa University offers a possible solution. Working with colleagues in Slovenia, Spain, and France, KU researchers have developed a new water treatment system that can effectively tackle this class of emerging pollutants using a bio-composite material that combines a porous organic polymer with enzymes to break down various polluting and harmful molecules. In laboratory tests, when contaminated water passes through a column filled with this material, pollutants are removed with remarkable efficacy.

"The enzyme bio-composite acts on the pollutants in the water and breaks them down as the water passes through the column," says Syed Salman Ashraf, Chair of Biological Sciences at KU, explaining that the material fixes a high density of enzymes in place.

"The novel properties of the solid support make the enzymes work better than they normally would. So, it appears to be working better than other conventional approaches," Ashraf adds.

A fast and efficient solution

In a study published in the *Journal of Hazardous Materials*, the team showed how the system can degrade more than 99% of seven different pollutants within an hour. In addition to paracetamol, chemicals successfully removed from the water include mercaptobenzothiazole, a highly allergenic chemical found in rubber, and salicylic acid, a common topical skin treatment.

Dinesh Shetty, assistant professor of chemistry at Khalifa University, highlights the ability of the new bio-composite material to remove and degrade various types of pollutants from different sources of contaminated water, including those from a specific industrial effluent rich in a particular pollutant. It could even be used on general wastewater treatment plant effluent "that may still have traces of physiologically active emerging pollutants," Shetty says.

To take this innovation from the laboratory to practical implementation, the team needs to demonstrate scalability and cost-effectiveness. "If provided sufficient funding, we could have a 10 to 100-liter water treatment system ready within two to three years," Shetty says. "And eventually a 1000-liter system ready in another two to three years."

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Elmerhi N., Al-Maqdi K., Athamneh K., Mohammed AK, Skorjanc T., Gándara F., Raya J., Pascal S., Siri O, Trabolsi A., Shah I., Shetty D. and Ashraf S.S., Enzyme-immobilized hierarchically porous covalent organic framework biocomposite for catalytic degradation of broad-range emerging pollutants in water. *J Hazard Mater* (2023).

MESCIOGLU / ISTOCK / GETTY IMAGES PLUS

Waste-not ideology improves toxin removal from contaminated waters

A nanomaterial synthesized using decomposed garlic and lemon juice shows promise in removing organic and inorganic toxins from wastewater.

The production of plastic produces phenols, organic compounds known to destroy aquatic ecosystems when they seep into our water. To mitigate the dangers, a research team at Khalifa University has created a photocatalyst from organic byproducts, which could be used as a high-performing and stable photoanode in the electrochemical treatment of water.

Electrochemical oxidation is one exciting approach to remove phenols, alongside inorganic pollutants such lead, mercury and arsenic, from wastewater. Applying a voltage across two electrodes in a wastewater-electrolyte solution prompts phenol molecules to migrate toward one electrode, where they are oxidized, creating phenol radicals. Further chemical reactions reduce these radicals to carbon dioxide or water.

This process can be enhanced with sunlight if the anode is made from a light-sensitive material, or photoelectrocatalyst. “Photoelectrochemical processes offer a renewable and environmentally friendly alternative to conventional treatment methods,” says Fawzi Banat, Chair of the Chemical Engineering Department at KU. “Notably, this method selectively oxidizes target pollutants, while minimizing the generation of harmful byproducts, ensuring cleaner water treatment.”

Banat and his colleagues from the Department of Chemistry and the Center for Catalysis and Separation, together with collaborators from India and the United Kingdom, have created chemically stable photo-electrocatalysts from the two-dimensional material tungsten sulfide. Moreover, they showed optimization could be achieved by incorporating gold nanoparticles.

Two-dimensional materials, substances just a few atoms thick, have several advantages for catalytic applications. First, their optoelectronic properties can be controlled, exhibiting a high electrical conductivity to ensure efficient transfer of electrons through the electrode. Second, they have a high surface-to-volume ratio that improves their catalytic activity.

Banat and the team engineered their tungsten sulfide photocatalyst using organic sulfur from decomposed garlic. Gold nanodots were incorporated onto its surface following a lemon-juice-based reduction process. “Our two-dimensional tungsten sulfide photo-electrocatalysts are fabricated using organosulfur sources, giving high chemical stability and strong absorption of visible light,” explains Banat. “We then successfully incorporated citrate-stabilized gold nanodots into the nanosheets to reduce charge-carrier recombination, improving overall efficiency.”

Experiments proved the remarkable efficacy of the gold-tungsten sulfide photoanode in oxidizing the phenol in an electrolyte solution in 60 minutes under visible light. When arsenic was added to the mix, this was oxidized too. Reproducibility testing went on to indicate the stability of the photoanode for prolonged use.

“Our next step is to investigate using waste sulfur from the petroleum industry to synthesize the two-dimensional tungsten sulfide nanomaterials,” says Banat. “This is the waste-to-wealth concept.”

Bharath, G., Rambabu, K., Alqassem, B., Morajkar, P.P., Abu Haija, M., Nadda, A.K., Gupta, V.K., and Banat, F. Fabrication of gold nanodots decorated on 2D tungsten sulfide (Au-WS2) photoanode for simultaneous oxidation of phenol and arsenic (III) from industrial wastewater. *Chemical Engineering Journal* **456**, 141062 (2023).

Catalyzing the future

Cutting-edge research in reaction and separation technologies promises a cleaner and more sustainable world.

SIDDHARTH SIVA/REDUX

Making groundbreaking strides in energy and environmental science since its establishment in 2018, Khalifa University's Center of Catalysis and Separation (CeCaS) is the only one of its kind in the United Arab Emirates. The center operates under a clear mission: to be a global leader in the development of catalytic technologies and emerging materials to provide innovative solutions that promise a sustainable future.

"Our vision is to lead in emerging materials for catalysis and separation technologies, a market worth trillions of US dollars," explains Kyriaki Polychronopoulou, the director of CeCaS and a professor of mechanical engineering. "This aligns with our mandate to produce new technologies and support market expansion in the UAE's research and technology ecosystem."

Kyriaki Polychronopoulou is inspiring young scientists to develop catalytic technologies and emerging materials.

Innovating separation technologies

CeCaS specializes in six research themes, each led by experts dedicated to advancing critical areas: fuels; energy-demanding separations; environmental and biocatalytic processes; multiscale materials modeling; accelerated discovery of new catalytic materials; and surface functionality in catalysis and separation.

Ahsan Qurashi, Deputy Director of CeCaS, has made notable contributions in clean energy systems. His research group focuses on developing new materials and approaches for electrocatalysis.

"We've demonstrated nickel and copper single-atom catalysts for the oxygen evolution reaction and characterized them using synchrotron radiation. We've also filed a patent for a novel support for ammonia synthesis using atmospheric nitrogen," Qurashi says. This innovative approach achieved impressive efficiency.

Another group focuses on fuels and developing catalytic materials for producing blue ammonia and blue hydrogen, which are cleaner forms of these chemicals produced with reduced carbon emissions. In particular, Dinesh Shetty and colleagues have improved the performance of a process that converts glucose and nitrate into ammonia using a special catalyst made from a covalent organic framework.

One other active project involves breaking down methane into blue hydrogen using nickel metal supported on mesoporous desert sand silica. "We intend to convert the UAE's desert sand into innovative materials, such as mesoporous silica," says Khalid Al-Ali, who leads the project with Chin Kui Cheng associate professor at the Chemical & Petroleum Engineering Department at Khalifa University. "So far, our results have shown that the material we synthesized can enhance hydrogen production from methane by at least two to three-fold. We also obtained carbon nanotubes from the same reaction," Al-Ali adds.

SIDDHARTH SIVA/REDUX

The CeCaS team has made significant contributions to the UAE's ecosystem and economy.

Advanced materials to tackle pollution

Maguy Abi Jaoude, environmental and biocatalysis lead and associate professor at the Chemistry Department at Khalifa University, is tackling global pollution issues with advanced materials. Her team explores light-driven catalysis to make environmental cleanup of air and water more sustainable and effective. For example, they are developing innovative integrated solutions including freestanding photocatalytic membranes to remove toxic pollutants from water, which target forever chemicals that do not break down in the environment. These include antibiotics, microplastics and perfluoroalkyl-and polyfluoroalkyl substances (PFAS) and synthetic chemicals with water-repellent and nonstick properties.

"In air pollution treatment, one challenge is the high energy demand of thermal catalysis, which is not sustainable. Light-driven catalysis is not fully understood and hasn't reached commercialization due to performance issues," Abi Jaoude notes. The scientists explore ways of using light and heat to reduce energy costs and intensify technologies. Their goal is to understand and improve these processes to make catalysis more sustainable and effective in cleaning polluted environments.

Nahla Al Amoodi, separation technologies lead and assistant professor at the Chemical & Petroleum Engineering Department at Khalifa University, works on developing hybrid materials and membranes for the separation of gas and liquid systems, such as carbon capture, olefin/paraffin separations, and multiphase liquid separations.

"We focus on gas and liquid separations. For gas separation, we work on decarbonization and carbon capture using hybrid adsorbents based on metal-organic frameworks, 3D printed adsorbents, and upcycling waste materials. We also develop mixed-matrix membranes functionalized with nanomaterials for paraffin/olefin separation," Al Amoodi explains. For liquid separation, her team focuses on microfluidic platforms to perform passive phase separation by manipulating the surface chemistry of the channels.

CeCaS is also developing advanced synthesis and characterization techniques for various applications. These include the synthesis of porous catalytic materials for capturing carbon dioxide from the atmosphere and the development of new polymers for removing pollutants from wastewater. "We have assembled an interdisciplinary team of researchers who are using traditional materials chemistry techniques to synthesize new materials that can be used as catalysts but also for other applications such as in chemical or biological sensing," says Sharmarke Mohamed, who leads the

Researchers develop innovative solutions that promise a sustainable future.

SIDDHARTH SIVA/REDUX

accelerated discovery of new catalytic materials theme.

A regional impact

CeCaS has made significant contributions to the UAE's ecosystem and economy. The center has collaborated with industrial partners to scale up catalytic materials, such as a catalyst for CO_2 conversion to methane, which is currently being tested by a French company. CeCaS has been instrumental in training PhD students and skilled researchers, generating publications, patents, and startups.

The UAE faces unique challenges in the energy sector, particularly with its reliance on petrochemical industries and the need for sustainable practices. Abdallah Berrouk, multiscale and data-driven modelling lead at CeCas and a professor at the Mechanical & Nuclear Engineering Department at Khalifa University, has been addressing these challenges by developing computational frameworks that minimize the necessity for extensive physical testing. His work significantly enhances material characterization and process scaling, benefiting existing production protocols and aligning with the strategic goals of key regional initiatives.

Berrouk's research is also crucial for the Abu Dhabi National Oil Company (ADNOC) carbon capture program, an ambitious plan to increase carbon capture and utilization fivefold by 2030.

"By enhancing the predictivity of catalyst performance through a combination of multiscale modelling and machine learning, my research aids in the efficient deployment of catalytic processes vital to ADNOC's oil and gas operations," he explains.

Mohammad Abu Haija, surface functionality in catalysis and separation theme lead associate professor at the Chemistry Department at Khalifa University, focuses on designing and developing functional materials with specific characteristics and investigating their structural, electronic, and chemical properties. These materials show great potential in various applications such as optoelectronic devices, clean energy, and environmental challenges.

"The development of advanced catalytic materials to achieve desired properties and functionalities with high performance requires a fundamental understanding of their surface and structural properties. Our research is centered around controlling the synthesis and understanding the surface chemistry of catalytic materials," Abu Haija explains.

While it's still early to measure national economic impact, CeCas has already made progress in many aspects, Polychronopoulou adds. "Our impact can be measured at different levels: the KU ecosystem, the Abu Dhabi economy, and the country, particularly through our recent efforts in research translation and entrepreneurship."

A hub for talent and innovation

CeCaS has established itself as a thriving hub for talent and innovation, attracting researchers and students from diverse backgrounds who are eager to tackle complex challenges in catalysis and separation processes involving intriguing materials innovation. The Center's commitment to interdisciplinary research and cutting-edge technology has created an environment where young scientists and engineers can thrive.

Ismail Salim, a PhD student working under Abdallah Berrouk's supervision, explained that he joined CeCaS because of its strong focus on catalysis and separation reactions. His research focuses on building a robust machine learning framework and understanding the intricacies of dry methane reforming reaction data. "With significant support from colleagues, especially in data preparation and experimental setups, I have gained invaluable hands-on experience with experimental devices and characterization techniques," says Salim.

Similarly, Kedar Jivrakh, another PhD student at CeCaS, was attracted to the center's innovative project on carbon capture and conversion using 3D-printed structured catalysts. "Through exposure to modern 3D printing and material testing equipment, and training on these setups, I have polished my research skills, preparing me for future career growth," Jivrakh says,

"CeCaS fosters a collaborative environment that motivates and nurtures student talent from undergraduate to PhD levels," adds Abi Jaoude. "Students independently collaborate, sharing ideas and generating innovative solutions. This synergy is evident in their output, such as manuscripts, poster presentations, and conference participation."

A mussel-inspired designer adsorbent for efficient pollution control

Interdisciplinary collaboration between research centers at Khalifa University finds functionalized polydopamine nanoparticles to be highly effective at adsorbing dyes present in industrial waste.

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With an estimated 700,000 tons of dyes used in industrial processes each year, the pollution of surface and groundwater poses a serious environmental threat demanding a sustainable, selective and cost-effective approach. Inspired by the behavior of mussels, which excrete the polymer polydopamine (PDA) in order to stick to a surface, an interdisciplinary research team from Khalifa University has developed a customized adsorbent that selectively targets anionic dyes.

The adsorbent, designed by scientists from the Center for Membrane and Advanced Water Technology (CMAT) and the Research and Innovation Center for Graphene and 2D Materials (RIC2D), consists of nanoparticles of PDA functionalized with an ionic liquid called IL-3 aminopropyl ammonium acetate to selectively engineer the adsorption properties. When tested in the lab with the anionic dye Alizarin Red S (ARS), it was found to be a highly efficient adsorbent, offering promise for anionic dye removal from contaminated water flows. Tests on mixtures of ARS and other dyes (commercially dubbed MB, MO and CR) also confirmed its selective adsorption of ARS1.

The regeneration and reusability of the PDA-IL adsorbent were validated through a series of four consecutive adsorption/desorption cycles, using methanol to regenerate the adsorbent, without notable deterioration in its performance or structure. The team is confident that the adsorbent will work with other anionic dyes.

To date, most research on adsorbents for pollution control has focused on targeting cations rather than anions, due to the high challenge posed by the latter. KU's research brings new opportunities for targeting difficult to remove pollutants.

"Ionic liquids have unique properties and there is a wide catalog of these materials. This will enable us to create so-called 'designer adsorbents,' which can be tweaked and modified for the target pollutant on hand," explains chemical engineer Hassan Arafat, RIC2D Senior Director. "This approach could have a wide range of environmental field applications."

Alwan, R.A., Zhuman, B., Kumar, M., Arafat, H. & AlNashef, I. Mussel-inspired polydopamine functionalized with ionic liquid as a novel, eco-efficient adsorbent for the selective removal of anionic pollutants from aqueous solutions. *Chem. Eng. J.* **454** 140498 (2023).

Smart materials for more advanced wastewater treatments

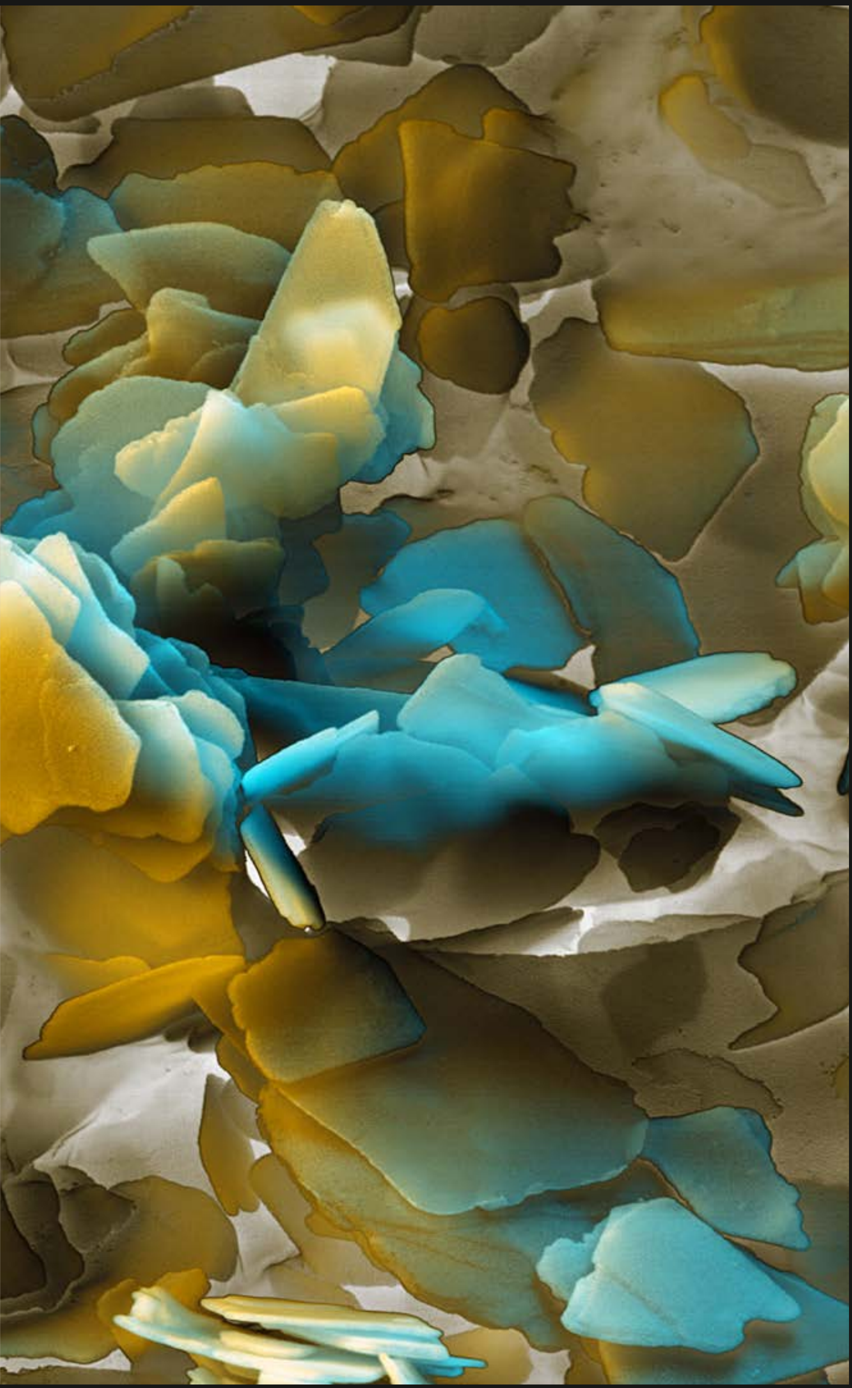
In the future, heterojunction membranes may be utilized to efficiently degrade pollutants in water, guaranteeing clean and safe drinking water.

Stimuli-responsive membranes offer more efficient ways to capture and break down persistent organic pollutants, ensuring cleaner water and a healthier environment.

Conventional water treatment methods have long relied on filtration, sedimentation, and disinfection techniques to eliminate impurities and ensure water safety. Yet, these methods encounter challenges when it comes to addressing persistent organic pollutants, which are often resistant to degradation and can exist in the environment for extended periods.

Now, a Khalifa University team led by Ludovic Dumée and postdoctoral fellow Priyanka Kumari at Khalifa University has achieved an exciting breakthrough in the pursuit of cleaner water. Harnessing the power of smart materials, their cutting-edge technology is set to revolutionize wastewater treatment and have a positive impact on our daily lives. The research team developed an approach using stimuli-responsive materials containing heterojunctions. Designed at microscopic scale, these employ metal-oxide sandwich layers composed of titanium dioxide and zinc oxide to efficiently capture and catalytically degrade pollutants.

To demonstrate the real-world potential of their approach, the researchers made a prototype sep-



EYE OF SCIENCE / SCIENCE PHOTO LIBRARY

"By leveraging these smart materials, we can make important strides in protecting our environment and improving the quality of life for communities worldwide."

aration device that has heterojunctions incorporated into its membranes. By effectively triggering the reactivity of the materials, the heterojunction membranes facilitate a more efficient breakdown of pollutants present in the wastewater. In particular, the enhanced charge-transfer process occurring at the interface of the two metal oxides, significantly improves the overall efficiency of the cleaning process.

"The exponential need for freshwater puts pressure on our limited resources and requires new pathways to achieve high-quality water recovery from wastewater treatment and desalination," says Dumée. "Our novel stimuli-responsive membranes offer perspectives to support the intensification of water production, with lower operating costs and minimized chemical requirements."

The exciting innovation also opens up possibilities for other applications, such as the design of compact and efficient water treatment systems. "By leveraging these smart materials, we can make important strides in protecting our environment and improving the quality of life for communities worldwide," Dumée concludes.

Kumari, P., Bahadur, N., Conlan, X.A., Zeng, X., Kong, L., O'Dell, L.A., Sadek, A., Merenda, A. and Dumée, L.F. Stimuli-responsive heterojunctions based photo-electrocatalytic membrane reactors for reactive filtration of persistent organic pollutants. *Chemical Engineering Journal* **146**, 1–17 (2023).

Electrifying heavy metal ion recovery and reuse from wastewater

A new separation technique using porous electrodes traps metal ions from wastewater, offering smarter, greener solutions for heavy metal pollution.

The ever-increasing demand for metals across various industries has resulted in fast-track, large-scale mining and processing operations that create substantial volumes of wastewater. Left untreated, this wastewater rich in highly acidic and toxic heavy metals poses risks to humans, aquatic life, and the environment.

Traditional techniques developed to prevent the release of heavy metals into the environment include chemical precipitation, ion exchange, and membrane filtration. However, these techniques are costly, offer limited recovery efficiency, and can generate secondary contaminants.

Now, a team led by Fawzi Banat and Mohammad Abu Haija from Khalifa University has devised a capacitive deionization method to selectively and effectively remove metal ions, such as copper and iron, from wastewater using electrically charged electrodes. Negatively charged cathodes made of a highly porous activated carbon derived from date seeds attract and immobilize the positively charged metal ions on their surface, once a voltage is applied.

Using a thermochemical treatment, the researchers went on to find ways to reuse the recovered metal ions. They transformed them into metal oxide using a thermochemical treatment, and turned the activated carbon support into carbon fibers, creating a photoactive electrode to convert ambient carbon dioxide into value-added chemicals, such as formic acid.

"The process is energy efficient and allows electrode regeneration," Banat says. "Utilizing date-seed-derived activated carbon, an eco-friendly material obtained from agricultural waste, aligns with circular economy principles. In addition to reducing costs and environmental footprint, the method enables continuous operation and long-term sustainability,

> **"In addition to reducing costs and environmental footprint, the method enables continuous operation and long-term sustainability."**

OMERSUKRUGOKSU / ISTOCK / GETTY IMAGES PLUS

offering a solution for mining industries looking to improve waste management practices and maximize resource recovery efficiency."

To improve performance, the researchers modified the cathode surface using polyaniline, generating a composite with multiple functional groups that readily bind metal ions. This enhances the catalytic activity, number of adsorptive sites and electrochemical properties of the cathode. The composite removed much of the metal ions from model mining wastewater solutions, outperforming its unmodified precursor. It also effectively trapped mixtures of metal ions from more complex mining and industrial wastewater.

The team plans to scale up the technology to validate its real-life effectiveness and explore advanced regeneration methods, Banat says. Further work will investigate the catalytic potential of the recovered metal oxides in converting CO_2 into valuable chemicals further to support sustainability and resource recovery efforts.

Bharath, G., Hai, A., Rambabu, K., Abu Haija, M. & Banat, F. Sustainable electrochemical process for recovery of metal ions in synthetic mining wastewater and their utilization in photocathodic CO_2 reduction into formic acid. *Resources, Conservation & Recycling* **190**, 106778 (2023).

Academia and industry unite for a sustainable UAE

Researchers at Khalifa University are pioneering applied research and AI tools to integrate renewable energy into national power grids with real-world solutions.

"Sometimes industry and academia speak two different languages, we aim to bring the two together and find common ground to tackle key challenges in the energy sector," says Mohamed El Moursi, Director of Khalifa University's Advanced Power and Energy Center (APEC) and theme lead for KU's active transmission and distribution system research.

Researchers at KU are crafting the future of electric energy systems for the United Arab Emirates and beyond; facilitating the efficient integration of renewable and non-renewable energy resources and energy-storage systems into smart grids. They are also involved in developing artificial intelligence tools, architecture and control systems for smart grids, microgrids and transport electrification.

"We are working toward sustainable national power for the UAE and hope to ensure that the transition from non-renewables to renewables, including solar, wind, nuclear and green hydrogen production, storage and utilization, is as smooth as possible," El Moursi says.

To achieve this, APEC teams are developing state-of-the-art smart grids and the strategies to integrate renewables into transmission and distribution power networks. Strategies include optimizing renewable energy systems while employing multifunctional energy storage systems to ensure higher grid flexibility and stability.

These goals span multiple sectors across society; and to achieve them, APEC's research teams are collaborating closely with both national and international industry partners.

Stability saves the day

A power system's stability refers to its ability to return to an acceptable state of equilibrium operating condition following a disturbance, small or large; referred to as small-signal and transient stability respectively.

A recent collaboration with the Abu Dhabi Transmission and Dispatch Company (TRANSCO) and Manitoba Hydro International (MHI) in Canada resulted in the development of new AI-based software that helps system operators predict small-signal and transient stabilities in TRANSCO's power network, which has renewable and nuclear power integrations. The software, dubbed 'Stability Assessment, Visualization, and Enhancement' (SAVE), features a user-friendly interface to better inform operators and improve the integration of renewable energy sources into the UAE power system.

"Successful renewable energy integration relies on ensuring the stability of the power grid," says El Moursi. "SAVE applies advanced AI, deep-learning and system-identification techniques to assess overall system stability. It can capture the inherent dynamic characteristics of the power grid, providing fast and accurate predictions that operators can act on."

Designed with a user-friendly interface, SAVE is now used successfully by TRANSCO and the Emirates Water and Electricity Company, and will soon be available internationally.

Efficient energy management

A second significant project at KU has been the development of the Renewable Energy

The Terra or Sustainability Pavilion at the Expo 2020, held in Dubai.

Management System (REMS) platform. REMS provides operators with a tool to plan, integrate and control energy provision from a mix of renewable and non-renewable power sources. It can forecast intermittent renewable power generation and load demand, then control the scheduling of renewable power generation at specific times. This improves efficiency and flexibility; and improves the cost-effectiveness of the overall power grid operation.

"REMS improves the energy dispatch capabilities of hybrid renewable power plants, achieving efficient ancillary services. Moreover, the mix of renewable energy systems can be controlled as a coherent hybrid system with minimum utilization of energy storage systems," El Moursi explains.

> **"APEC is now part of an advanced ecosystem generating high-impact applied solutions for key challenges."**

These two exemplary projects, along with other ongoing projects, illustrate the importance that Khalifa University places on bridging between academic and industrial partners. "The university encourages international engagement, and APEC is now part of an advanced ecosystem generating high-impact applied solutions for key challenges nationally and internationally," El Moursi says.

SUDARSAN THOBIAS/ SHUTTERSTOCK.COM

Did you know?

A power system's stability refers to its ability to return to an acceptable state of equilibrium operating condition following a disturbance.

Carbon capture brought to life by tweaking the plumbing

Straightforward modifications to gas turbine power generators can reduce the energy required to capture exhaust carbon emissions.

In an advance that takes industrial carbon capture a step closer to commercial viability, researchers at Khalifa University have shown that relatively straightforward modifications to power plant ‘plumbing’ can reduce the amount of additional energy needed to capture carbon emissions.

Combined cycle gas turbine (CCGT) power plants are a more flexible, fuel-efficient and environmentally friendly method of energy generation than coal or oil-fired power plants. By routing waste heat from the gas-turbine exhaust to a steam turbine, CCGT plants can generate up to 50% more power than conventional gas-fired power plants for the same amount of fuel. They are also readily configurable for carbon capture and storage (CCS), bringing the potential to greatly reduce carbon emissions.

Capturing carbon from carbon dioxide (CO_2) exhaust gas, however, comes at a cost. Additional technology and equipment are required, and energy is used in the capture cycle.

As part of a long-term effort to establish CCS as a commercially viable technology for CCGT power generation, researchers Nahyan Arshad and Ahmed Alhajaj from the Research and Innovation Center on CO_2 and Hydrogen (RICH) at Khalifa University have identified key process enhancements that can improve CCS efficiency.

“While many efforts are aimed at developing new ‘sponges’ for better carbon capture, we are looking at how tweaking the system’s ‘plumbing’, adjusting the process and setup used to capture carbon, can lead to significant energy and cost savings,” says Alhajaj.

Through a comprehensive analysis of different process technologies using a multifactor approach accounting for both financial costs and energy consumption, Alhajaj and Arshad identified several standard technologies that can yield substantial improvements when combined.

“We found that cooling solvents more effectively, and splitting and compressing gases differently can make capturing carbon cheaper and less energy intensive,” explains Alhajaj.

The best enhancement was obtained with a cool/rich/lean combination. Here absorber inter-cooling is used to cool the CO_2 absorber column for higher absorption efficiency, rich solvent splitting maximizes temperature differential in the column for reduced energy losses, and lean vapor compression reduces the energy input needed to regenerate the absorption column.

> **“We found that cooling solvents more effectively, and splitting and compressing gases differently can make capturing carbon cheaper and less energy intensive.”**

Together, these enhancements reduced overall financial costs by 8.95% and energy consumption by 6.25%. “Our unique approach provides a comprehensive view of both economic and energy impacts, ensuring the proposed solutions are both economically and environmentally viable,” Alhajaj says. “With these enhancements it is possible to lower the energy penalty of CCS to 2.8 gigajoules per ton of CO_2 captured, with significant reductions in both capital and operational costs, offering a viable path forward for industry.”

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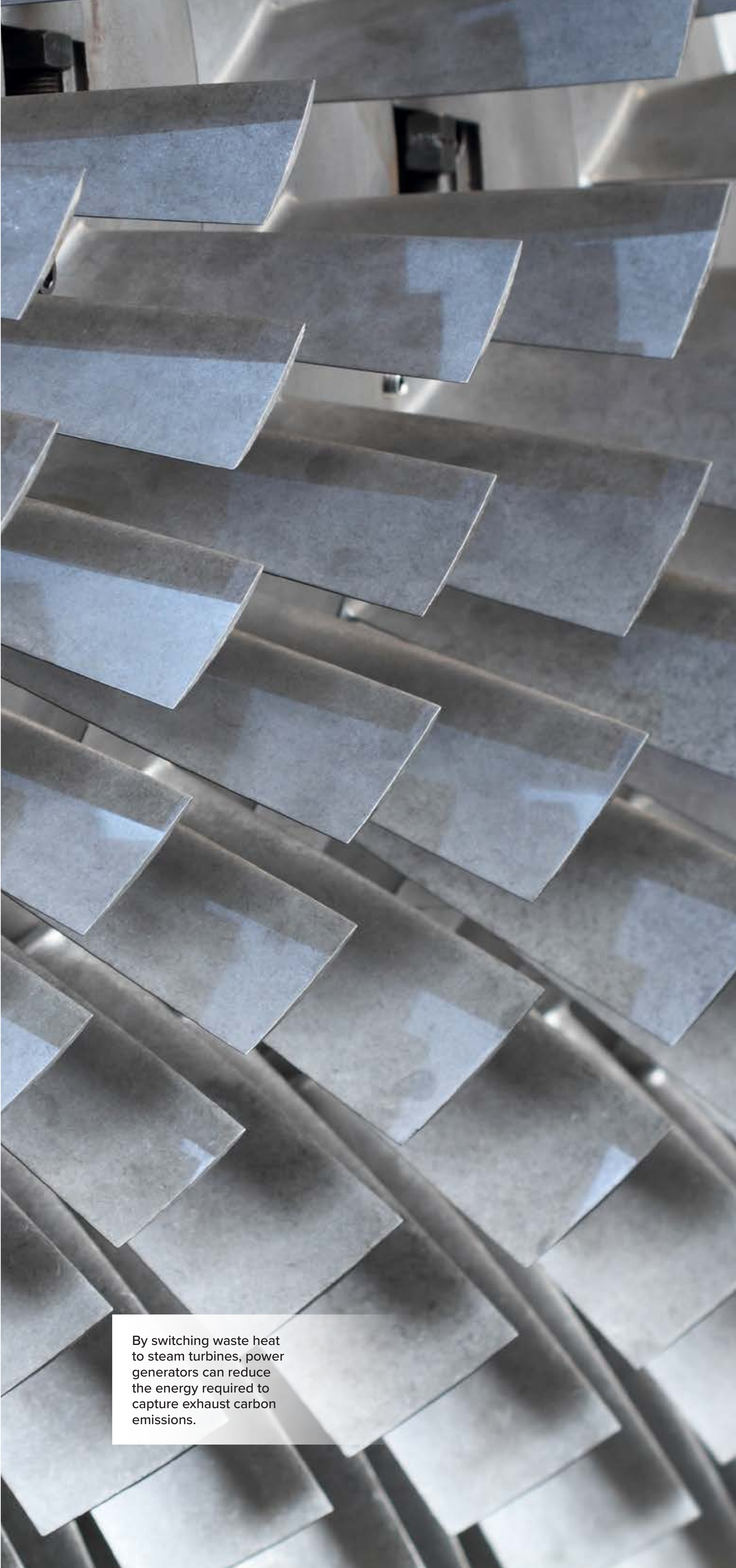

By switching waste heat to steam turbines, power generators can reduce the energy required to capture exhaust carbon emissions.

8.95%
Reduced overall financial costs obtained with a cool/rich/lean combination.

6.25%
Reduced energy consumption obtained with a cool/rich/lean combination.

CCGT plants can generate up to
50%
more power than conventional gas-fired power plants for the same amount of fuel.

Arshad, N. and Alhajaj, A. Process synthesis for amine-based CO_2 capture from combined cycle gas turbine power plant. *Energy* **274**, 127391, 2023.

Toward a greener iron and steel industry

With the steel industry accounting for a significant portion of global CO_2 emissions, calculating the technical and economic feasibility of future steel factories with reduced carbon emissions is vital in the transition toward a greener sector.

Khalifa University is exploring low-carbon solutions for the iron and steel industry.

Accounting for 2.6 gigatons of global carbon dioxide emissions annually, steel production ranks as the largest industrial consumer of coal, surpassing emissions from all road freight combined. However, there are intrinsic limitations on decarbonizing the iron and steel industry, leading to its classification as a hard-to-abate sector. To tackle this challenge, Valerie Eveloy, a professor of mechanical and nuclear engineering at Khalifa University, and her team are exploring low-carbon solutions for the iron and steel industry.

Adopting Hydrogen and renewables

Among conventional steel-making processes, gas-based direct reduction of iron (DRI) combined with electric arc furnaces (EAFs) stands out as a relatively low carbon-intensive option. Yet, only 7% of global steel production uses these techniques.

In DRI, the reducing agent that strips away oxygen from iron or to leave behind metallic iron, has primarily been coal or natural gas so the DRI-EAF method has been predominantly deployed in regions with

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access to abundant and affordable natural gas. Eveloy's team has modeled steel plants that use hydrogen as the reducing agent; a game-changing approach with immense potential for achieving net-zero emissions, particularly when hydrogen is produced from water, generating oxygen and heat as byproducts.

The researchers assessed the effectiveness and cost of hydrogen DRI-EAF in various locations where solar and/or wind energy could power hydrogen production and electrified processes. They found that, under favorable conditions, hydrogen DRI-EAF could compete economically with conventional processes and offer up to 90% reduction in CO_2 emissions.[1,2] With significant international attention, large-scale commercialization is expected to begin in the next decade.

"Energy-intensive industries, such as steel making, are in the midst of profound changes. Steel producers in the region are turning their attention to low-carbon hydrogen, alongside efforts to improve energy and material efficiency," explains Eveloy.

Addressing high emissions

The most widely adopted process of steel production is blast furnace-basic oxygen furnace (BF-BOF). It relies heavily on burning coke, derived from coal, to produce carbon monoxide, which reacts with iron ore and reduces it to molten iron and CO_2. Oxygen is then blown into the molten iron at a high temperature and pressure to remove impurities and produce crude steel. This process emits significant amounts of carbon dioxide due to the large quantities of coke and energy used.

Eveloy's team, alongside researchers from the University of Zaragoza in Spain, has looked at how to overcome the high carbon emissions using power-to-gas technology, a way to produce a synthetic gaseous fuel (methane) using green hydrogen from water electrolysis and CO_2 from steel-making, using electric power. They analyzed how the integration of power-to-methane in the BF-BOF process could reduce its carbon footprint and how this would affect costs.

Injecting methane into the blast furnace as a fuel directly replaces some of the coke. Furthermore, as part of the power-to-gas process, CO_2 emissions generated in the plant are captured for producing the methane, recycling in the same plant. The oxygen generated in the electrolysis of water in the power-to-gas process can meet the entire oxygen demand of a steel-making plant, eliminating the need for an energy-intensive air separation process to provide it.[3]

Integrating these technologies into traditional steel production could slash the carbon emissions of a steel plant by up to 34%. However, there is a trade-off: extra energy is required (around 17 megajoules per ton of hot metal) at extra cost (around $378 per ton of carbon saved).[4]

Fluctuating electricity prices and government subsidies addressing climate change could significantly improve the viability of these technologies, especially as companies face the prospect of higher carbon taxes in the future.

1. Elsheikh H., Eveloy, V. Renewable Hydrogen based Direct Iron Ore Reduction and Steel Making with Grid Assistance. *Energy Conversion and Management* **297**, 2023.
2. Elsheikh H., Eveloy, V. Assessment of Variable Solar-and Grid Electricity-driven Power-to-hydrogen Integration with Direct Iron Ore Reduction for Low-carbon Steel Making. *Fuel* **324**, 124758, 2022.
3. Perpiñán, J., Bailera, M., Peña, B., Romeo, L.M., and Eveloy, V. Technical and economic assessment of iron and steel-making decarbonization via power to gas and amine scrubbing. *Energy*, **276**, 2023.
4. Perpiñán, J., Bailera, M., Peña, B., Romeo, L.M. and Eveloy, V. High oxygen and SNG injection in blast furnace iron-making with Power to Gas integration and CO_2 recycling. *Journal of Cleaner Production* **405**, 2023.

INSIDE VIEWS

HIGH-SPEED COMPUTING SEEN THROUGH LIGHT-ENABLED CIRCUITRY

Jaime Viegas, Associate Professor at the Department of Electrical Engineering at Khalifa University.

KHALIFA UNIVERSITY

With seven US patents to his name and a wealth of experience spanning decades, Jaime Viegas delves into the realm of silicon photonics, optical sensors, fiber optic sensors, digital holography, metamaterials design and fabrication. His latest endeavor involves harnessing the power of light-active microelectronics to revolutionize AI algorithm processing.

Can you give us an overview of your research?

My research mainly focuses on photonics, or light-driven electronics, particularly the development of optical microchips. My team exploits various physical processes integrated in miniaturized systems that fit into a microchip.

We moved from using optical microcircuits for communication and sensing to AI photonic chips. Over the past three years, we have concentrated on implementing AI algorithms using photonic components for high-bandwidth processing. These microchips promise to enhance data-stream processing efficiency, boosting processing speeds while saving energy.

Which key discovery has influenced your current research and how?

Researchers are actively developing new computational paradigms using photonic and quantum computing, driven by the increasing data-gathering and storage capacities of cloud-computing systems. There is a need to further increase computational power while minimizing energy consumption. We are applying our expertise in miniaturizing light circuits to implement specific functions capable of achieving those ultra-highspeed computational steps at chip level.

How did your research journey lead you to your current position at Khalifa University?

I was a PhD student at the University of Porto in Portugal and did my research residency at the University of North Carolina at Charlotte, working on photonic sensors. I spent a year and a half in Charlotte to gain experience in photonic fabrication. Through contacts at MIT, I learned about opportunities at the Masdar Institute, one of three universities that eventually formed Khalifa University. In line with the UAE government's interest in semiconductors, they were looking for people with experience in photonics and cleanroom processing, which led to the Microsystems Engineering program that I joined about 13 years ago, and in which I've set up the first photonics lab and cleanroom for microfabrication in the country.

Collaboration is key to research and innovation. Tell us about your ongoing collaborative projects.

Our primary industrial partner is GlobalFoundries, a leading semiconductor chip manufacturer. This collaboration has been crucial in providing our students with early access to cutting-edge semiconductor processes for photonic and radiofrequency microsystems.

We've tackled challenges in integrated photonics components, addressing issues where a cascade of devices don't perform as expected. Traditionally, heaters were used to fix these mismatches but, with collaborators from GlobalFoundries, our students proposed a solution considering the curvature of light during the design phase. This eliminated the need for heaters, improving device performance. The collaboration resulted in several patents for components with enhanced performance, showcasing the practical impact of our work.

What are the major challenges in microsystems engineering?

One significant challenge is finding students willing to learn across diverse disciplines, from electronics and thermal sciences to optics and mechanics. Integration also poses a challenge when combining materials and processes that may be incompatible or lack scalability for real-life applications.

INSIDE VIEWS

PRINTING MATERIALS BY DESIGN

Rashid K. Abu Al-Rub, Professor of Mechanical Engineering at Khalifa University.

KHALIFA UNIVERSITY

Rashid K. Abu Al-Rub has always been fascinated by nature's intricate engineering of the microstructure of materials to give them function. A structural engineer by training, the Lead of Advanced Digital & Additive Manufacturing (ADAM) Group at Khalifa University channels this fascination into his research, combining insights from the architectural design of large structural systems, such as buildings and bridges, and nature to innovate in materials science.

> **"Recent advances in digital-design software have removed a lot of the constraints that engineers faced when designing components for fabrication using conventional manufacturing methods."**

What has been the focus of your work in the past few years?

My research has centered on engineered metamaterials, a unique class of engineered materials distinguished by their tailored architectural design at the macro, micro, or nano scale. Specifically, I explore the multifunctional properties of a special class of metamaterials known as triply periodic minimal surfaces (TPMS). These are surfaces that repeat themselves periodically in three-dimensional space and have smooth, intricate and intertwined topological features.

While TPMS have been well-known to mathematicians for more than 160 years, their complicated design posed fabrication challenges when using traditional manufacturing methods. However, recent advances in additive manufacturing and 3D printing have opened the door to metamaterials with very complicated microstructures. I consider myself lucky to have started working on TPMS metamaterials a decade ago, when the 3D-printing boom started. Today ADAM is at the forefront of TPMS-metamaterial research.

What are the potential applications of these engineered materials?

We have developed numerous types of TPMS metamaterials and characterized their mechanical and physical properties. We found that these materials hold promise across a spectrum of applications such as lightweight yet robust structures, catalytic substrates for carbon-dioxide capture and conversion, feed spacers and membranes in water technologies, acoustic and electromagnetic absorbers, heat exchangers, heat sinks, and energy storage. I can say with confidence that our research on TPMS metamaterials is not only gaining traction within academia and industry but also contributing to the global surge of interest in metamaterials.

What do you consider to be the most exciting advance in additive manufacturing?

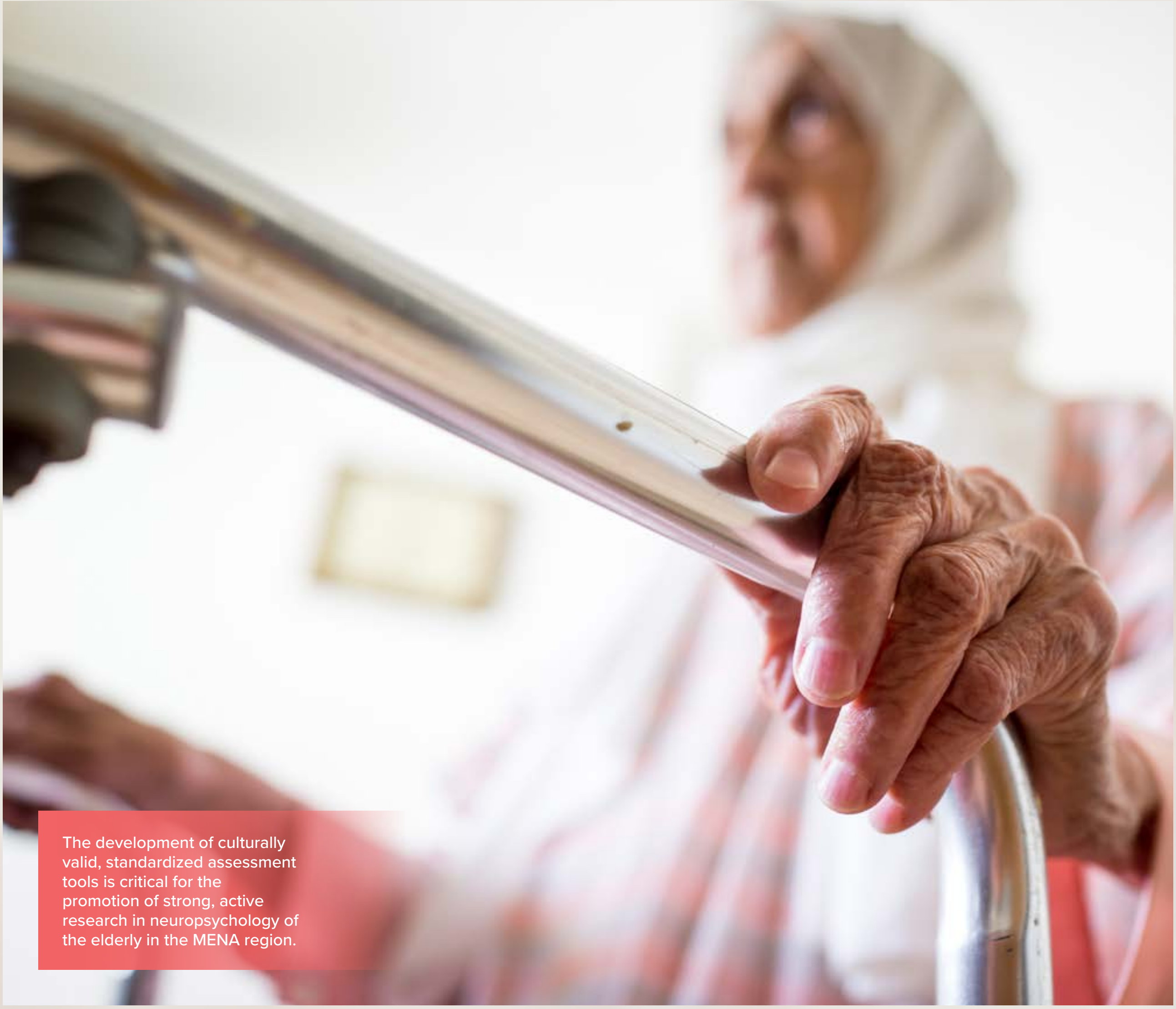
Beyond the 3D printers themselves, the true excitement lies in digital-design software, without which 3D printers are not functional. Recent advances there have liberated engineers from many of the constraints they faced with conventional manufacturing methods.

What breakthroughs do you anticipate in the next decade?

I see two possible breakthroughs. The first is the ability to quickly design a material's architecture by simply specifying the desired properties and performance using digital-design tools, perhaps based on artificial intelligence. The second is the significant increase in the speed of manufacturing plastic and metal parts using 3D printers. We can reduce fabrication times from hours or days to minutes. These two breakthroughs will definitely change the game.

Addressing language barriers in dementia assessment

Validated and standardized neuropsychological tests that can assess cognitive abilities in Arabic could better ensure earlier, and more accurate, diagnosis of neurodegenerative diseases in the Middle East and North Africa.



JASMIN MERDAN/ MOMENT/ GETTY IMAGES

The development of culturally valid, standardized assessment tools is critical for the promotion of strong, active research in neuropsychology of the elderly in the MENA region.

With nearly half a billion inhabitants across some 20 countries, the Middle East and North Africa region is projected to witness significant growth in the number of people living with neurocognitive disorders. Today, dementia affects 1.1% to 2.3% of over-50s, rising to between 13.5% and 18.5% among the over-80s.

The region has much linguistic diversity, with residents speaking colloquial forms of Arabic and several other languages. This poses a significant challenge for healthcare professionals working to assess the cognitive abilities of someone speaking an understudied language, such as Tamazight or Domari.

To address the lack of validated and standardized neuropsychological tests that can assess cognitive abilities in Arabic, researchers Mohamed Seghier and Oula Hatahet from Khalifa University's Department of Biomedical Engineering and Biotechnology, in collaboration with a researcher from the Cleveland Clinic Abu Dhabi, have shed light on the neuropsychological tests used in the region to test various cognitive domains, such as memory, attention, language, visuospatial abilities and executive functions.

Their findings underscore the reliance on unvalidated translations of English tests, lacking standardization and risking misdiagnosis. They also highlight a lack of rigorous assessment criteria and a shortage of trained professionals.

"Over-reliance on translated versions of existing cognitive assessment tools is not the way forward. However, the development of culturally valid, standardized assessment tools is contingent to the promotion of strong, active research in neuropsychology in the MENA region," says Seghier.

The complexity of language use, with patients switching between Modern Standard Arabic for formal contexts and Colloquial Arabic for everyday activities, further complicates test development and administration. The researchers stress the need to develop culturally unbiased tests, tailored to diverse linguistic and cultural groups.

Although similar initiatives have already taken place for Korean and Spanish speakers, creating tests for every spoken language may not be feasible, and translated versions (even with the help of artificial intelligence) might be the only option for some populations.

Beyond the language barrier, the lack of comprehensive epidemiological data about dementia in the MENA region poses another challenge. Collecting high-quality data about dementia is extremely difficult in some countries, due to a lack of resources, inadequate healthcare infrastructure, stigma and public disinterest in participating in research studies.

"The creation of a MENA society in neuropsychology can help raise awareness about the importance of that field and its relevance for the development of assessment tools for the growing aging population of the MENA region."

"As the region strives to address the cognitive health needs of its aging population, the creation of a MENA society in neuropsychology can help raise awareness about the importance of this field and its relevance for the development of assessment tools," says Seghier. "This will improve cognitive assessments for patients and healthcare outcomes for all."

To enhance neuropsychological standards, the researchers advocate initiatives such as the establishment of a regional neuropsychological society, open-access databases, cross-country exchange programs to facilitate knowledge sharing, and training opportunities for aspiring clinical neuroscientists and neuropsychologists.

"Unfortunately, some myths and taboos about dementia are still present," explains Hatahet. "For this reason, we encourage the use of media platforms to raise awareness about the different types of dementia, challenge stereotypes and foster a more inclusive society, ensuring that people living with dementia are treated with respect."

Hatahet, O.; Roser, F.; and Seghier, M.L. Cognitive decline assessment in speakers of understudied languages. *Alzheimer's & Dementia: Translational Research & Clinical Interventions*, **9**(4), e12432, 2023.

SAFEGUARDING AGAINST FUTURE OUTBREAKS OF INFECTIOUS DISEASE

Dean Everett, Professor of Infectious Diseases and Lead for the KU Infection Research Unit, Department of Public Health and Epidemiology, College of Medical and Health Sciences at Khalifa University.

Dean Everett is an internationally recognized molecular microbiologist whose research focuses on pathogen genomics, antimicrobial resistance and infectious disease surveillance. After 23 years working in Africa, followed by a term as Chair of Molecular Microbiology and Global Health at the University of Edinburgh in the United Kingdom, Everett joined Khalifa University and is now leading efforts in developing the national antimicrobial resistance (AMR) surveillance consortium in the United Arab Emirates.

How would you describe your research?

As a molecular microbiologist, my interest is looking at the molecular epidemiology of pathogens; how they arrive in a country, examining their transmission and infection mechanisms, and how they spread and evolve. My primary focus lies in understanding the genetic drivers behind the virulence of microbes that would normally be just part of your everyday flora and which fall under the umbrella of AMR. At present, AMR and respiratory pathogens are my main area of research.

I'm also proud to support the Abu Dhabi Public Health Center's research agenda as a senior academic professor. We have a number of ongoing studies with them, for example one on severe acute respiratory infection (influenza and respiratory syncytial virus), which has surged since we've taken off our face masks following the COVID-19 pandemic. But AMR is by far the biggest one, because it's the biggest problem, it's a real issue here as it is globally. The UAE has 13 priority pathogens that are monitored because of their levels of drug resistance.

Why is AMR such a major problem in Abu Dhabi and the rest of the UAE?

The sizable multiethnic community contributes significantly to the spread of AMR pathogens. With millions of individuals traveling in and out of the country, coupled with the flourishing tourism industry, the UAE serves as a major hub for microbial exchange. We've seen the emergence of new pathogens here that we never had before, such as the drug-resistant fungus *Candida Auris* in 2019, which infects more than 1,000 people a year.

AMR is a global problem. The World Health Organization has designated it one of 10 global threats to humankind. The very nature of AMR and our ability to get samples from hospital and lab partners, alongside digitized clinical data, and analyze it together, means the UAE can really take a global lead in the fight against AMR. That's part of what we've done in the AMR national surveillance consortium. We just produced the first nine national papers covering 14 years of antibiotic resistance across several major pathogens. Research at this scale has never been done here before. The project involves 341 hospitals and clinics across the country and is a testament to how we work together in the UAE.

Our information feeds directly into the Ministry of Health and Prevention, which then advises hospitals on appropriate infection control practices to contain and reduce the numbers of these bugs that are circulating.

What excites you about your work?

I love the idea that these little organisms can beat us and kill us, and I want to know why. I'm like a child in a candy store. I don't just focus on one infection. I look at everything and ask the question, how is it that these different little organisms that we can get a million of on the tip of a pinhead can infect us and adapt to us so well? Understanding why and how will ultimately enable us to stop it happening in the future.

What motivated you to join KU?

The diversity of the faculty and KU's ambition. I collaborate with people from all over the world with different knowledge, viewpoints and experiences, which I wouldn't have been exposed to if I hadn't come here. This opportunity to work alongside such experts is truly inspiring.

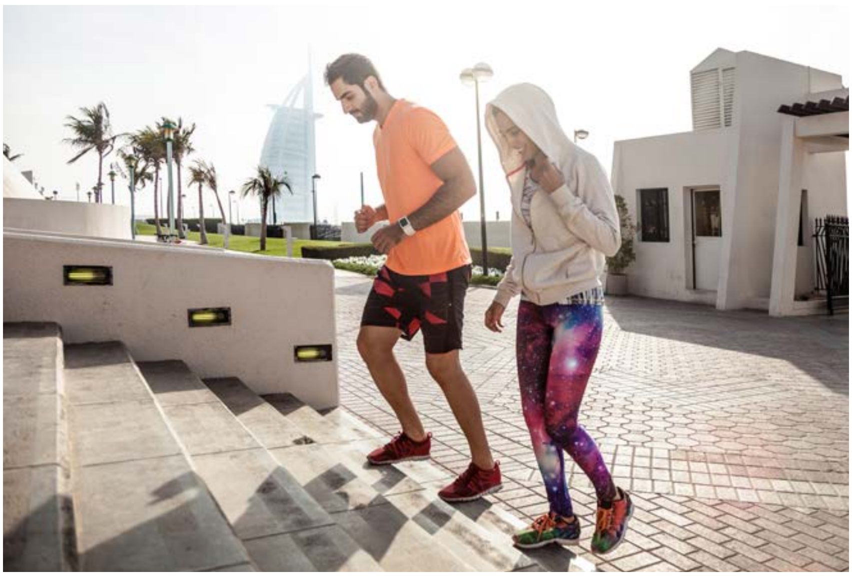
SCIENTIFIC DEFINITIONS AND FACTS

Overcoming AMR

With millions of individuals traveling in and out of the country, coupled with the flourishing tourism industry, the UAE serves as a major hub for microbial exchange, and has 13 priority pathogens that are monitored because of their levels of drug resistance.

Harnessing body movements to power electronic devices

Utilizing 2D nanomaterials, advances in energy-harvesting technologies could revolutionize the way we yield electrical power.



LEOPATRIZI/ E+/ GETTY IMAGES

In a world increasingly reliant on technology, finding efficient and sustainable power sources is more critical than ever before. Traditional batteries often fall short as they require frequent charging and contribute to environmental pollution. But what if we could harness the energy from our everyday movements to generate electricity? Imagine a future where simply walking, stretching, or even typing could power our devices, revolutionizing the way we think about energy.

Research scientist Shoaib Anwer and fellow Khalifa University academics Muhammad Umair Khan, Mohammad Baker and Lianxi Zheng have engineered a unique self-powered device called a triboelectric nanogenerator (TENG). The device is capable of converting mechanical energy from body movements into electrical power, radically changing the way we power small electronics, monitor human health and contribute to a greener environment.

"Imagine a tiny, flexible device that you can wear comfortably on your body, like a wristband or a patch. This device contains layers of special materials that, when rubbed or pressed against each other during your everyday movements, generate electricity. It's like magic, but it's actually science at work," Shoaib explains.

Now, the team has found a way to make these devices more efficient and powerful by incorporating advanced 2D nanomaterials—ultra-thin sheets with remarkable electrical and mechanical properties—into the design of the TENG.

One of these nanomaterials, called Ti3C2Tx-MXene, acts like a supercharger for the device. By sandwiching it between layers of other materials, the scientists have boosted the TENG's ability to generate electricity, allowing each movement made by the wearer to produce yet more power.

Shoaib and his collaborators further refined the design with electrode engineering, again using 2D nanomaterials. These tweaks have resulted in a device that can generate electricity with astonishing efficiency.

"The new device can be used as a pressure sensor to monitor different movements of the human body. This means that it could help doctors and scientists better understand how our bodies work and detect any abnormalities or changes in our health," Lianxi explains.

The TENG can also power all sorts of electronic devices from LED lights to calculators, according to Shoaib. "It's like having a portable charger strapped to your body, ready to power up your gadgets whenever you need it. And here's the really exciting part: because the TENG harnesses the natural movements of our bodies, it's a sustainable and environmentally friendly power source. Instead of relying on batteries that need to be constantly replaced and discarded, we can generate electricity simply by going about our daily lives," he says.

With further research and development, it holds the potential to revolutionize not only the way we use energy but also our impact on the environment, Shoaib notes. "So, the next time you take a step or move your arm, remember, you could be powering the future of technology!"

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1. Anwer, S.; Khan, M.U.; Mohammad, B.; Rezeq, M.; Cantwell, W.; Gan, D.; and Zheng, L. Engineering of electrodes with 2D Ti3C2Tx-MXene sheets and chloride salt for robust and flexible high electrical power triboelectric nanogenerator. *Chem. Eng. Journal*, **470**, 2023

INSIDE VIEWS

HELPING HEARTS TO BEAT FOR LIFE

Moni Nader, Associate Professor at the Department of Medical Sciences, College of Medicine and Health Sciences, Khalifa University.

KHALIFA UNIVERSITY

Moni Nader's fascination with cardiovascular disease and science began when he started to appreciate the amazing activity of the heart.

"What initially attracted my interest was the way it could pump blood nonstop around the body until the last day of a person's existence," Nader says. Soon enough he found himself in what he describes as a prodigious field of research, which has much research potential and is full of knowledge gaps that need to be filled. "Given its importance to sustaining life, it is imperative that we can maintain the heart's proper function and fix any problems when they occur," he says.

What is the primary goal of your research?
I want to understand the structural and functional changes that occur in the hearts of diabetic and hypertensive patients. By better understanding these pathologies, we hope to be able to identify potential therapeutic routes to reduce the negative, everyday effects of these conditions.

The myocardium, the muscular tissue within the heart wall, is responsible for the pumping. Our team's recent work has broadly focused on the pathological remodeling of the myocardium in serious cardiac conditions. Specifically, we are exploring the so-called signalosomes: cellular control centers crucial for regulating heart contraction strength and rate. These signalosomes have been associated with the onset and progress of diabetic cardiomyopathy and hypertension.

> "I became fascinated by the amazing activity of the heart: the way it can pump blood nonstop around the body until the last day of a person's existence."

What stands out as the highlight of your research career to date?
Our research has revealed new roles for dynamic proteins in the normal and abnormal function of the heart. Understanding these roles has paved the way to the development of novel therapeutic approaches and has highlighted the need to pharmaceutically target these proteins in the treatment of cardiovascular disease.

Why did you choose Khalifa University to do this research?
Khalifa University of Science and Technology offers a great support network to conduct research. I have found that both the infrastructure and the environment are nurturing for my projects and facilitate the expansion of my expertise in the field. The existence of multidisciplinary colleagues and departments helps to diversify project outcomes and contributes to the development of local scientists' skills.

What do you consider the most exciting development in cardiac research in the past few years?
The ability to reprogram stem cells into beating cardiac muscle cells, or cardiomyocytes, is so exciting. This offers hope for individuals affected by a heart attack or myocardial infarction, where the damaged myocardium loses its cardiomyocytes. It is nearly impossible to regenerate these types of cells, and so the scar formed in the infarcted zone is made of a tissue that is less elastic and has less capacity to contract. This narrows the survival windows for these patients. The strides made in engineering cardiomyocytes have vital clinical applications and must be further developed.

What breakthrough do you anticipate in the next decade?
I expect to see the bioprinting of a fully functional heart, or cardiac tissues such as valves and coronary arteries, ready for cardiac transplants and cardiac tissue regeneration or replacement.

How AI can help improve the accuracy of multimodal gait analysis

Using a combination of advanced sensors and AI, scientists are improving neurological disease diagnosis by studying how a person walks.

Walking—a seemingly mundane activity—is central to a medical innovation thanks to the convergence of artificial intelligence and cutting-edge sensor technology. Recent advances can be leveraged to decode the subtle nuances of human gait, offering profound insight into neurological disorders.

How we walk can reveal important information. A slow gait, for example, could indicate cognitive decline, hip pain or a heart problem. An unsteady stroll may be a sign of an ear infection or stroke. Recognizing the diagnostic potential of gait analysis, researchers at Khalifa University are pioneering groundbreaking approaches to improve its accuracy and efficacy.

A recent KU study shows how important gait has become as a tool for diagnosis and recovery monitoring, particularly for neurological diseases, and how under-utilized AI is in the field. The review examined 66 studies, some that used AI, and some that did not. All the studies used at least two ways to record and analyze a person's gait, such as wearable sensors or cameras.

The team wanted to try to understand where the research gaps in this domain were, says biomedical engineer Aamna Al Shehhi.

In comparing the outcomes of these studies, the team found that combining multiple types of gait analysis data, such as signals from both the brain and muscles, provides a more complete picture of a person's health. The researchers also learned that using a combination of types of sensors is more effective for analyzing gait patterns in patients with neurological disorders. However, the study revealed that AI-driven algorithms outperformed traditional methodologies.

Al Shehhi notes the limitations of feature extraction—the process of manually identifying and extracting relevant characteristics from gait data that are used to understand a person's walking pattern—and dataset quality in traditional approaches. "With advanced AI models, there is huge potential to address those gaps, learn the complex relationships between different modalities and improve gait analysis accuracy," she says. "It's clear from our paper that the field is behind in terms of adopting those more advanced techniques."

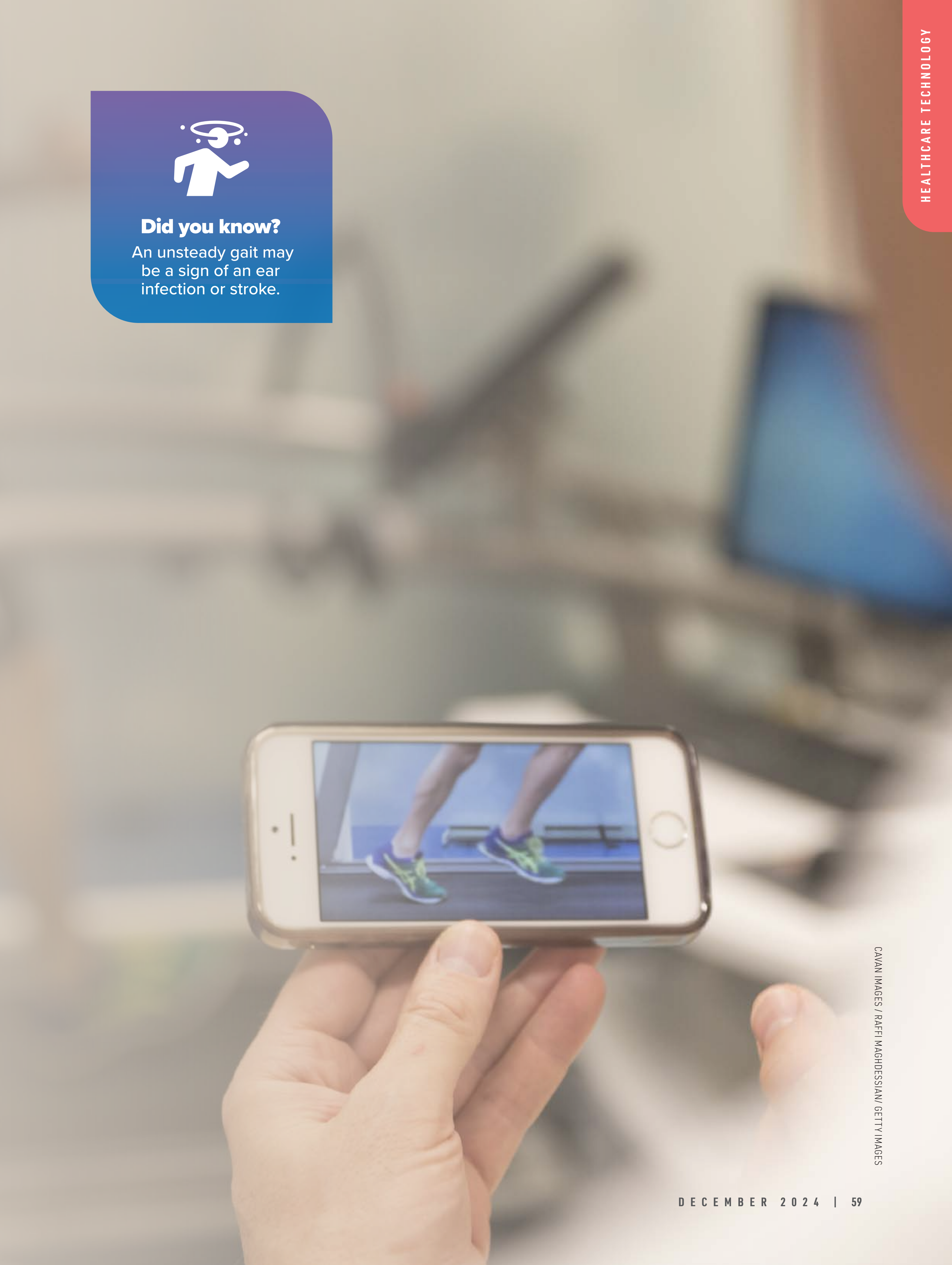
Armed with the findings, the researchers will work on developing even better AI models. Using KU's state-of-the-art rehabilitation lab, which includes special headsets that detect brain signals and inertial measurement unit (IMU) sensors to detect joint movement, biomedical engineer Rateb Katmah is collecting synchronized multimodal data to build novel AI models for gait analysis. The goal, he says, is to create the most accurate models possible.

"So far, we've collected data from 50 healthy subjects, who are walking on the treadmill while we collect data such as brain signals, muscle activity, joint angle, and ground reaction force," Katmah explains. "Then we will integrate all this data into the AI model to tell us whether it was a normal gait or not. And if it's not normal, we can determine whether the gait is closer to, let's say, the gait of Parkinson's disease or stroke patients."

Katmah and Al Shehhi hope this work will lead to portable smart devices that can be used to more easily and objectively conduct gait assessments and expedite diagnoses.

Katmah, R., Shehhi, A.A., Jelinek, H.H., Hulleck, A.A., and Khalaf, K. A Systematic Review of Gait Analysis in the Context of Multimodal Sensing Fusion and AI. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* **31**, 4189-4202 (2023).

Did you know?
An unsteady gait may be a sign of an ear infection or stroke.



CAVAN IMAGES / RAFFI MAGHDESSIAN/ GETTY IMAGES

USING LIPID INDICES TO SIGNAL CARDIOVASCULAR AND RENAL OUTCOMES

Eman Alefishat, Associate Professor at Khalifa University's Department of Medical Sciences and Assistant Dean for Medical Education at the College of Medicine and Health Sciences.

With a PhD in physiology and pharmacology from the University of Nottingham in the United Kingdom, Eman Alefishat began her academic career at the University of Jordan in 2011, going on to assume roles there including assistant dean for hospital affairs and director for the PharmD program. In 2019, she joined Khalifa University as a founding faculty member to establish the College of Medicine and Health Sciences.

What is your role at the College of Medicine and Health Sciences?

I serve as the assistant dean for medical education, where I oversee the curriculum, assessments, and program outcomes. I actively contribute to various committees and task forces at the college, university, community, national, and international levels. I also serve as a faculty member at the Harvard Macy Institute-Harvard Medical School on the Leading Innovation in Health and Education course. My research primarily focuses on antimicrobial resistance and cardiometabolic and immune biomarkers, and improving health-related outcomes.

Tell us about your recent research activities

Within my research projects on cardiometabolic diseases, our recent work involves collaboration with multiple clinical sites to collect data from patients with diabetes and healthy controls.

Our current project focuses on utilizing lipid indices as predictors of cardiovascular and renal outcomes among individuals with type II diabetes, using a significant dataset from various health centers in Abu Dhabi. This research aims to assess the association between lipid indices and health-related outcomes, with the goal of determining their potential as predictors of cardiovascular/renal outcomes. We are at the data analysis stage and will publish our results soon.

Additionally, we intend to conduct a study to investigate the predictive ability of these indices in the progression from prediabetes to diabetes.

What recent initiatives have been launched at the College of Medicine?

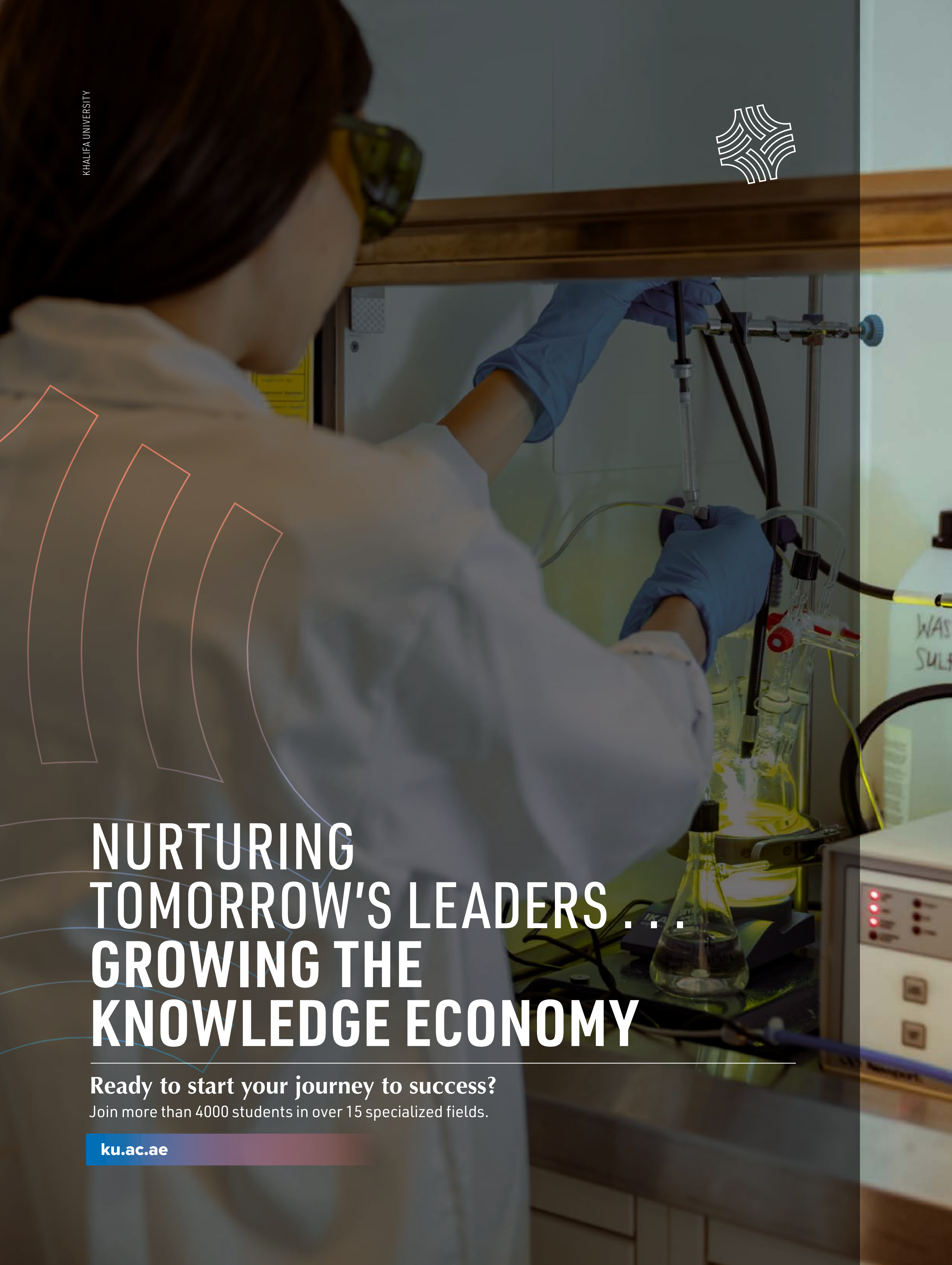
We drive several initiatives aimed at identifying and supporting students' areas of interest to facilitate their progress. We've established clear criteria and rubrics, awarding an Area of Excellence certificate to students meeting these standards. Our program spans various disciplines, encompassing clinical skills in internal medicine, surgery, pediatrics, community outreach, and peer tutoring.

What about active collaborations and clinical partnerships?

At the level of our students' clinical training, we maintain robust partnerships both locally and internationally. In the UAE, our primary clinical partner is Sheikh Shakhbout Medical City (SSMC), with additional training provided at Cleveland Clinic Abu Dhabi (CCAD) and other UAE-based healthcare facilities.

During their final year, our students also undertake electives across the Emirates and internationally. For their clinical electives, our students have the opportunity to receive clinical training at prestigious institutions such as George Washington Hospital, Cedars-Sinai, and other healthcare institutions in the United States, as well as the University of Ottawa, in Canada.

Within my own research, I have established collaborations with healthcare centers here in Abu Dhabi, including CCAD and SSMC, and across the UAE. Additionally, I collaborate with institutions regionally and internationally, in the United States, United Kingdom, Jordan, and many other countries.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