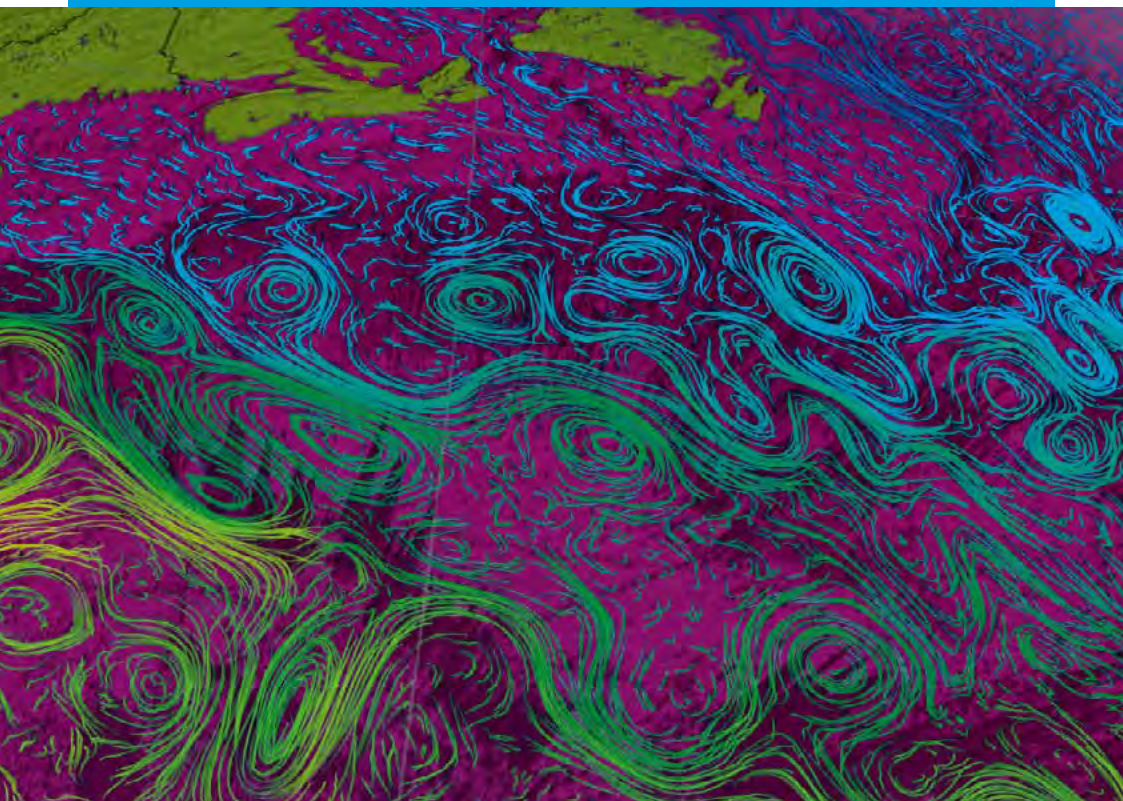
IHE Delft Innovations for Water and Development



“We can’t solve problems by using the same kind of thinking we used when we created them.”

Albert Einstein

United Nations
Educational, Scientific and
Cultural Organization

Institute for
Water Education
in partnership with UNESCO

Dear reader,

Realising that present and future water-related problems require out-of-the-box thinking and unusual business approaches, IHE Delft supports innovation in all our core activities of education, research and capacity development.

Our innovations are not just of a technological nature; they include new educational programmes and research findings. In all cases, their adoption and use also has social, economic, environmental, governance, institutional and political dimensions. Research-based innovations originate from the six research themes of IHE Delft that are well aligned with relevant international and national science programmes, including the UNESCO science programme.

They cover core thematic areas of sustainability as well as cross-cutting themes, namely:

- **Safe Drinking Water and Sanitation**
- **Water-related Hazards and Climate Change**
- **Water and Ecosystems Quality**
- **Water Management and Governance**
- **Water, Food, and Energy Security**
- **Information and Knowledge Systems**

To celebrate the 60th anniversary of IHE Delft, we have selected 60 examples of innovation to feature in this second edition of the Innovations booklet. An important aspect of our innovation, and indeed of much of the activity at the Institute, is that ideas are created with our global partnership network to develop, implement and validate novel solutions that ultimately aim to improve the quality of life on our planet.

Professor Eddy Moors
Rector

Innovations overview

IHE Delft focus areas

Safe Drinking Water & Sanitation
Water, Food & Energy Security
Water-related Hazards & Climate Change
Information & Knowledge Systems
Water & Ecosystems Quality
Water Management & Governance

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3	SimBasin: A serious game for large river basins
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28	Algammox: a hybrid photo-activated sludge process
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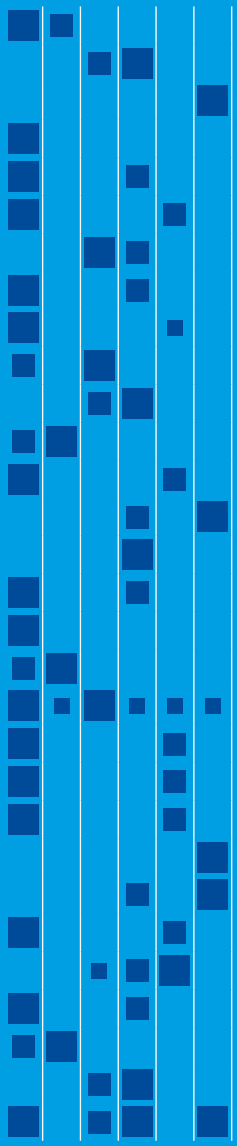

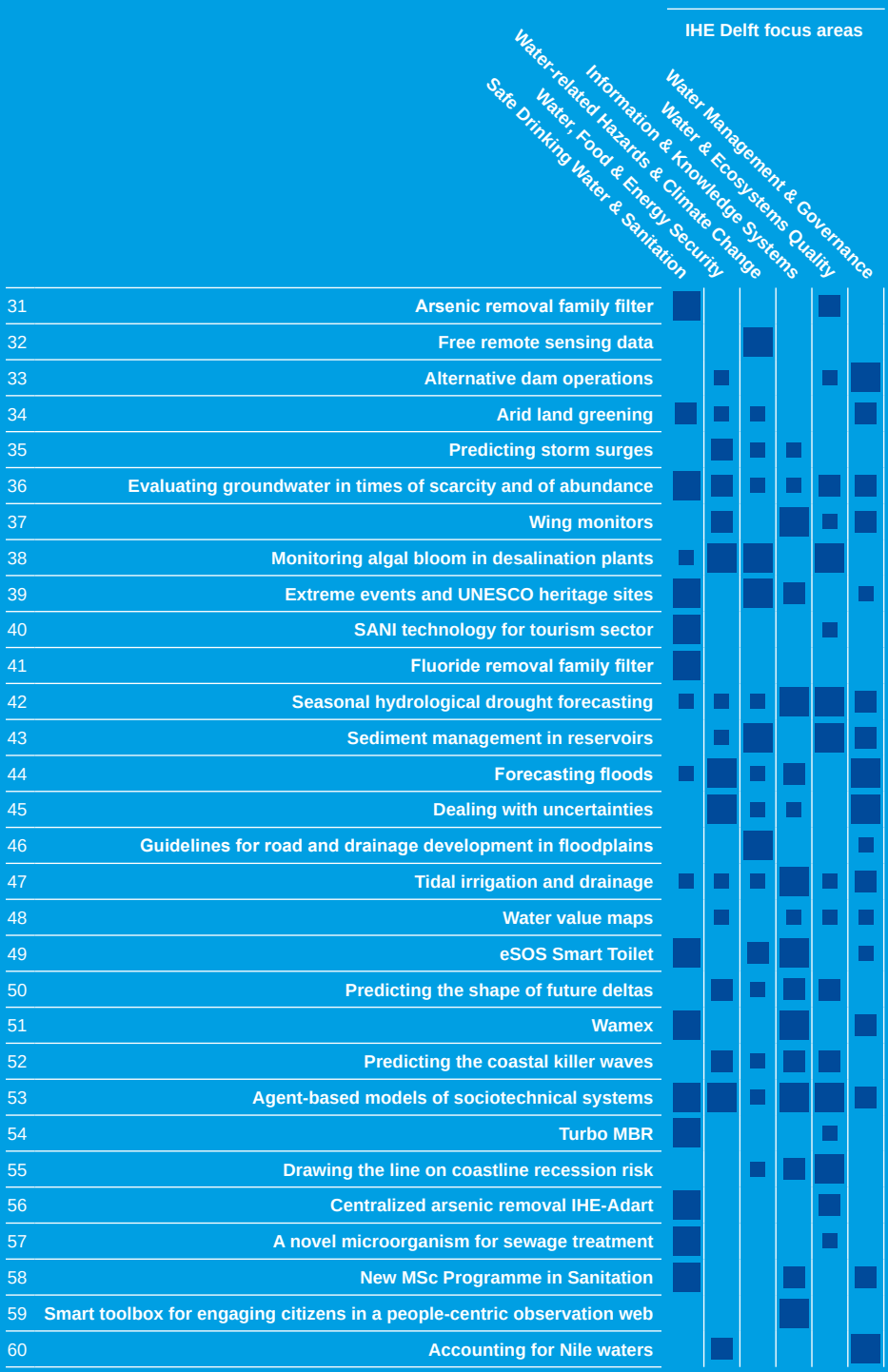
IHE Delft focus areas
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Water & Ecosystems Quality
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1

The Tiger Worm toilet

The world is witnessing the highest levels of forced human displacement on record and the length of displacement is increasing. Humanitarian agencies are therefore looking for more sustainable sanitation options for camp settings. One potential solution is the Tiger Worm Toilet, a simple vermifilter: a filter which contains composting worms. The worms convert human waste into worm waste (vermicompost). The human waste is treated in situ leading to a reduction in the volume of solids, reduced emptying frequency and easier emptying (as the by-product is a dry humus-like material which is generated at the top of the system).

This concept has been successfully tested at a household level in urban, rural and camp settings in six countries. The two current projects are developing and testing communal toilets, phased additions of the worms, a new worm species and direct drop systems, in two camps in Ethiopia and Myanmar (Burma).

Locations: Ethiopia, Myanmar (Burma)
Contact: Claire Furlong (c.furlong@un-ihe.org)
Partners: Oxfam (GB), Bill & Melinda Gates Foundation

2

Ground Truth 2.0: Socio-technical approach for citizen observatories

The Ground Truth 2.0 approach centres on real-life interactions between people and technology. This innovative socio-technical approach is based on LivingLabs principles. An innovative co-design method provides the link between the social dimensions of citizen observatories (e.g. stakeholder analyses, engagement strategies, and the analysis of drivers & barriers for stakeholder participation) and enabling technologies for citizen observatories. With this approach, local needs and governance goals, cultures, customs and languages are matched with appropriate functionalities, resulting in customized citizen observatories that will have the envisaged, case-specific societal and economic impacts.

Ground Truth 2.0 is a European Union Horizon2020 project, setting up and validating six citizen observatories in real conditions, with four European and two African demonstration cases in specific areas of natural resource management. The approach strengthens the full feedback loop in the information chain, from citizen-based data collection to joint decision making and cooperative planning. The ultimate objective is the global market uptake of the concept and enabling technologies.

Ground Truth 2.0 has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No.689744

Locations: The Netherlands, Belgium, Spain, Sweden, Zambia, Kenya | **Contact:** Uta Wehn (u.wehn@un-ihe.org) | **Partners:** HydroLogic Research, Akvo, Tygron, VITO, Starlab, Altran, CREAF, Stockholm University, Gavagai, Earthwatch, TAHMO, Upande, WWF Zambia

Project co-funded by the EUROPEAN UNION

3

SimBasin: A serious game for large river basins

Sustainable basin management is important for both people and ecosystems. Increasing science policy and inter-sectoral dialogue is recommended as a means to balancing competing demands and achieving this; however, this dialogue is not necessarily easy to achieve. To overcome these obstacles, the SimBasin game has been developed. The game initially aimed to communicate the complex trade-offs in river basins and enable research policy dialogue in the Magdalena-Cauca basin, Colombia. However, the game has now also been used in other contexts, and over 200 people have played the game worldwide.

Players manage a fictional river basin over 30 years and the impacts of their decisions are simulated using WEAP water resources modelling software. As well as providing a discussion space, the game gives interesting examples of computer models and stakeholders' mental models interacting with, and enriching, each other.

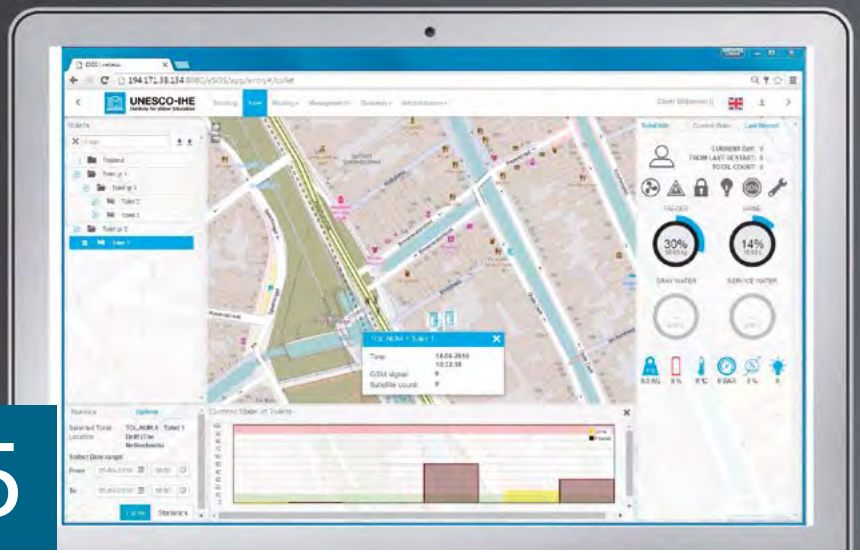
Location: Colombia
Contact: Gerald Corzo Perez (g.corzo@un-ihe.org)
Partner: TNC (The Nature Conservancy)

4

The Shit Killer

Solutions for effective and sustainable faecal sludge management (FSM) represent a significant global need. Tremendous amounts of faecal sludge are produced globally on a daily basis from onsite sanitation: 2.7 billion people worldwide are served by onsite sanitation technologies and that number is expected to grow to 5 billion by 2030. FSM presents a global challenge. A new technological concept for sterilization and dehydration of excreta (faeces and urine) has been developed by IHE Delft and Tehnobiro d.o.o. The technology makes use of microwave generators that are part of a specially designed unit that can convert pathogenic human waste into clean water and inert dry fertilizer. The concept has been successfully tested in the Netherlands and Kenya and a pilot demonstration unit is currently under construction and will be applied in Jordan.

Location: Worldwide
Contact: Tineke Hooijmans (t.hooijmans@un-ihe.org)
Partner: Tehnobiro d.o.o. (Slovenia)



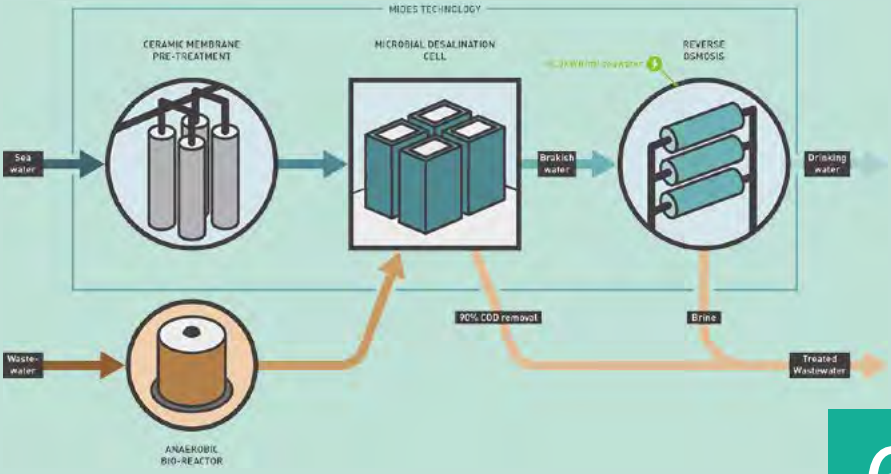
5

eSOS Monitor and Sanitation Business Model Evaluator

The eSOS Monitor and Sanitation Business Model Evaluator are a two-in-one tool for the operational management of the sanitation chain and for the evaluation of different sanitation business models and associated costs, respectively. The eSOS Monitor is an operational software tool to manage the entire sanitation chain in actual circumstances and real situations. It has been successfully tested in tough field conditions in The Philippines.
The Sanitation Business Model Evaluator is a decision support tool that can be applied to both actual cases and also for future options (e.g. choice of sanitation systems and business model). It has been tested in a case study in Thailand.

The eSOS Monitor is part of the award-winning innovation eSOS Smart Toilet and is at the heart of the novel eSOS concept of IHE Delft. Shortly after launch of the eSOS Monitor, the software features were adopted by several toilet manufacturers worldwide (e.g. India) and are already in use in real life situations.

Location: Worldwide
Contact: Damir Brdjanovic (d.brdjanovic@un-ihe.org)
Partner: SYSETCH.ba (Bosnia and Herzegovina)



6

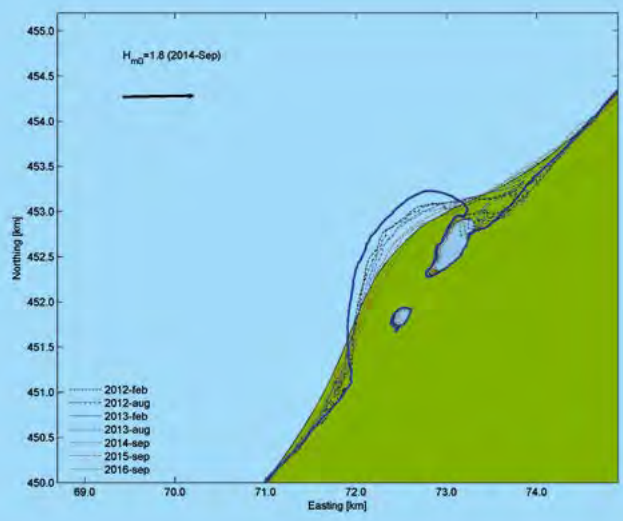
Microbial desalination for producing cheaper drinking water

IHE Delft and partners are developing a revolutionary microbial desalination approach which reduces the energy required to produce safe drinking water. The technology uses microbial desalination cells (MDC) as a pre-treatment for conventional reverse osmosis desalination. A pilot-scale production plant is under development. The use of electroactive bacteria in a MDC unit powers the process using significantly less energy for desalination and wastewater treatment. The new technology has great potential to be applied in water-stressed areas as a more sustainable water treatment option.

The MIDES (MIcronial DESalination) consortium of research and commercial organisations has been collaborating to further explore the potential of MDC technology by increasing desalination rates, reducing biofouling and scaling of membranes, optimising the microbial-electrochemical process and improving the economic feasibility of the system.

Locations: Chile, Spain, Tunisia
Contact: Sergio Salinas (s.salinas@un-ihe.org) | **Partners:** Aqualia, FUJIFILM, IMDEA-Water, LEITAT, Mikrolin, Oncontrol Technologies, SimTech, SGL Group, University of Gabes

Project co-funded by the EUROPEAN UNION



7

Complex coastline evolution simulation ‘for dummies’

For decades, most researchers in coastal processes have focused on making increasingly complex models to carry out more detailed and, at the same time, longer simulations. But now and then it can be refreshing to try the opposite: explain and simulate complex behaviour with very simple model concepts. A recent model development has done just that: applying coastline model concepts from the 1950s in a new, unrestricted framework, where the coastline is represented as a series of ‘strings of pearls’.

The result was a virtual world, where islands can move and merge, spits and capes can develop freely and the effects of hard structures or geology are easily represented. The concept has been shown to work in examples like the famous Dutch Sand Motor and already its serious application in projects is about to begin. The simplicity of the method, unrestrained geometric possibilities and user-friendliness, make it attractive for use at scales from local (10 km) to global.

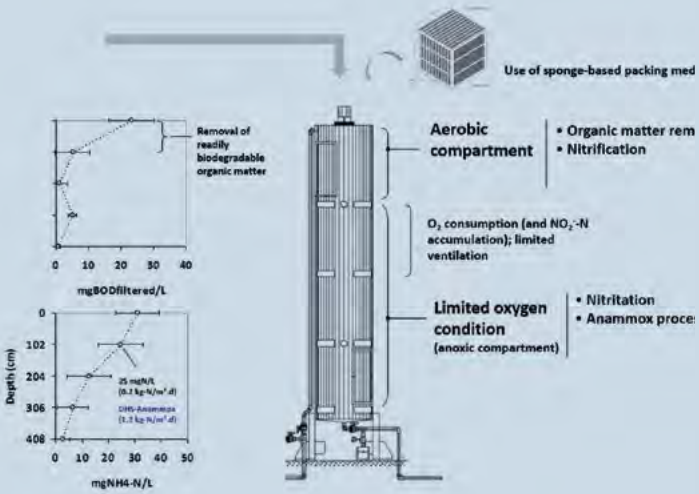
Location: Worldwide
Contact: Dano Roelvink (d.roelvink@un-ihe.org)
Partner: Deltares

8

Global Sanitation Learning Alliance

IHE Delft and partners recently established an alliance for education in the field of sanitation. The alliance started with an e-learning course on Faecal Sludge Management developed in 2016 and this has since been extended with several innovative educational offerings such as the Graduate Professional Diploma Program (GPDP) and a new one-year MSc in Sanitation. Although IHE Delft has developed and delivered distance learning for two decades, the e-learning course on Faecal Sludge Management is the first example of an IHE Delft e-learning course that is jointly developed and simultaneously delivered by partners at 6 different locations in Europe, Sub-Saharan Africa and South East Asia, thereby substantially increasing its reach. The alliance already has 600 members who enjoy its benefits and it is still expanding with new delivery partners. There is a vibrant community of professionals who are participating in this course and other courses and programs. The scope of the alliance will be expanded soon by other types of faecal sludge courses (e.g. MOOCs) and other related online courses and is soon expected to host several thousand sanitation professionals.

Location: Worldwide | **Contact:** Damir Brdjanovic (d.brdjanovic@un-ihe.org)
Partners: BMGF (USA), Eawag (Switzerland), UKZN (South Africa), CSE (India), AIT (Thailand), 2iE (Burkina Faso), BUET (Bangladesh)



9

Sponge-based Anammox technology

IHE Delft and partners tested a novel sponge-based trickling filter that can boost the growth of slow-growing Anammox organisms for the removal of nitrogen compounds from wastewater in a shorter time using fresh activated sludge as an inoculum. Furthermore, through natural air convection, complete autotrophic ammonium removal over nitrite as performed by Anammox bacteria can be achieved with no need for external (additional) aeration.

These favourable features and characteristics make sponge-based trickling filters economically effective and attractive as post-treatment steps for anaerobic wastewater treatment, as well as an interesting option for plant upgrades.

Location: The Netherlands
Contact: Carlos M. Lopez Vazquez (c.lopezvazquez@un-ihe.org)
Partners: Delft University of Technology (TU Delft), Federal University of Mina Gerais (UMFG)

10

Multiple water systems to cope with water scarcity

To cope with freshwater scarcity in coastal cities and regions, new and smart solutions such as multiple water systems can contribute to optimizing the water supply networks and increasing water availability.

The introduction and combination of the use of seawater and treated wastewater in the urban water cycle can supplement by up to 60% the supply of drinking water provided by conventional and/or seawater desalination systems. This increases the lifespan and reduces the costs of the latter, since: (i) seawater can replace up to 30% of the water consumed in households for toilet flushing; and (ii) treated wastewater can provide up to 30% of the water required for cleaning and irrigation in urban settlements.

Overall, the combination of multiple water systems can contribute to mitigating the effects of climate change on water scarcity caused by droughts while maintaining cost-effectiveness.

Location: Cuba | **Contact:** Carlos M. Lopez Vazquez (c.lopezvazquez@un-ihe.org)
Partners: CUJAE (Cuba), INRH (Cuba), IIIA (Cuba), HKUST (Hong Kong), TU Delft (The Netherlands), UCT (South Africa), UniValle (Colombia)

11

AfriAlliance: The Africa-EU innovation alliance for water and climate

Africa is one of the regions most in need of innovative solutions for tackling water and climate change challenges. However, many parts of Africa are suffering from widespread institutional fragmentation. AfriAlliance is an initiative in which many partners are joining forces to support cooperation within Africa and between Africa and the EU, in the field of innovation for water and climate.

AfriAlliance's ultimate objective is to increase African preparedness for climate change challenges. It does so by fostering the innovation process through several mechanisms and activities: AfriAlliance identifies and matches social innovations and needs, it helps improve water and climate monitoring and forecasting by developing a 'triple sensor approach', facilitates knowledge sharing and technology transfer through a series of face-to-face events and an innovative online platform, and 'action groups' bring together African and European peers with relevant knowledge and expertise to work jointly towards innovative solutions.

AfriAlliance has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 689162.

Locations: Africa, Europe | **Contact:** Uta Wehn (u.wehn@un-ihe.org)
Partners: WRC, Waternet, ICLEI Africa, RIOB, GWP, AfWA, WASCAL, BothEnds, Akvo, 2iE, CSIR, WE&B, OIEau, ITC UT, WssTP

Project co-funded by the EUROPEAN UNION

12

Recirculation Aquaculture Systems (RAS)

The innovative experimental pilot-scale recirculation aquaculture system (RAS) for African catfish production has been designed and developed (feed production, a hatchery and an on-growing system) for optimization and recovery of resources in the food production chain in Cuba. It includes nutrient retrieval, energy recovery, and wastewater reuse from RAS wastewater treatment systems. African catfish densities of approximately 130 kg/m^3 were obtained at a catfish production capacity of approximately 20 tons/year, fourfold more than the current fish farming practices in Cuba.

Several other full-scale innovative RAS systems for intensive production of eel, sea bass, and sea bream have already been constructed in Croatia under the leadership of IHE Delft.

Locations: Cuba, Croatia
Contact: Hector Garcia (h.garcia@un-ihe.org)
Partners: HESY Aquaculture B.V. (The Netherlands), EDTA (Cuba)

13

MFI0.45: A more effective tool for fouling assessment in desalination

IHE Delft has been at the centre of implementing the modified fouling index (MFI) to more accurately assess particulate fouling in desalination operations. The relative unpredictability of membrane fouling with the standard silt density index (SDI) has always been an impediment in reverse osmosis and other pressure-driven desalination systems.

First proposed in 1980, the MFI was further developed at IHE Delft and KWR Watercycle Research Institute. The technique was adopted in 2015 as a standard method by ASTM International after it was submitted by IHE Delft (ASTM D8002 - 15).

Previously, only the SDI was used to assess water quality in pressure-driven systems.

The MFI provides more standardized values in predicting rates of fouling by considering fouling mechanisms proportional to the concentration of foulants in water, as well as being unaffected by temperature variations. These MFI qualities lead to an increased system performance, lower energy consumption, reduced maintenance, and extended membrane life.

Locations: Worldwide (The Netherlands, Israel, Chile, Cuba, Mexico, Australia, UAE, Oman, KSA)
Contact: Maria Kennedy (m.kennedy@un-ihe.org)
Partners: KWR, Akvoregia

14

Leadership for city-to-city learning on adaptation

Medium-sized cities are finding that they are unprepared for the new demands on water resources, pollution control and flood protection. Many of these challenges are shared by other cities, regionally and even globally. Often they have complementary strengths and weaknesses and by cooperating, they can offer reciprocal support and know-how. IHE Delft, the Center of Water Management and Climate Change and the Asian Institute of Technology in Vietnam aim to assist cities in developing the internal leadership (e.g. skills, knowledge and networks) and common vision needed to encourage learning from each other. To achieve this aim, they have developed a training course on 'Leadership for city-to-city learning on adaptation'.

The training course is intended for mid-level climate professionals from four Vietnamese cities, with a history of working together in projects. These professionals will progress through six months' intensive work and learning, involving two 3-day training sessions and a challenging on-the-job group assignment to implement city-to-city learning. In this way, the course will strengthen the existing cooperation between these cities and with the local knowledge/education institutes.

The leadership course takes place in each of the four Vietnamese cities. This novel model can be used for training other city groupings in different regions and countries.

Location: Vietnam | **Contact:** Berry Gersonius (b.gersonius@un-ihe.org)
Partners: Center of Water Management and Climate Change (VNU-WACC), Asian Institute of Technology, Vietnam (AIT-VN)

15

Free and open source software tools for urban water management

IHE Delft has a long history of providing a rich classroom experience in hands-on learning in the water sector. Continuing with this tradition, a number of innovative software tools have been developed that help the student to experiment and learn various useful techniques in the domain of urban water cycle management. Two such tools are showcased here.

SWMM5-EA is a desktop educational tool that helps novice learners to apply Darwinian evolution-based optimization theory to optimally design sustainable drainage systems (SUDS). This tool has already been successfully used in a number of Masters and PhD research projects both within IHE Delft and worldwide.

RRPAM-WDS is a desktop tool for short and medium-term renewal planning of buried water pipe systems (water supply, drainage). Developed in 2016 to fill a gap in the asset management teaching curriculum, the tool has already been introduced both in the Institute's classrooms and outside training settings and was well received by users.

Location: Worldwide
Contact: Assela Phatirana (a.phatirana@un-ihe.org)
Partners: Vitens Evides International, WaterNet

16

Global Partnership of Laboratories for Faecal Sludge Analyses

Faecal Sludge (FS) characterization and experimentation is an emerging area in the field of sanitation. Laboratories equipped with facilities for FS analyses have entered into a partnership with the goal of standardizing methods of FS characterization and delivering training courses for both students and sanitation professionals.

The new FS laboratory of IHE Delft will be built either at the nearby wastewater treatment plant Harnaschpolder, or at IHE Delft's premises. It will be used for basic and advanced training so that trainees can improve their skills and embark on practical FS work with increased confidence.

In addition, it will serve FS researchers at the newly established centre of excellence 'Delft Blue Innovation', which has its research facilities nearby and was established in cooperation with IHE Delft.

Location: The Netherlands, India, South Africa, Thailand, Zurich | **Contact:** Damir Brdjanovic (d.brdjanovic@un-ihe.org) | **Partners:** BMGF (USA), Eawag (Switzerland), UKZN (South Africa), CSE (India), AIT (Thailand), Delfluent Services BV, Delft Blue Innovations (The Netherlands)

17

Empowering innovation uptake through research

While applied research activities carried out locally on pilot-scale demonstration systems or case studies mainly led by research and knowledge institutions is contributing to the development and preparation of design, operation and maintenance guidelines, the involvement of water professionals supports the adaptation and adoption of innovations by the local water sector in accordance with local conditions and needs.

As recently demonstrated in Cuba, long-term sustainability and uptake was enhanced by (i) the introduction of the new guidelines as lecturing material in local university curricula, (ii) formation of highly qualified water professionals knowledgeable on the innovations (at BSc, MSc and PhD level) to strengthen the academic and professional water sectors, and (iii) training courses taught to local water professionals combining the fundamentals (new guidelines) and technical and practical aspects (know-how on the pilot-scale systems) of the innovations.

Location: Cuba
Contact: Carlos M. Lopez Vazquez (c.lopezvazquez@un-ihe.org)
Partners: CUJAE (Cuba), INRH (Cuba), IIIA (Cuba)

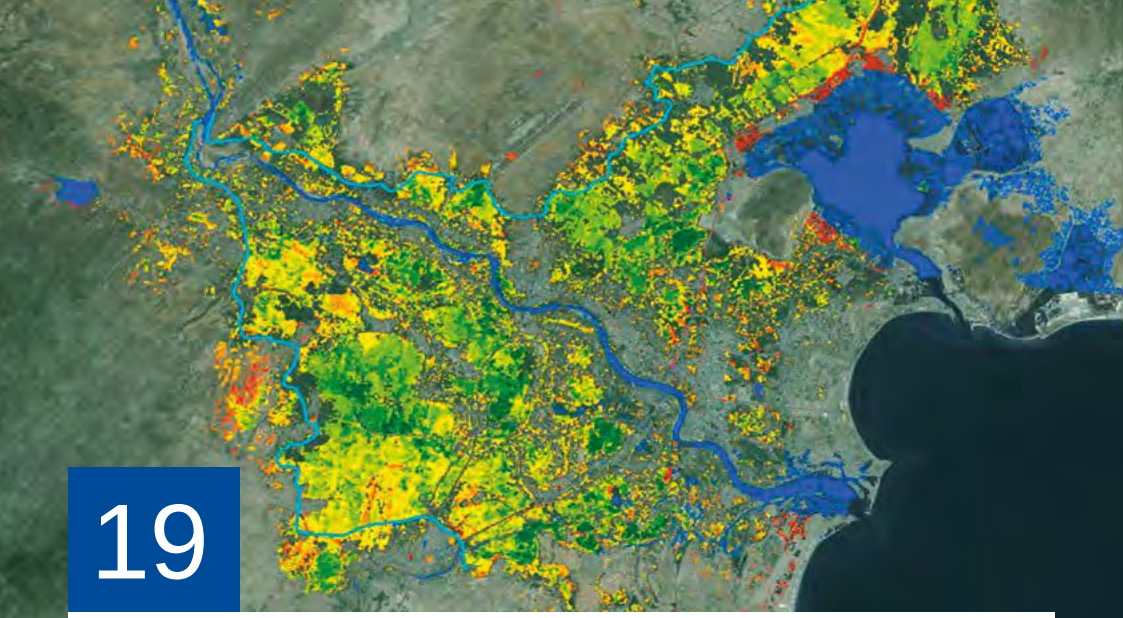
18

Wastewater reuse for food production

A membrane bioreactor (MBR) technology has been developed and designed for the treatment of food processing industries' wastewater in Cuba, to reuse the water and recover the nutrients. The treated effluent and sludge produced by the MBR system have been applied to support local agricultural activities at a demonstrative scale. The water quality of the MBR allowed a safe and continuous source of water for crop irrigation, while the sludge was used to enhance the quality of the soil.

The MBR technology and reuse of safe water and sludge in intensive agriculture was for the first time conducted in Cuba.

Location: Cuba
Contact: Hector Garcia (h.garcia@un-ihe.org)
Partners: IIIA (Cuba), ALMES d.o.o. (Croatia)



19

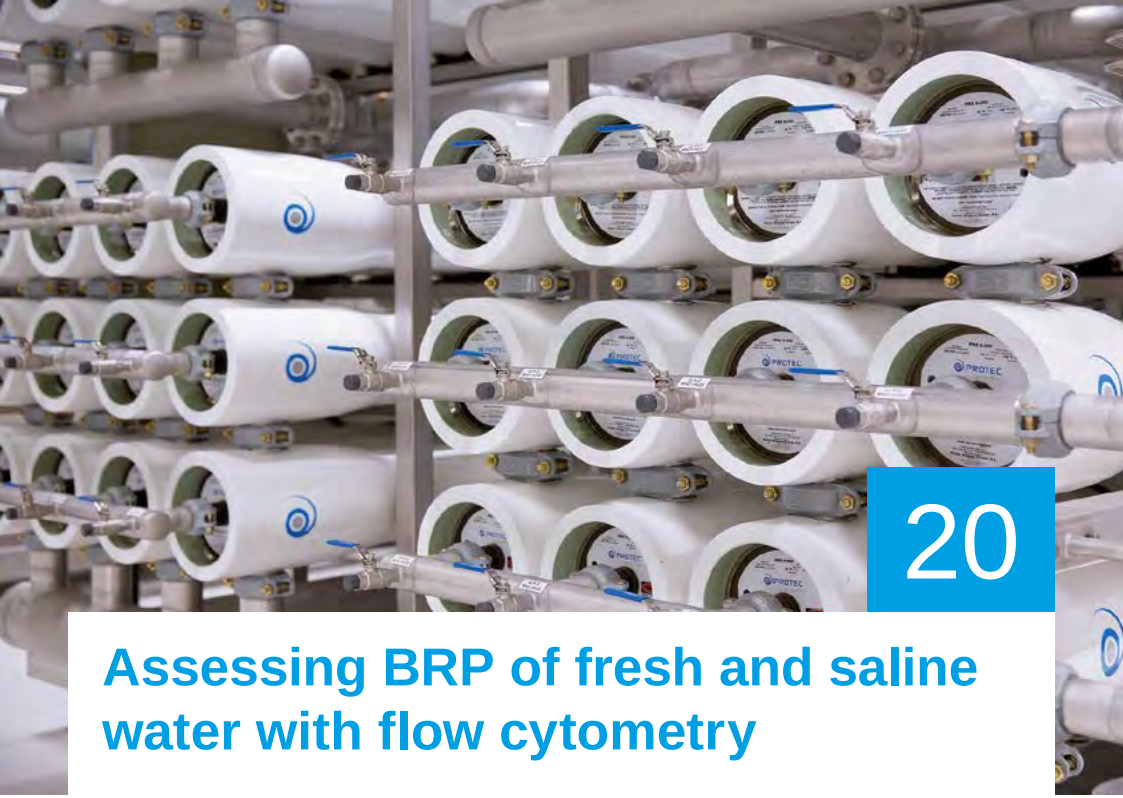
WA+: an emerging global standard for water accounting

The key questions in water management are simple and yet hard to answer: is there sufficient water available for all users, and for how long? Effective management strategies heavily depend on reliable data which is often not available.

Open-access Remote Sensing data can offer crucial information in this context. The Water Accounting Plus (WA+) framework, jointly developed by IHE Delft, IWMI, FAO, and WWAP, provides a quick scan of water resources conditions in a river basin using such datasets.

The framework evaluates water consumption, water productivity and goes beyond the classical water balance approach, by linking land and water management. The WA+ reporting is based on sheets meant for decision makers, detailed tables for technical experts, and spatially-distributed maps. WA+ has been applied in many countries worldwide and the system is constantly being upgraded using the latest available technologies.

Locations: South and South-East Asia, Middle East, Africa, South America
Contact: Elga Salvadore (e.salvadore@un-ihe.org)
Partners: IWMI, FAO, WWAP



20

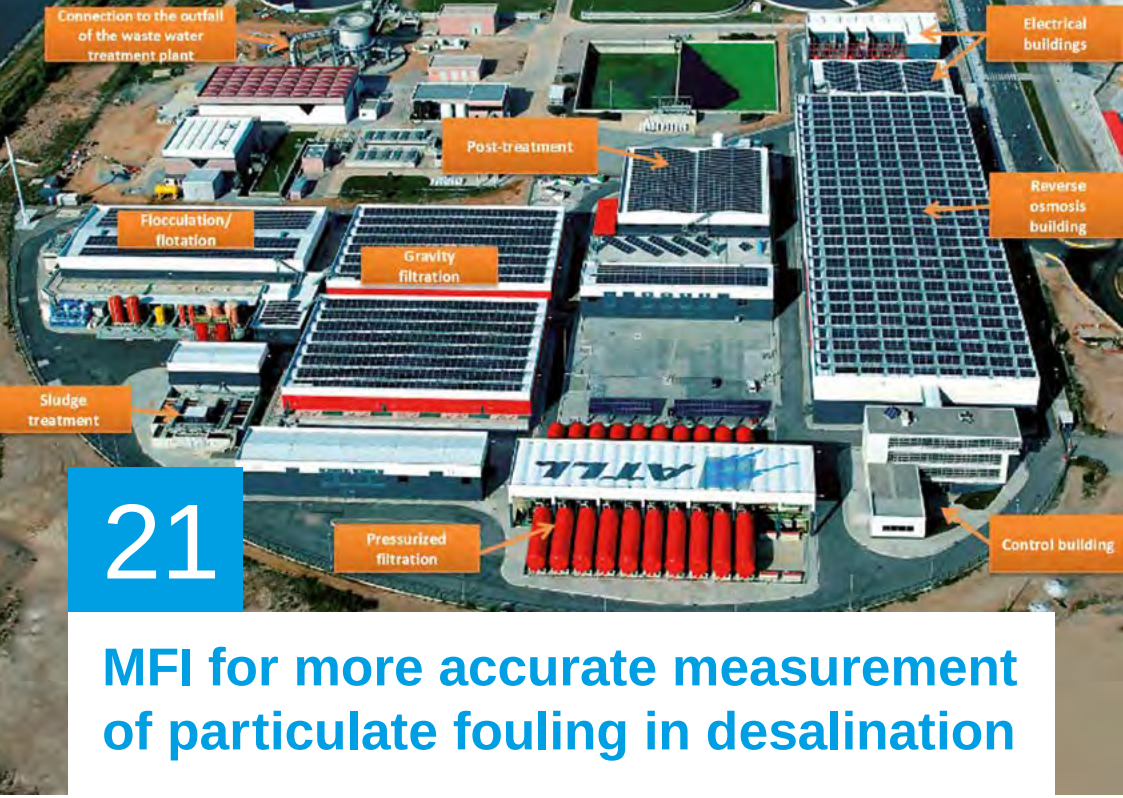
Assessing BRP of fresh and saline water with flow cytometry

Current methods of assessment of bacterial regrowth potential (BRP) in fresh and saline water are time-consuming, costly, and limited to specific bacterial strains.

IHE Delft, in collaboration with the Wetsus Institute, has developed a method for monitoring the BRP in seawater samples using a natural consortium of marine bacteria and flow cytometry for bacterial counting. The use of a natural consortium enables a much broader and diverse substrate range than a single pure culture and thus offers a more realistic interpretation of biofouling occurring, especially in SWRO membrane systems. This method is also faster than conventional bioassays.

In addition, IHE Delft together with Oasen has further developed an established method for assessing the biological stability of low-nutrient waters, such as after RO including remineralisation. It is expected that the number of drinking water plants using RO technology will continue to increase rapidly.

Locations: Australia, United Arab Emirates, Oman, The Netherlands
Contact: Maria Kennedy (m.kennedy@un-ihe.org)
Partners: Oasen Drinkwater, Wetsus



21

MFI for more accurate measurement of particulate fouling in desalination

Colloidal and organic fouling in seawater reverse osmosis (SWRO) desalination systems results in permeability decrease, higher energy costs, increased salt passage, additional cleaning, and the use of chemicals. In practice, indices like the silt density index (SDI) and modified fouling index (MFI) are used to assess particulate fouling, but these methods are not sensitive enough to detect small particles and do not take into account the deposition of particles/ colloids in reverse osmosis (RO) systems.

The MFI with ultrafiltration membranes (MFI-UF) at constant flux was developed by incorporating the effects of particle/ colloidal deposition and flux.

The resulting assessment of RO feed water quality is more accurate. The MFI-UF can also be used to predict the rate of fouling in RO systems.

This method enables engineers, plant operators and scientists to design more efficient plants, as well as to improve the operation and monitoring of organic and particulate/colloidal fouling in SWRO systems.

Locations: The Netherlands, Spain, France, United Arab Emirates
Contact: Maria Kennedy (m.kennedy@un-ihe.org)
Partner: Akvoregia

22

ATP-based methods to better control biological fouling

The monitoring of bacterial activity and bacterial growth in the feed water of reverse osmosis (RO) systems is important for controlling the biological fouling of RO membranes. Biological fouling causes an increase of energy use per cubic meter of desalinated water and an increase of salt passage through RO membranes.

With previous methods, adenosine triphosphate (ATP) could be measured accurately at low levels in seawater due to the interference of salt with the luciferin/luciferase reaction, which inhibits light production and ATP measurement.

IHE Delft, working with the Promega Corporation, has developed two methods to measure bacterial ATP in seawater: the direct method and the filtration method.

Locations: Australia, United Arab Emirates, Oman, The Netherlands, Spain, USA
Contact: Maria Kennedy (m.kennedy@un-ihe.org)
Partner: Promega

23

BEWOP: boosting the effectiveness of Water Operators' Partnerships

The capacity development model underlying the Water Operators' Partnerships is one where capacity development occurs through the interaction of staff from two or more water operators on a not-for-profit and solidarity basis. Within BEWOP, IHE Delft is engaged in creating and developing didactic tools to support the capacity development activities carried out in WOPs. This process is innovative, as it involves developing the tools in cooperation and consultation with water operators – thus strictly demand-driven – to ensure internal uptake and coverage of actual needs by the tools. The tools are expected to be developed as 'off-the-shelf' products that can be used independently by water operators during their WOP partnerships and beyond. This approach has the added value of sustainably building capacity, and anchoring it for the long-term, by ensuring that the transfer and development of knowledge occurs between the WOP mentor and mentee, in terms and topics that are of importance to them.

Location: Worldwide
Contact: Klaas Schwartz (k.schwartz@un-ihe.org)
Partner: UN-Habitat

24

Utility Management Simulation Game (UMSG)

The UMSG is an interactive role-playing game (developed under the BEWOP project), where participants take the roles of general, operational, commercial, and financial managers and negotiate on investment decisions for a drinking water utility. Participants decide on tariff rates, infrastructure expansion, human resource management, maintenance, and capacity development investments for a 'game year', and then receive feedback on how their decisions have impacted the relevant Key Performance Indicators (KPIs). The heart of the learning experience of the UMSG lies between promises, uncertainty, and negotiation.

Due to the complex inter-relations between decisions and outcomes, the UMSG leads players to continuously reconsider how their choices impact the utility's performance. This supports them in reflecting and analysing what causal relations can exist in water utilities, which facilitates learning about the challenges in managing a water utility. These include the inter-relationship between technical and capacity development investments, and necessitates discussions among participants to seek a common goal through consensus.

Location: Worldwide
Contact: Klaas Schwartz (k.schwartz@un-ihe.org)
Partner: UN-Habitat

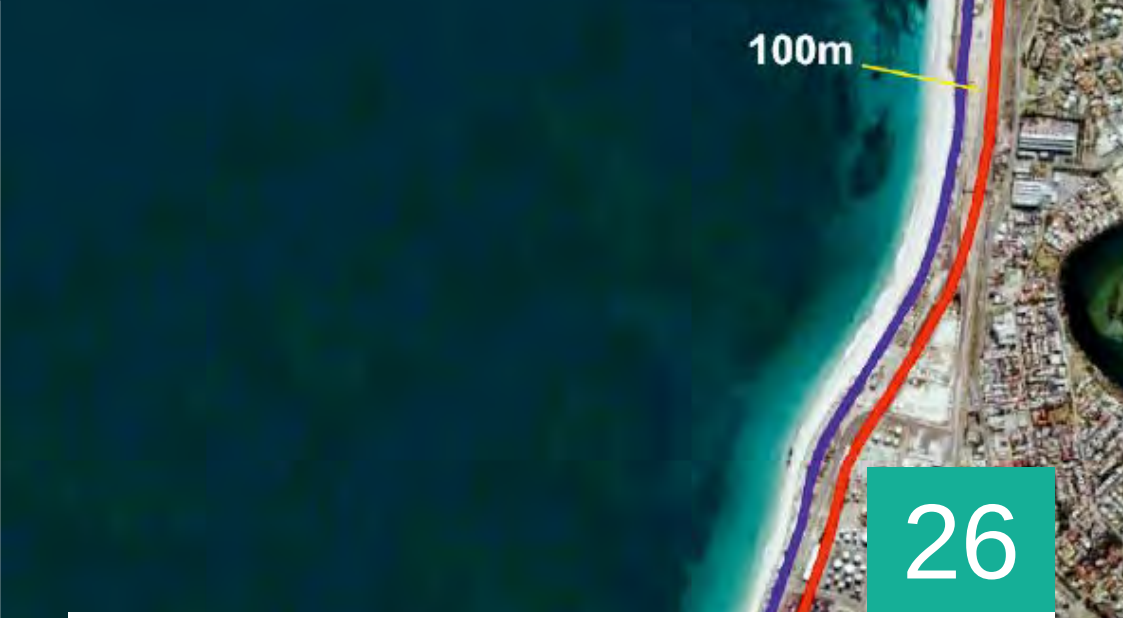
25

External scaling monitor to maximize recovery in BWRO systems

Maximizing recovery in brackish water reverse osmosis (BWRO) is essential in order to limit both the production of brine and specific energy consumption (kWh/m^3). The principle of the scaling monitor is based on creating a small increase in recovery in an (external) RO element where normalized permeability and pressure drop are continuously monitored.

The company Grundfos, in collaboration with IHE Delft and Oasen, has developed a scaling monitor that can be used to continuously optimize the required dose of antiscalant in relation to the recovery for different feed water qualities. This scaling monitor is currently being applied at Oasen.

Locations: The Netherlands, Denmark
Contact: Maria Kennedy (m.kennedy@un-ihe.org)
Partners: Grundfos, Oasen Drinkwater



26

Rapid assessment of climate change on inlet-interrupted coasts

Most coastlines around the world are interrupted by inlets connecting the ocean to estuaries, lagoons, and rivers. Coastlines in the vicinity of inlets will be affected not only by climate change-driven variations in oceanic processes (e.g. sea level rise) but also by climate change-driven variations in terrestrial processes (e.g. rainfall/ runoff). The combination of their sensitivity to several climate change-driven variations in system forcing and their heavy human utilization, renders the thousands of inlet-interrupted coasts around the world highly vulnerable to climate change impacts.

IHE Delft has developed an innovative, easy-to-use mathematical model (SMIC-Scale Aggregated Model for Inlet interrupted Coasts) to obtain estimates of local scale (< 25 km alongshore) coastline change due to all relevant climate change impacts. Model applications in four representative systems show that methods historically used to assess coastline response to climate change may be under-predicting potential coastline recession by up to 50-75%.

The model is being further developed for all types of inlet systems. So far the capability to better represent the effects of climate change and human-induced future variations in the catchment, and on how coastlines adjacent to two (of the three) main types of coastal inlets present around the world have been added.

Locations: Vietnam, Australia, Sri Lanka, USA
Contact: Roshanka Ranasinghe (r.ranasinghe@un-ihe.org)
Partners: Delft University of Technology, Deltares

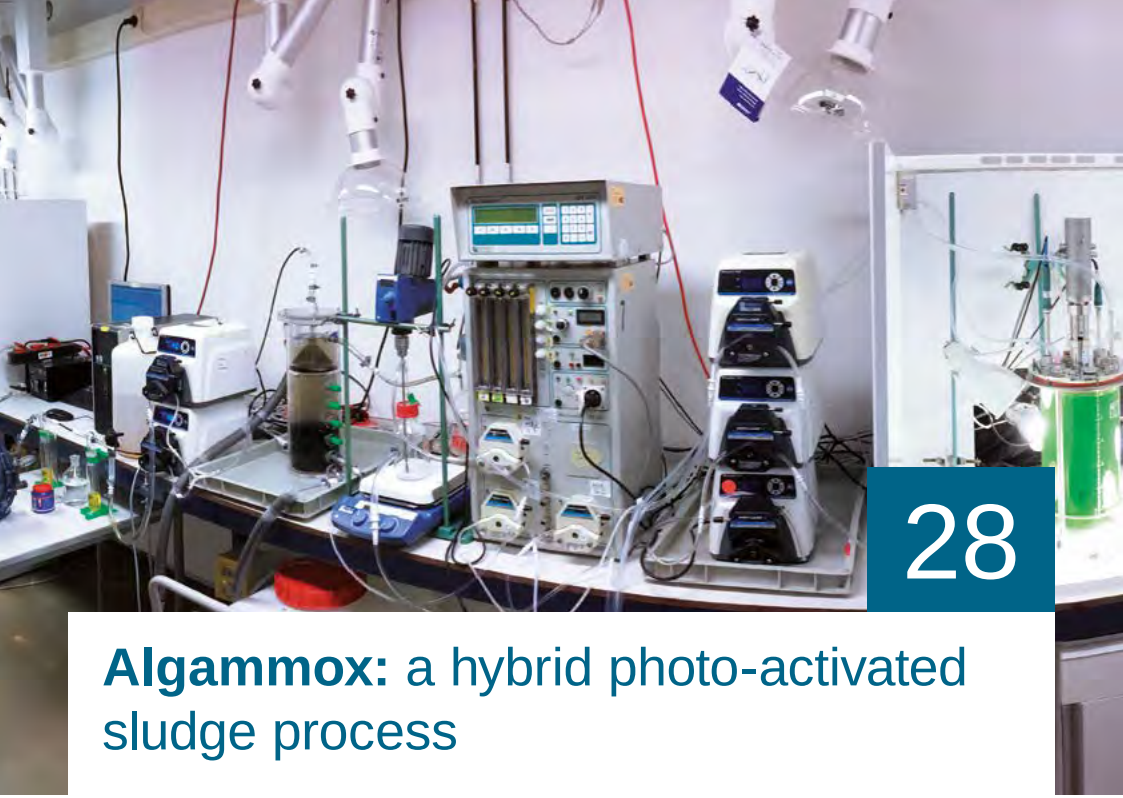
27

GPDPs: tailored e-learning opportunities for sanitation professionals

The Graduate Professional Diploma Program (GPDP) programme is a new educational product of IHE Delft that disseminates sanitation and sanitary engineering knowledge to professionals unable or not wishing to pursue an MSc degree in Sanitation and Sanitary Engineering, or with an MSc Degree in a related field, who wish to specialize professionally. The programme consists of a sequence of four or five online courses, regular short courses or a combination.

The online courses can be followed part-time, without interrupting a daytime career. In order to ensure that the program fits the personal circumstances of the applicant, courses will be selected and a personal study plan will be designed in collaboration with a study advisor. The total duration of the program depends on this study plan, with a minimum of 1.5 and a maximum of 4.5 years. Following up on the successful launch of the first GPDP, IHE Delft has developed and launched four additional GPDPs, namely Water Supply Engineering, Water and Wastewater Treatment Technology, Flood Risk Management and Urban Water Networks, and Cleaner Production and Resources Management.

Locations: The Netherlands, worldwide
Contact: Martin Mulenga (m.mulenga@un-ihe.org)
Partner: Bill & Melinda Gates Foundation



28

Algammox: a hybrid photo-activated sludge process

Wastewater treatment by the photo-activated sludge process combines the advantages of the conventional activated sludge process with those of high rate algae ponds. In such a symbiotic ecosystem, a consortia of algae and bacteria in well-settling flocs efficiently removes and recovers nitrogen and phosphorous at much lower energy inputs and land requirements than other competing technologies. The latest innovation is the inclusion of Anammox bacteria in photo-bioreactors, which we have named the Algammox process.

Algammox is an acronym derived from algae and +Anammox, in which Anammox is a widely-accepted acronym for Anaerobic Ammonium Oxidation. Anammox was discovered in Delft in the 1990s.

IHE Delft and partners have proved that the concept work , but we need to test whether the method is as robust under changing conditions as in real life.

Such a combination of algae and bacteria as in the Algammox technology, is currently in the development phase. The two underlying technologies, namely algae-based systems for production biogas and other biofuels, and Anammox systems for anaerobic ammonia conversion, are considered well established technologies, applied at full scale.

Locations: Israel, USA, Zimbabwe
Contact: Peter van der Steen (p.vandersteen@un-ihe.org)
Partners: Aquanos, University of South Florida, Universidade Eduardo Mondlane

29

WeSenseIt: citizens as water sensors

Given the large diffusion of mobile phones, citizens can complement the often insufficient density and resolution of data collected by traditional monitoring networks. This is particularly helpful for emergency services as well as policy makers with respect to critical events such as floods and droughts. Moreover, the involvement of citizens in data collection promotes a more active role for local communities with regards to understanding and taking care of the environment.

Citizens capture hydrological data using Apps and physical sensors that can connect to portable devices such as smartphones and tablets. Relevant data is also extracted from the interactions of citizens on social media sites such as Twitter and Facebook.

IHE Delft is developing innovative methods to optimally design new generations of monitoring networks that include sets of dynamic sensors capturing data with diverse spatial and temporal characteristics (e.g. via smartphone video-based rainfall reports), and methods to incorporate the heterogeneous data collected via citizen observatories into hydrological and hydraulic models.

Also, through an innovative combination of governance analyses and stakeholder engagement, IHE Delft is aiming to maximize the social innovation potential of citizen observatories in terms of improved community resilience and strengthened water governance.

Locations: Italy, United Kingdom, The Netherlands
Contact: Leonardo Alfonso (l.alfonso@un-ihe.org)
Partners: Consortium of 13 institutions

Project co-funded by the EUROPEAN UNION

30

eSOS® concept

The innovative eSOS (emergency Sanitation Operation System) concept is designed to provide a sustainable, innovative, holistic and affordable sanitation solution for emergencies before, during and after disasters. eSOS not only reinvents the (emergency) toilet and treatment facilities, but also uses existing information and communication technology to bring innovation and potential cost savings to the entire sanitation operation and management chain, and most importantly, is expected to improve the quality of life of people in need.

Several components of the eSOS concept such as the eSOS Smart Toilet, eSOS Monitor, Sanitation Business Model Evaluator and Shit Killer have passed the experimental application and are currently under further development at a pilot level with the ultimate goal of entering into commercial exploitation in the near future. Bringing these technologies up to this readiness level (RTL 9 as described by NASA) will enable eSOS's transfer from a concept to real-life application.

Location: Worldwide
Contact: Damir Brdjanovic (d.brdjanovic@un-ihe.org)
Partner: Bill & Melinda Gates Foundation

31

Arsenic removal family filter

Hundreds of millions of people, mainly in rural areas of developing countries, are exposed to high arsenic levels in drinking water on a daily basis. Arsenic is a human carcinogen, and its presence in drinking water increases cancer mortality risk and causes liver failure, as well as cardiovascular, neurological and several other diseases.

The IHE Arsenic Removal Family Filter is based on a low-cost adsorbent and has been demonstrated to effectively remove arsenic from drinking water. The filter can produce enough arsenic-free drinking water for a whole family. The filter is simple to operate, does not require electricity and can be produced locally.

Location: Bangladesh
Contact: Branislav Petrusevski (b.petrusevski@un-ihe.org)
Partner: Vitens

32

Free remote sensing data

Freely available remote sensing data have made a jump in both availability and quality in the last two years, with the addition of ESA Sentinel Programme datasets to the family of freely available remote sensing data. Also, the Open Source software that can be used to extract information from these datasets has come of age. At IHE Delft we are promoting and training in the use of sustainable Open Access datasets and Open Source geospatial software and we are also assisting partners in the implementation of semi-operational systems based on free data. This allows stakeholders to monitor the dynamics of rivers and lakes throughout the hydrological year, at almost no cost and with no need for maintenance licences.

This information, coupled with the few existing gauging stations, will allow for a low-cost, and hopefully shared, hydrological baseline that can be accessed by universities, local and national bodies, and individual users.

Locations: Kenya, Mozambique, Tanzania
Contact: Paolo Paron (p.paron@un-ihe.org)
Partners: Ramani, iMMAP

33

Alternative dam operations

The increasing demand for food and energy has sparked a revival of large dam construction in the Global South. In the wake of this new era of dam building, learning from existing dams will provide opportunities to plan, operate and govern new dams in a more equitable and sustainable way.

Through innovative water systems modelling, alternative dam operations can be tested to ensure the economic development is combined with a more equitable use of the resources of people and ecosystems (ecosystem services).

Dam operators need to be involved in co-creating these alternative dam operating policies. The application for the Lower Zambezi in Mozambique showed that operating the planned Mphanda Nkuwa dam in conjunction with the existing Cahora Bassa dam will be beneficial. This is in terms of dam safety and downstream water level fluctuations, as less water is spilled during flood situations and steady releases are provided by Mphanda Nkuwa throughout the day. Less hydropower will be produced for Cahora Bassa, but this will be compensated for by Mphanda Nkuwa.

Location: Mozambique
Contact: Pieter van der Zaag (p.vanderzaag@un-ihe.org)
Partners: Universidade Eduardo Mondlane, Hidroeléctrica de Cahora Bassa, WaterNet (Southern Africa)

34

Arid land greening

There is widespread unutilized alluvial aquifer potential in many semi-arid and arid lands in Africa. We have already proven that in the Mzingwane Catchment in arid southern Zimbabwe there is sufficient water stored in these dry riverbeds to support 1,000 to 3,000 ha of irrigation year-round.

The newly launched A4Labs action research will test the application of improved abstraction and irrigation technologies with farmers, local authorities, universities, NGOs and the private sector. By working together with different stakeholders in the field, A4Labs is aiming to co-create and test innovative solutions that are applicable in the local context.

Working in three different river basins (Mzingwane in Zimbabwe, Limpopo in Mozambique and Tekeze in Ethiopia) encourages South-South learning.

Locations: Ethiopia, Mozambique, Zimbabwe
Contact: Pieter van der Zaag (p.vanderzaag@un-ihe.org)
Partners: Mekelle University, Oxfam, Dabane Trust, Acacia Water and many others

35

Predicting storm surges

Novel methods for more accurate prediction of ocean surges have been developed, and implemented in software tools. These methods are based on the methods of nonlinear dynamics, chaos theory, statistics and artificial neural networks, developed in the framework of hydroinformatics. Several enhancements and innovations have demonstrated that this predictive chaotic model can serve as an efficient tool for accurate and reliable short-term predictions of storm surges, in order to support decision makers in coastal flood prediction and ship navigation.

This approach has been thoroughly tested in predicting the North Sea surge at Hoek van Holland in the Netherlands and has excellent potential to become a complementary method used by practitioners along with the traditional numerical ocean models.

Location: The Netherlands
Contact: Dimitri Solomatine (d.solomatine@un-ihe.org)
Partners: Deltares, Delft Cluster

36

Evaluating groundwater in times of scarcity and of abundance

Improving the knowledge on groundwater resources in the Valle del Cauca in Colombia and the interaction between groundwater and surface water, both in times of water scarcity and of water abundance, will help the local environment agency in charge to manage the resource sustainably.

In collaboration with Deltares and CVC (Regional Environment Agency in Colombia), IHE Delft is researching the dynamics of groundwater in the Valle del Cauca, an area of key socio-economic importance in the country. Improving both the knowledge and capacity on groundwater resources as well as the interaction with surface water through field research and modelling will allow the combined use of surface water and groundwater to be improved, as well as help understand the role of groundwater in flooding.

Location: Colombia | **Contact:** Micha Werner (m.werner@un-ihe.org)
Partners: Deltares, Corporación Autónoma Regional del Valle del Cauca (CVC), Universidad de Antioquia (Medellin), Universidad del Norte (Baranquilla), Cenicaña

37

Winged monitors

Monitoring water and ecosystem qualities and quantities is often done using point-sampling approaches, with relatively low revisit frequency, due to logistics and cost concerns. At IHE Delft we are making use of remotely piloted aerial systems such as drones (or unmanned aerial vehicles - UAV) and kite aerial photography (KAP) to expand the point sampling to a (geo) spatially explicit sampling, with hyper-spatial resolution and the potential for a very high revisit.

This approach is not only bringing new knowledge about the natural systems such as the Mara River Wetland in Tanzania, or the Limpopo River in Mozambique, but also about the interactions between natural and anthropic dynamics, that helps create a better and timely understanding, as well as management of natural resources and hazards.

We are also experimenting with UAV technologies in an urban context, mapping low-income districts of Maputo, to understand the varying distribution of water quality better and to advise on their management.

Locations: Mozambique, Tanzania
Contact: Paolo Paron (p.paron@un-ihe.org)
Partners: BirdLife International (Tanzania), National Water Directorate, UEM and FIPAG (Mozambique)

38

Monitoring algal bloom in desalination plants

Seawater desalination technology is capable of solving water scarcity in arid regions of developed and developing countries. An emerging threat to this technology are algal blooms, which can cause the shutdown of desalination plants, due to operational problems caused by algal-derived substances known as transparent exopolymer particles (TEP). IHE Delft has developed a new method to monitor TEP during algal blooms, to provide engineers and operators with a tool for developing strategies to mitigate operational problems in desalination plants.

This method has been tested in pilot and full-scale desalination plants in several countries.

Locations: The Netherlands, Scotland, Spain, Cyprus
Contact: Maria Kennedy (m.kennedy@ un-ihe.org)
Partners: Wetsus, PENTAIR, Evides

39

Extreme events and UNESCO heritage sites

A new approach to flood risk assessment and the development of optimal green-grey-blue infrastructure measures at heritage sites, proposed by IHE Delft and AIT, aims to protect the ancient world heritage city of Ayutthaya Island. The results obtained so far highlight the importance of the innovative selection and design of green-grey-blue infrastructure, in order to achieve the adaptive capacity of flood protection measures, while preserving the heritage character of the area.

The new approach, which combines green-grey-blue infrastructure measures, is the result of four years' research into extreme flood events under PEARL activity. The new approach addresses the risk of extreme events in a holistic manner and has the potential to provide multiple community benefits, to face new threats and to enhance resilience.

Location: Ayutthaya, Thailand
Contact: Zoran Vojinovic (z.vojinovic@un-ihe.org)
Partner: AIT (Thailand)

40

SANI® technology for tourism sector

The Sulphate Reduction, Autotrophic Denitrification and Nitrification Integrated (SANI) process can reduce sewage sludge production by up to 90%, minimizing energy consumption, as well as odour and greenhouse-gas emission. In addition, it can reduce the cost of sewage treatment and space requirement by up to 50% and also increase pathogen removal. These characteristics and performance make it suitable to be used in coastal zones, either for treatment of urban wastewater, wastewater generated from the tourism sector, or saline wastewater generated by using seawater for toilet flushing or due to saline water intrusion.

It can also support the use of seawater for toilet flushing (through the treatment of the saline wastewater generated), contributing to saving fresh water and thus increasing water availability. IHE Delft and partners pioneered the first application of the SANI technology at the tourist location Varadero in Cuba.

Location: Cuba | **Contact:** Carlos M. Lopez Vazquez (c.lopezvazquez@un-ihe.org)
Partners: Technological University of Havana (CUJAE), National Water Resources Institute, Food Research Institute, Hong Kong University of Science and Technology (HKUST), TU Delft

Project co-funded by the EUROPEAN UNION

41

Fluoride removal family filter

Millions of people in Africa (Sudan, Ethiopia, Uganda, United Republic of Tanzania, Ghana, Kenya, Zimbabwe, Mozambique, etc.), Asia (Jordan, China, Pakistan, India, Thailand, Sri Lanka, Iraq, Iran, Morocco, Algeria, etc.), Europe, America and Australia are exposed on a daily basis to high fluoride levels in drinking water. Long-term exposure to elevated fluoride concentration in drinking water is responsible for dental and skeletal fluorosis, and increases incidence of other diseases.

The IHE Fluoride Removal Family Filter, based on low-cost, locally available material, coated with aluminum, has been demonstrated to effectively remove fluoride from drinking water. The filter is simple to operate, does not require electricity, and can be produced locally.

Location: Ghana
Contact: Branislav Petrusevski (b.petrusevski@un-ihe.org)
Partner: VIA Water

42

Seasonal hydrological drought forecasting

A new approach to providing drought forecast information that couples seasonal meteorological forecasts and hydrological modelling for water users in drought-prone areas has been developed by researchers at IHE Delft. This methodology provides key information on the occurrence of dry spells, low soil moisture conditions and reservoir levels. The research was developed in the context of a European 7th Framework research project focusing on drought forecasting and warning that was carried out in close collaboration with partners across Africa and Europe. In some climatic regions of Africa, forecasts were found to be reliable for selected indicators of drought up to lead times of 3-4 months, allowing users such as rain-fed farmers, irrigated farmers and reservoir operators to take timely action to reduce the impacts of drought events.

Location: Africa
Contact: Shreedhar Maskey (s.maskey@un-ihe.org)
Partners: Consortium of 19 institutions

Project co-funded by the EUROPEAN UNION

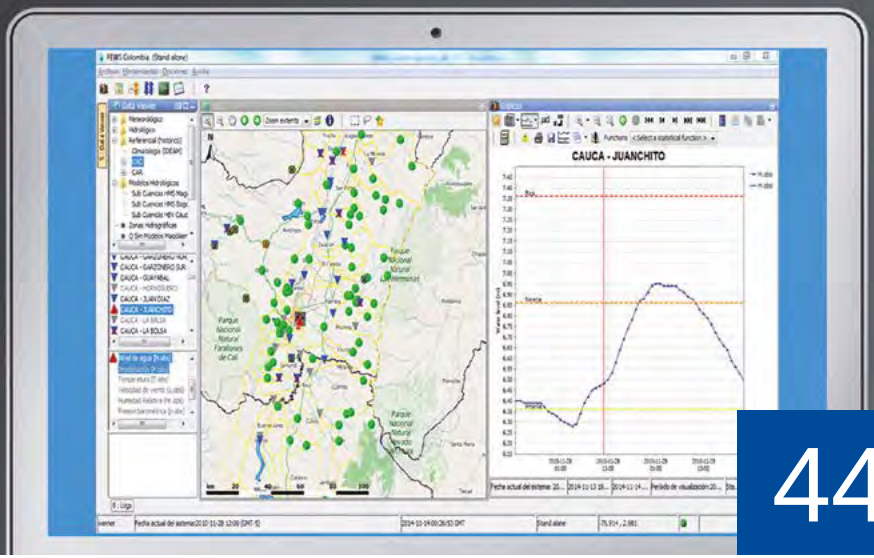
43

Sediment management in reservoirs

Reservoir infilling is still an underestimated issue in many parts of the world, both during the design and operation that leads to reduced reservoir capacity and alteration of the original operation schemes. Sediment provenance studies have so far been conducted mostly with a mono-disciplinary approach, either from the mineralogical point of view or from the hydraulic modelling point of view. IHE Delft has developed a combined, multidisciplinary approach, to gain more realistic insights into the sediment source areas and their transport and deposition, providing more useful sediment management tools to dam operator agencies.

This novel approach includes multidisciplinary assessment of sediment sources in reservoirs, by combining mineralogical fingerprinting with 2/3D morphodynamic modelling.

Locations: Mozambique, Sudan | **Contact:** Alessandra Crosato (a.crosato@un-ihe.org)
Partners: Hydraulics Research Centre (HRC-Sudan), Ministry of Water Resources and Electricity of Sudan



44

Forecasting floods

State-of-the-art forecasting methods to provide operational flood forecasting in Colombia have been piloted, combining hydrometric real-time ground data with meteorological and hydrological models. Pilot applications in three basins in Colombia show the potential for providing operational forecasts to communities at risk, to reduce flood damage such as that caused by the destructive floods of 2010-2011. IHE Delft has been working in collaboration with Deltares and IDEAM, the Colombian Hydrometeorological agency, as well as regional institutions, on establishing an operational flood forecasting service.

Through joint development in three pilot basins, knowledge and capacity have been established, and IDEAM is now working towards providing the service at a national level to all the communities at risk in the country.

Location: Colombia | **Contact:** Micha Werner (m.werner@un-ihe.org)
Partners: Deltares, Instituto de Hidrología Meteorología y Estudios Ambientales (IDEAM), Corporación Autónoma Regional del Valle del Cauca (CVC), Corporación Autónoma Regional de Cundinamarca (CAR)

45

Dealing with uncertainties

Using the innovative statistical and machine learning methods of dealing with uncertainty, a model-based methodological framework allowing for flood inundation/hazard mapping has been developed. It will be used to assist the Malaysian government in making appropriate decisions for the assessment and management of flood risk based on flood mapping under uncertainty, with application to the Johor River basin. The new approach helps to understand how the uncertainty associated with topographic sources of digital elevation maps (DEMs, cell size for grids, spacing of river cross-sections), hydrological data (errors in observation data) as well as model structures (1D, 2D or 3D) and parameters, affects the flood inundation/ hazard maps.

Location: Malaysia
Contact: Dimitri Solomatine (d.solomatine@un-ihe.org)
Partner: Department of Irrigation and Drainage Malaysia

46

Guidelines for road and drainage development in floodplains

The economic development of river deltas requires good transport connectivity and roads play an important role in this. However, roads fragment the valuable floodplain systems and change their natural dynamics and ecology and at the same time, are regularly damaged by floods, resulting in costly repair works. To address these issues, improved coordination is needed between the agencies involved, as well as the introduction of adequate road planning and design options. Two basic options exist: more closed road design or more open road design, the latter aiming to maintain the natural floodplain dynamics as much as possible through culverts and bridges. Both options have different impacts on transport, ecology, agriculture, flood protection and finance.

The Roads and Floods project (IHE Delft with Deltares and WWF) has developed a set of innovative best practice guidelines for road planning and design in vulnerable floodplains, based on an extensive study of the interactions between roads and floods in the Mekong delta. The study was commissioned by the Mekong River Commission, and guidelines have been adopted by its flood management programme and the Cambodian and Vietnamese National Mekong Committees.

Location: Vietnam
Contact: Wim Douven (w.douven@un-ihe.org)
Partners: Mekong River Commission (MRC), Deltares, WWF

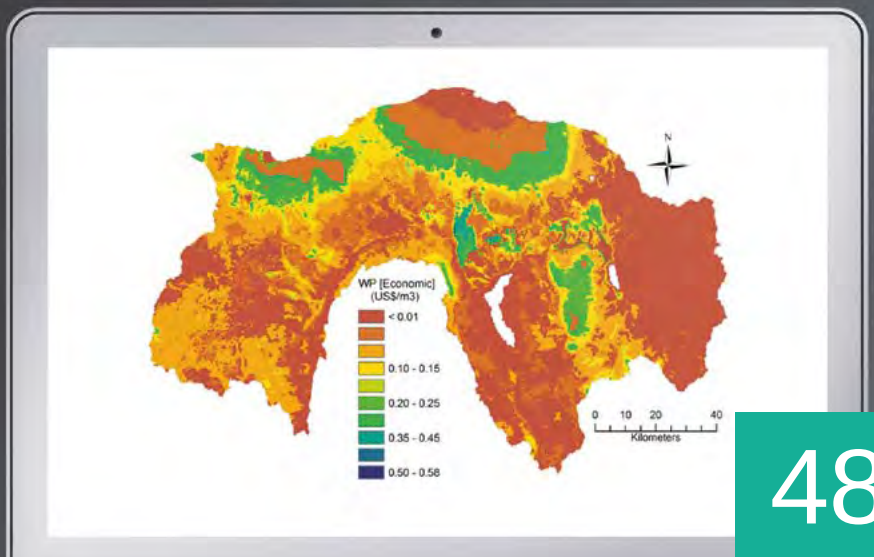
47

Tidal irrigation and drainage

The idea is to utilize high tides for irrigation and low tides for drainage and flushing, instead of using hydraulic structures (e.g. a weir, dam or pumps). This innovative thinking is inspired by Banjarese and Buginese people in Kalimantan and Sumatra, who reclaimed already tidal lowlands by using simple technology.

Optimizing tidal irrigation by using knowledge and technology has resulted in improved agricultural development and supported food security programmes in Indonesia. The country has large lowland areas with an estimated area of about 34 million ha, out of which about 20 million ha is tidal lowland.

Location: Indonesia
Contact: Sur Suryadi (f.suryadi@un-ihe.org)
Partners: Ministry of Public Works Indonesia, Sriwijaya University



48

Water value maps

Based on a detailed land use map, and combining information on the function of each landscape element in a river basin, in economic, social and ecological terms, with information of actual evapotranspiration and biomass production, it is possible to develop water value maps of river basins. The amount of biomass produced is a measure for either the economic value of a commercial crop (if the land use is commercial agriculture), or improved livelihood (if the land use is subsistence farming) or an increase in the value of ecosystem goods and services (if the land use is natural).

The volume of water transpired is a measure of the environmental impact. Information on the origin of the water consumed, either directly from rainfall, or from groundwater or rivers and lakes, adds valuable information on the opportunity cost of the transpired water. Such a map is useful for planning and decision-making in river basins, in particular when coupled with a hydrological model, with which scenarios of human and climate-induced changes can be simulated, and hence changes in economic, social and ecological values produced in a river basin.

Locations: Tanzania, Kenya | **Contact:** Pieter van der Zaag (p.vanderzaag@un-ihe.org)
Partners: Jomo Kenyatta University of Agriculture and Technology (Kenya), European Space Agency (Tiger Bridge project)

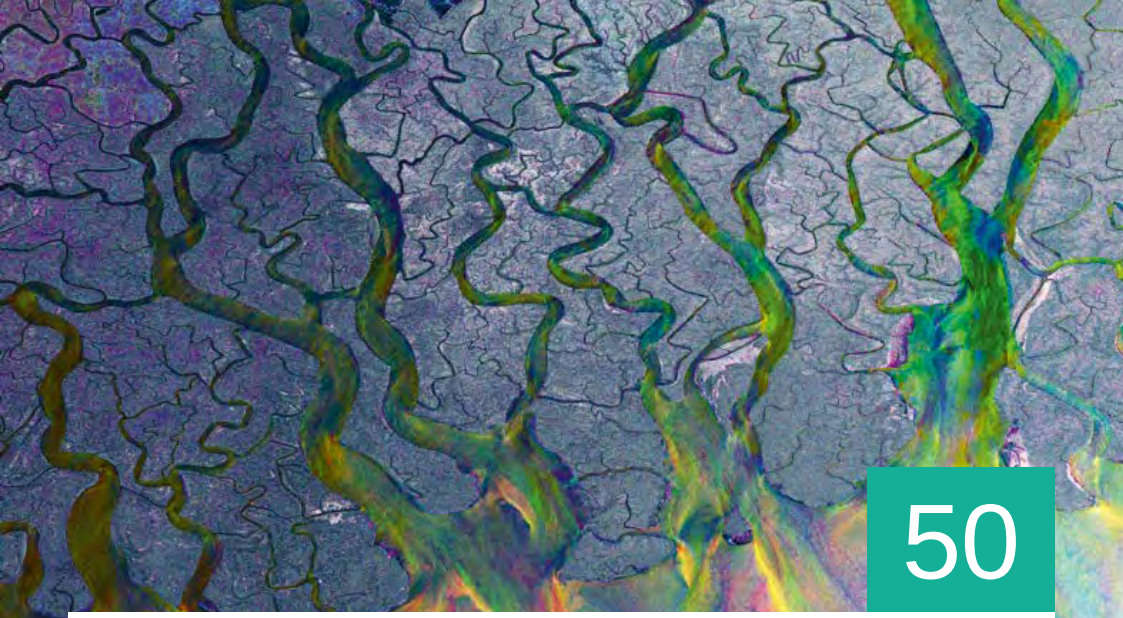
49

eSOS® Smart Toilet

In disaster areas where many people live together in poor conditions, diseases are lurking. Sanitation plays an important role – a hole in the ground or overflowing emergency toilets are breeding grounds for bacteria and viruses. If the flow of waste is better managed, the risk will be reduced and the quality of life will improve considerably. To address this issue IHE Delft and partners have envisioned an award-winning eSOS Smart Toilet, one that is not only hygienic, safe and affordable, but also serves as a source of information about the situation in the area where it is located.

The experimental version of eSOS toilet was successfully tested in the Philippines for functionality and acceptance. This lightweight, easy-to-maintain toilet is equipped with sensors that collect the relevant data using specially designed monitoring software. Based on this information, the operation and maintenance of toilets can be significantly improved making the entire sanitation chain more sustainable. A prototype of the eSOS Smart Toilet is currently being developed and will be tested in Nairobi, Kenya.

Locations: The Netherlands, Philippines, Kenya
Contact: Damir Brdjanovic (d.brdjanovic@un-ihe.org)
Partners: FLEX Design (The Netherlands), SYSTECH.ba (Bosnia and Herzegovina), Sanergy (Kenya)



50

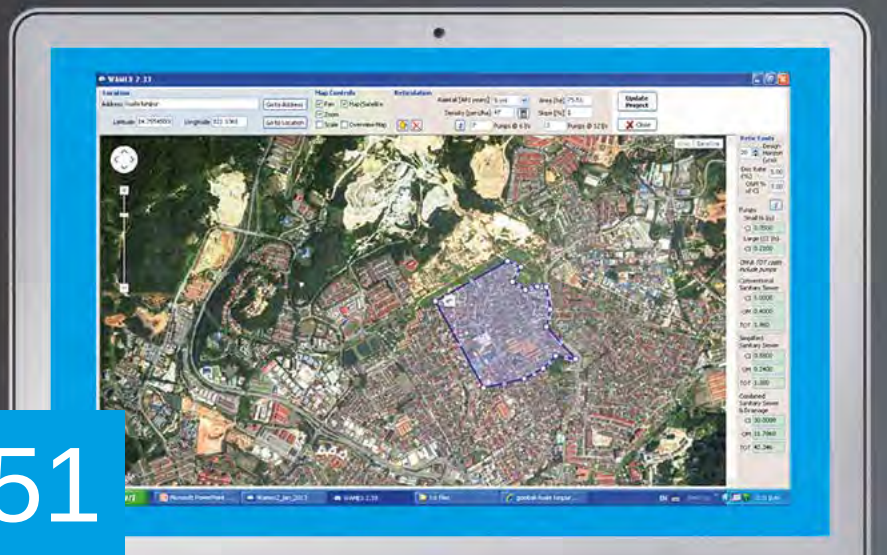
Predicting the shape of future deltas

In countries like Bangladesh, future changes in land use, sea level rise and upstream changes in the flows of water and sediment will have a serious impact on the development of rivers, estuaries and coasts. The management of embankments and other flood protection measures and the development of chars (polders) may greatly affect erosion and sedimentation patterns and extreme flood levels throughout the delta. To prepare for this, planners urgently need a tool to predict natural developments and the effects of the measures, at the scale of the whole delta system, yet sufficiently detailed to allow an evaluation of local works (e.g. cross dams).

In collaboration with local partners, IHE Delft has developed a methodology to simulate such long-term morphological developments using Delft3D software. Though much further validation and refinement is needed, the pilot application has provided a proof-of-concept for predicting the future shape of deltas.

Recent applications include the San Francisco Bay and delta and the Lagune d'Ébrié near Grand Bassam in Ivory Coast, the Coastal Embankment Improvement Programme in Bangladesh and the coastal evolution near St Louis, Senegal.

Location: Bangladesh
Contact: Dano Roelvink (d.roelvink@un-ihe.org)
Partner: Institute for Water Modelling (IWM)



51

Wamex

The Asian Development Bank (ADB), together with IHE Delft, has developed WAMEX as a novel and intuitive tool that aims to help decision makers and planners develop options for addressing various scenarios related to wastewater and sanitation management. This tool is useful for the planning of new systems, upgrading of existing systems and preparing budgets and cost estimates. It also allows users to build their own ‘what-if’ scenarios, enabling them to explore many different wastewater schemes and sanitation options.

The software tool contains a series of conventional and emerging technologies consistent with the ADB’s thrust of promoting innovations in sewage collection, wastewater treatment and sanitation. It also has an intuitive built-in GIS functionality that enables users to set up and assess different wastewater reticulation options and find their optimal solutions.

Location: Worldwide
Contact: Zoran Vojinovic (z.vojinovic@un-ihe.org)
Partner: ADB

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Predicting the coastal killer waves

Most people realize that storms can generate surges and big waves, and that these may inundate low-lying coasts. Existing forecasting systems duly predict such effects, and safety assessments of coastal defences take them into account. What is far less well known is that groups or sets of waves create much longer waves, with long periods of up to several minutes that do the real damage. On coasts such as those of West-Africa, sudden swell events can cause widespread inundation and erosion because of this phenomenon: during Typhoon Haiyan in the Philippines, entire villages, that would have been considered safe according to conventional forecasting systems, were wiped out. The good news is that such 'surfbeat' waves as well as their impacts on various types of coasts can be reliably predicted by the open-source XBeach model, developed by IHE Delft in partnership with Deltares, TU Delft and other partners. Connections have been made to link this model with existing forecasting systems, e.g. in the EU project RISCKIT. As it is increasingly possible to see storms and swell systems coming, this means that much better warnings can be given to vulnerable populations.

Nowadays XBeach has become a de facto standard for coastal storm impact prediction, with developers, users and beneficiaries from all over the world.

Location: South Pacific
Contact: Dano Roelvink (d.roelvink@un-ihe.org)
Partner: Secretariat of the Pacific Community

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Agent-based models of sociotechnical systems

IHE Delft and TU Delft have been developing Agent-Based Models (ABM) of sociotechnical systems for the purpose of understanding how different institutional policies can influence the creation and propagation of vulnerabilities in urban areas. Such models provide invaluable means for understanding the behaviour of actors in order to develop adaptive risk management strategies and policies.

An agent can be an actor in a social/institutional network (e.g. a human being, an operator deciding to shut down a pumping station, or a community member who lives in a flood-prone area). It may also represent an institution, for example a water utility company which wants to implement flood prevention measures or a government deciding on a new land development policy (or a design standard) for flood protection. The focus of these innovative models is on interacting agents and how their interaction can lead to creation and propagation of vulnerabilities and risk. The idea behind ABM is to emulate, rather than to calculate, (optimal) states of the system and to explore the possible development paths (i.e. possible states of the system or possible futures). This in turn is then used to evaluate which development paths are acceptable for new policy formulation. The model developed has been evaluated in European and International case studies.

Location: St. Maarten
Contact: Zoran Vojinovic (z.vojinovic@un-ihe.org)
Partner: TU Delft

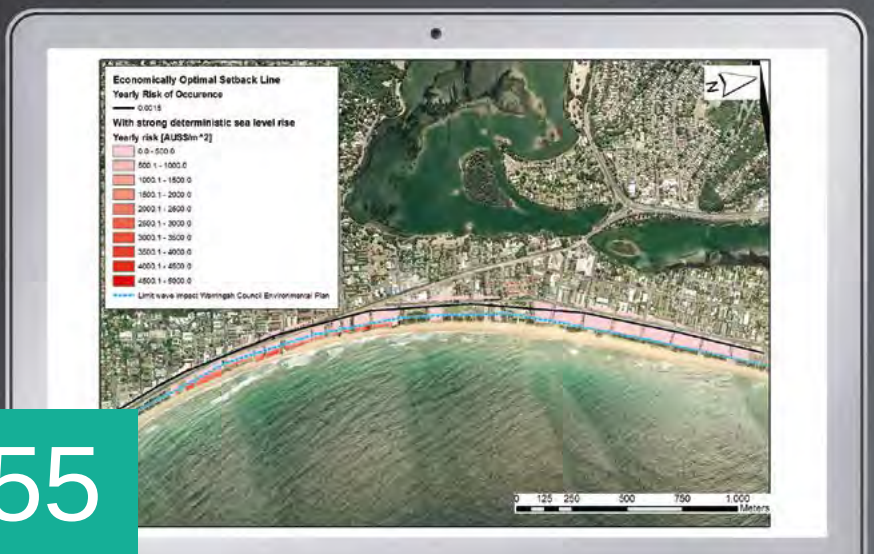
54

Turbo MBR

The Turbo MBR (membrane bio-reactor) combines high rate biological treatment with ultrafiltration membranes for treating wastewater. This produces an effluent of superior quality, suitable for reuse in decentralized settings, dramatically reducing the plant's footprint. The system operates at elevated biomass content which allows a reduction in the required unit volume, supported by highly efficient aeration devices (SDOX and Spece Cone).

The Turbo MBR is currently being tested in the Netherlands and shows a high performance at extreme loading rates. It can load up to three times faster than conventional systems.

Location: The Netherlands
Contact: Hector Garcia (h.garcia@un-ihe.org)
Partners: OVIVO, Blue in Green, ECO2, JCI Industries



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Drawing the line on coastline recession risk

Climate change and the growth of coastal communities will significantly increase the socioeconomic risks associated with coastline recession (i.e. long-term net landward movement of the coastline). Coastal setback lines are a commonly adopted management/planning tool to mitigate these risks. While it is widely recognized that planning decisions should be risk-informed, setback lines are presently determined using deterministic methods that cannot be related to considerations regarding the tolerability of risks. IHE Delft, in partnership with international and Dutch researchers, has recently developed a risk assessment approach for quantifying the risk posed by coastline recession and showing how it can be used to derive economically optimal setback lines. The approach has been demonstrated at Narrabeen Beach, Sydney, Australia and indicates that the presently adopted deterministic methods of defining setback lines may lead to economically sub-optimal stringent land-use planning decisions.

This model is now being applied in a commercial project in Sri Lanka to determine economically optimal setback lines for spatial planning by the Sri Lanka coast conservation department along the east coast of Sri Lanka. Possible applications in Japan and Thailand are under development.

Locations: Australia, Sri Lanka | **Contact:** Roshanka Ranasinghe (r.ranasinghe@un-ihe.org)
Partners: Jogejan Risk Management Consultants, Delft University of Technology, University of Queensland

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Centralized arsenic removal IHE-Adart

Arsenic is a human carcinogen, and its presence in drinking water increases cancer mortality risk and causes liver failure, as well as cardiovascular, neurological and several other diseases. Thousands of both small and large water supply systems that make use of arsenic-contaminated groundwater cannot provide their population with arsenic-free water due to poor efficiency or high costs of available arsenic removal techniques.

The IHE-Adart arsenic removal technology is based on arsenic adsorption on low cost adsorbent, a by-product from the drinking water industry, and is a patented *in situ* regeneration procedure. IHE-Adart has demonstrated the potential to produce arsenic-free drinking water from groundwater with very high arsenic concentration, while the generation of waste streams is heavily reduced in comparison with other arsenic removal technologies. The filter is simple to operate, does not require electricity and can be produced locally. The IHE-Adart process is robust, simple to operate and affordable for developing countries. Two full-scale plants based on IHE-Adart have been successfully operating for several years in Jabir (Jordan), and Backi Vinogradi (Serbia).

Locations: Hungary, Romania, Greece, Jordan, Serbia
Contact: Branislav Petrusevski (b.petrusevski@un-ihe.org)
Partners: Vitens, Water Authority Jordan (WAJ), PUC Subotica

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A novel microorganism for sewage treatment

The application of Thiothrix caldifontis could potentially reduce the footprint of wastewater treatment plants (WWTPs), besides offering the opportunity to recover phosphorus and sulphur from the activated sludge biomass.

Researchers of IHE Delft and TU Delft believe that sulphide present in sewage may be used as an energy source by this microorganism, to remove carbon, nitrogen and phosphorus in a novel sulphur-based metabolism. This discovery may change the negative perception of filamentous bacteria which are considered a nuisance at WWTPs. In combination with bulking-tolerant solid-liquid separation systems, it may also enable the development and application of sulphur cycle-based sewage treatment processes for the efficient removal of nutrients from sulphide-rich (saline and industrial) wastewaters, with reduced sludge production and increased energy recovery.

Location: The Netherlands
Contact: Francisco Javier Rubio Rincon (f.rincon@un-ihe.org)
Partner: TU Delft

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New MSc Programme in Sanitation

IHE Delft and partners have received a grant from the BMGF for establishing and implementing a new MSc Program in Sanitation. It is a new and unique, internationally recognized, fully accredited program designed for completion in 12 months. This elite program with scholarships for top talents at IHE Delft is Delft-based with thesis work abroad, while at the same time the program (or parts of it) will soon be delivered by dozens of partner universities from Asia, Africa and Latin America. State-of-the-art content has been developed and provided by the world's top experts from both academia and practice. This demand-driven and practice-oriented program yields graduates with the fundamental understanding, knowledge and skills necessary for creating an impact. Their generic skill development and preparation of an applied research thesis is embedded from the start under individual coaching and tailor-made guidance. The new programme will be launched on 23 April 2018.

Locations: Delft, worldwide | **Contact:** Mariska Ronteltap (m.ronteltap@un-ihe.org)
Partners: BITS (India), KUET (Bangladesh), 2iE (Burkina Faso), UNIVALLE (Colomb, AIT (Thailand), CEPT (India), TSUAB (Russia), MUJ (India), KU (Nepal), UKZN (South Africa), CDD (India), UoZ (Zambia), EU (Kenya), FUTRASAFODE (Argentina)

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Smart toolbox for engaging citizens in a people-centric observation web

The majority of citizens, both as individuals and as groups, often feel disengaged from influencing environmental policies. They also remain unaware of publicly available information. The SCENT project will alleviate this barrier. It will enable citizens to become the 'eyes' of the policy makers by monitoring land-cover/use changes in their everyday activities.

The SCENT toolbox consists of low-cost and portable data collection tools, an innovative crowd-sourcing platform, serious gaming applications for a large-scale image collection and semantic annotation, a powerful machine-learning-based intelligence engine for image and text classification, an authoring tool for easy customization by policy makers, and numerical models for mapping land-cover changes to the quantifiable impact on flood risk.

Location: Worldwide | **Contact:** Andreja Jonoski (a.jonoski@un-ihe.org) | **Partners:** ICCS Athens, Hellenic Rescue Team Attica, U-Hopper, XTeam software solutions, IBM Research Haifa, Danube Delta National Institute, Romanian Ornithological Society, C.C.I.C.C.

Project co-funded by the EUROPEAN UNION

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Accounting for Nile waters

Water accounting tracks sets of indicators and presents data in a number of standard reporting sheets. Through the Accounting for Nile Waters project, IHE Delft is making water accounting contextually relevant by including social, gender and ecological dimensions. The goal is to understand how new irrigation projects along the Nile in Ethiopia, Sudan and Egypt are re-configuring gendered labour and tenure relations, and what this means for equity and sustainability.

By experimenting with different theories and methodologies of representing river basin development experiences (e.g. remote sensing, storytelling, photo voice), we are bringing into the conversation common and less common perspectives on the rapid transformation of water distribution of the Nile river and the differences between its users, male and female, subsistence and commercial farmers and farm workers. In this way we are opening up debates between policy makers, water professionals, students and others interested in socioeconomic developments in the Nile basin. The Nile Water Lab website visualizes the rearrangements of Nile water flows.

Locations: Ethiopia, Egypt, Sudan | **Contact:** Hermen Smit (h.smit@un-ihe.org)
Partners: IWMI, Forum for Social Studies, University of Khartoum, Research Institute for Sustainable Environment, HRC, ENTRO, NBCBN, Ministry of Agriculture

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- **European Union (EU)**
- **Food and Agriculture Organization of the United Nations (FAO)**
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IHE Delft Institute for Water Education (formerly UNESCO-IHE) is the largest international graduate water education facility in the world and is based in Delft, The Netherlands. The Institute confers fully accredited MSc degrees and PhD degrees in collaboration with partners. Since 1957 the Institute has provided graduate education to more than 15,000 water professionals from over 160 countries, the vast majority from the developing world.

The mission of IHE Delft is to contribute to the education and training of professionals, to expand the knowledge base through research and to build the capacity of sector organizations, knowledge centres and other institutions active in the fields of water, the environment and infrastructure in developing countries and countries in transition.

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