Introduction

The World Water Challenge is an international contest for water solutions. It was created as a special program of the Science and Technology Process in the 7th World Water Forum to identify imminent water problems that the world is facing and to find feasible solutions based on the core value, "Implementation".

The program is aiming at identification of science, technology and policy based solutions to imminent water problems. Attracting great attention in the 1 st edition in 2015 at the 7th World Water Forum, the program has become one of the symbolic platforms of implementation which has been followed up in the Korea International Water Week over the past 3 years, focusing on scientific and technological methods that have contributed to the world's awareness on the importance of the roles of science and technology in solving water challenges.

This year, the World Water Challenge 2019 (WWCH 2019) will also take place as one of the signature programs of the Korea International Water Week (KIWW) 2019 in coming September in Daegu Metropolitan City, Republic of Korea.

This 5th edition of the World Water Challenge is expected to serve its role as an important platform to share not only innovative scientific/ technological methods but also policy towards solving the defined water problems around the world and to forge a broad network among the experts and stakeholders in water sector as well as the diverse pool of problem owners and solution providers.

Objectives

· To share appropriate and innovative ideas and know-hows based on science and technology that are applicable to the real world

· To raise the world's awareness on the water issues as well as the importance of the role of science and technology in solving the water challenges

· To provide a networking opportunity among participants from the water-related corporations and organizations to create a business opportunity and make an inroad into the global market by presenting those innovative solutions

Overview

· **Date & Time:** September 5th, 2019/ 13:00 -18:00

· **Venue:** #320(3F), EXCO, Daegu, Korea

· **Participants:** Participants of final round, water-related organizations and corporations, Medias and other interested persons

· **Host/Organizer:** Ministry of Environment, Rep. of Korea / Korea Water Forum

Program

Time	Contents
13:00 - 13:08	**Opening Address** Jung-moo Lee, President of the Korea Water Forum & **Welcoming Address** Hajoon Park, Assistant Minister, Ministry of Environment, Rep. of Korea
13:08 - 13:15	Introduction of the final competition criteria
	Main Topic 4: Smart Water Technologies
	Challenge: 'Smart' solutions for water management: definition and case of 'smart solutions' by region, sector, and target
13:15 - 13:30	Solution AgriHydro A Smart Technology to Better Irrigation Management in IWRM platform Dr. Hossein Dehghanisanij, Associate Professor, Agricultural Engineering Research Institute (AERI), Agricultural Research, Education and Extension Organization (AREEO), IRAN
	Main Topic 1: Efficient Water Management
	Challenge: Integrated management of diversified water resources
13:30 - 13:45	Solution Sponge – An innovation in irrigation for sustainable farming Mr. Sanjay Prasad, Project Leader, IVL-The Swedish Environmental Research institute, INDIA
	Challenge: Innovating financing for local water solutions
13:45 - 14:00	Solution A water kiosk at school Mr. Venuste Kubwimana, Secretary General, International Transformation Foundation, RWANDA
14:00 - 14:15	Q&A and Discussion
	Main Topic 2: Resource Recovery from Water and Wastewater System
	Challenge: Energy Efficiency in sewage, wastewater, and sea water recycling and reuse
14:15 - 14:30	Solution Novel Fertilizer Production from Human Urine in Membrane Distillation Process Ms. Ruth Habte Hailemariam, PhD candidate, University of Science and Technology (KICT School), ETHIOPIA
	Challenge: NEXUS for efficient utilization of limited water resources and energy recovery
14:30 - 14:45	Solution Improving Water Security through Water-Energy Nexus Approach in Danang city of Vietnam Dr. Pham Ngoc Bao, Senior Water and Sanitation Specialist, Institute for Global Environmental Strategies (IGES), Japan, VIETNAM

Program

14:45 - 15:00	Solution Solar Dew – Solar Water purification and desalination for households and communities Mr. Alexander François Marie van der Kleij, Head, SolarDew, THE NETHERLANDS
15:00 - 15:15	Q&A and Discussion
15:15 - 15:30	Coffee Break
Main Topic 3: Water and Natural Disasters	
Challenge: Urban flood prevention and management for sustainable water cycle and urban regeneration	
15:30 - 15:45	Solution Exploiting the synergies between sustainable urban drainage systems(SUDS) and urban farming in Vinh Yen City, Vietnam Ms. Bui Thi Hong Hieu, Researcher, Ministry of Construction (MOC) - Vietnam Institute for Urban and Rural Planning (VIUP), VIETNAM Mr. Hoang Anh Duc, Project Engineer, Ministry of Construction (MOC) - Vietnam Institute for Urban and Rural Planning (VIUP), VIETNAM
Challenge: The depletion and pollution of water caused by climate change	
15:45 - 16:00	Solution Rejuvenation of Lake Mahadevapura using Nature Based Systems Mrs. Rohini Pradeep, Project Manager, CDD Society, INDIA
16:00 - 16:15	Q&A and Discussion
Main Topic 1: Efficient Water Management	
Challenge: Integrated management of diversified water resources	
16:15 - 16:30	Solution Smart Technology for Integrated Management of Diversified Water Resources Ms. Wala'a Mhammad Khalaf Bani-Mostafa, Researcher, Water Authority of Jordan, JORDAN Dr. KukHeon Han, Researcher, Sungkyunkwan university, REPUBLIC OF KOREA
16:30 - 16:45	Q&A and Discussion
16:45 - 17:00	Coffee Break
17:00 - 17:10	**Closing Address** Chairman of Evaluation Committee
17:10 - 17:20	Group Photo
17:20 - 17:30	Closing

Contents

Selected Solutions for Final Round

No.	Solution Title
	Main Topic 1: Efficient Water Management
	Challenge: Integrated management of diversified water resources
1	Smart Technology for Integrated Management of Diversified Water Resources Ms. Wala'a Mhammad Khalaf Bani-Mostafa, Researcher, Water Authority of Jordan, JORDAN Dr. KukHeon Han, Researcher, Sungkyunkwan university, REPUBLIC OF KOREA
2	Sponge – An innovation in irrigation for sustainable farming Mr. Sanjay Prasad, Project Leader, IVL-The Swedish Environmental Research institute, INDIA
	Challenge: **Innovating financing for local water solutions**
3	A water kiosk at school Mr. Venuste Kubwimana, Secretary General, International Transformation Foundation, RWANDA
	Main Topic 2: Resource Recovery from Water and Wastewater System
	Challenge: Energy Efficiency in sewage, wastewater, and sea water recycling and reuse
4	Novel Fertilizer Production from Human Urine in Membrane Distillation Process Ms. Ruth Habte Hailemariam, PhD candidate, University of Science and Technology (KICT School), ETHIOPIA
	Challenge: NEXUS for efficient utilization of limited water resources and energy recovery
5	Improving Water Security through Water-Energy Nexus Approach in Danang city of Vietnam Dr. Pham Ngoc Bao, Senior Water and Sanitation Specialist, Institute for Global Environmental Strategies (IGES), Japan, VIETNAM
6	Solar Dew – Solar Water purification and desalination for households and communities Mr. Alexander François Marie van der Kleij, Head, SolarDew, THE NETHERLANDS
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7	Exploiting the synergies between sustainable urban drainage systems(SUDS) and urban farming in Vinh Yen City, Vietnam Ms. Bui Thi Hong Hieu, Researcher, Ministry of Construction (MOC) - Vietnam Institute for Urban and Rural Planning (VIUP), VIETNAM Mr. Hoang Anh Duc, Project Engineer, Ministry of Construction (MOC) - Vietnam Institute for Urban and Rural Planning (VIUP), VIETNAM
	Challenge: The depletion and pollution of water caused by climate change
8	Rejuvenation of Lake Mahadevapura using Nature Based Systems Mrs. Rohini Pradeep, Project Manager, CDD Society, INDIA
	Main Topic 4: Smart Water Technologies
	Challenge: 'Smart' solutions for water management: definition and case of 'smart solutions' by region, sector, and target
9	AgriHydro A Smart Technology to Better Irrigation Management in IWRM platform Dr. Hossein Dehghanisanij, Associate Professor, Agricultural Engineering Research Institute (AERI), Agricultural Research, Education and Extension Organization (AREEO), IRAN

World Water Challenge Topics

Topic 1 : Efficient Water Management (SDGs links : SDG 6.4 Water Use Efficiency)

- Urban water efficiency
- Agricultural water efficiency
- Industrial water efficiency
- Energy efficiency in water and waste water systems

Keywords : sustainable water resources management, water resources security, water production improvement technology, water supply management, water and industry, water-energy-food nexus, water resources development, trans-boundary water resources management, dam and river system operation

Topic 2 : Resource Recovery from Water and Wastewater Systems (SDGs links : 6.1 Safe Water, 6.2 Sanitation)

- Water recycling and reuse technologies
- Energy production from water and waste water cycles
- Nutrient recovery from waste water

Keywords : water and wastewater treatment technology, safe and clean technology for drinking water, sanitation and health science, sea water desalination, water-energy production technology, renewable energy, total water pollution load management, river quality management, hydropower technology

Topic 3 : Water and Natural Disasters (SDGs links : 11.5 Reduction of Economic & Human Losses)

- Climate change assessment and adaptation
- Drought analysis and management
- Urban floods and damage reduction
- Remote sensing and GIS applications to natural hazards

Keywords : climate change scenarios and prediction, drought analysis and management, water resources risk scenarios, risk assessment and adaptation, water and disasters, water related composite hazards, coastal disaster and tsunami, urban floods and resilience

Topic 4 : Smart Water Technologies (SDGs links : 6.5 IWRM)

- Management of urban, industry, and irrigation water
- Implementation of integrated water resources management
- Design and implementation of smart water grid
- Information and communication technologies for water management

Keywords : water and creative economy, smart water management, smart disaster management system, smart agricultural water management, standardized smart water grid technology, water management information systems, RS and GIS applications for securing water resources, best management practices of IWRM, advanced water governance through multi-directional information system.

Topic 5 : Ecosystem and Water (SDGs links : 6.6 Water & Ecosystems)

- Science and technology for green infrastructure management
- Economic valuation on ecosystem and water
- Effects of ecosystem on water quality

Keywords : water and environment, water and green growth, vulnerability analysis for water environments, marine ecology and sea level rise, wetland conservation and restoration, green infrastructure.

Evaluation Criteria for Final Round

Evaluation Items	Detailed Contents of Evaluation	Score
Comprehension	- If the solution provider exactly understands the problem including background, objectives, scope, cause and effect, and impact on the global water issues.	20
Contribution to "Sustainability"	- If the solution provider clearly understands the meaning of sustainability. - If the solution sufficiently demonstrates the contribution to achieving the sustainability in development. - If the solution provider considers possible alternatives in achieving sustainability in the solution.	25
Feasibility	- If the solution sufficiently satisfies the requirement of the problem owner with a feasible manner, such as economic, technical, legal, and political feasibility in its implementation. - If the solution is suitable for the implementation and easy for approaching its circumstance. - If science and technologies applied to the solution are practically applicable to the field. - If the local resources are efficiently used in the solution. - If the solution is designed to have a lasting impact on the problem.	25
Challenge	- If the solution effectively helps overcome any challenges and achieve the goals of water issues. - If the solution provider proposes innovative methods in solving the problem.	15
Impact	- If the solution provider well describes the expected effects of the solution on the lives of plants, animals, and human beings. - If the effects of activities in solving the water problems are obviously described.	15

World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 4

Smart Water Technologies

Challenge

'Smart' solutions for water management: definition and case of 'smart solutions' by region, sector, and target

Solution

AgriHydro A Smart Technology to Better Irrigation Management in IWRM platform

Dr. Hossein Dehghanisanij
Associate Professor, Agricultural Engineering Research Institute (AERI), Agricultural Research, Education and Extension Organization (AREEO), IRAN

Solution

AgriHydro a Smart Technology to Better Irrigation Management in IWRM platform

Hossein Dehghanisanij

Summary

Many different sectors are dependent on water, and as a result, where water resources are limited, conflicts over use arise. The commonly fragmented management of water resources is particularly inept at solving such conflicts and ensuring sustainable use of the resource. Further, most of the world's freshwater resources are used in the agricultural sector.

According to the Food and Agriculture Organization (FAO) the world's population is set to grow from 6 to 9.1 billion by 2050; a situation that will require food production to rise by 70% in the developed world and double in developing nations. Here in water is one of the most important issues, due to ever-increased demand and limited supply where agriculture is the main water user. Under such situation, implementing IWRM supports the equitable, efficient, and sustainable consumption of water, which is vital to balancing the social, economic and environmental dimensions. It is while less technology (supply and demand) applied to agricultural water consumption which causes less efficiency accordingly.

The small and medium-scale farmers (SSF) has a key role in water consumption and food production in many regions in the world. However, the studies show that in these regions the water use efficiency is low and water loss is high mainly due to the lake of knowledge and technology. Our experience showed that the technologies have not developed for these farms as much as for big farms. Accordingly, there is a lack of data to integrate the agricultural farms to the basin water resources management and water allocation is mostly based on long term data and information rather than real-time and updated data.

Our case studies showed that the development of user-friendly technologies on agricultural water management could spread quickly within the farmers' societies and help them to save water and energy consumption while improving their resilience and job sustainability. At the same time, those data could transfer to the cloud where other stockholders are involved and could have an impact on each other based on IWRM platform.

The smart water management (SWM) in agriculture involves the use of highly interconnected sensors and information in the measurement of farm variables. This kind of precise data allows farmers to make informed decisions regarding irrigation and may other on-farm activities. Given that there are approximately 500 million small and medium-scale farmers (SSF) around the world where women are significantly are involved, enabling them to take up smart irrigation management technology could be useful to ensure the food demands and fewer resources consumption. Owing to this, the idea of AgriHydro as a simple smart technology to better agriculture irrigation management and optimum water allocation at the field scale for SSF could introduce SWM under IWMI platform to connect farms' information to irrigation network or basin in up-stream. It needs to be noted that the application of the Internet of Things would be the main tools for our goal.

The objective of this idea (AgriHydro) is to contribute in introducing SWM that adequately meets the needs of small and medium-scale entrepreneurial farmers to very most proper water consumption based on crop demand, increase agricultural water productivity, and increase income and food security to have secured water access for agriculture production, and become more resilient to climate change.

Solution Description

Introduction to raising the challenge and sustainability

The Urmia Lake Basin with an area of 51.8 km2 with several vast productive plains in the valleys and around the Lake located at altitudes above 1280 m and up to 4886 m above mean sea level. Irrigated agriculture and horticulture for long have been the main occupation in the area. Rain-fed cultivation of cereals and to a lesser extent peas are also a common practice in all parts of the basin.
The water volume in the body of Urmia Lake has depleted about 30 billion cubic meters during 1995- 2015. The decline in lake water levels over recent years has led to the environmental and livelihood challenges and raised public sensitization along with the country.
The mean annual water level is currently more than four meters below the critical level (1274 m above sea level) needed to sustain ecosystems. In October 2015, it reached to the lowest level and southern parts of the lake totally dried. A wide range of users continue to extract water from the basin that feeds the lake and precipitation decreases by 18 percent in Urmia Lake Basin (ULB) compare to its long-term record. Besides, evaporation loss rate and regional demand on the water of different sectors, especially agriculture have increased.
The lake has faced extreme water loss in recent years due to overuse and mismanagement. The most important factor in creating this problem is the reduction of water inflows to the lake, which contributed to the equilibrium situation between evaporation and feeding the lake. The situation has been exacerbated by continuous droughts, resulting in a reduction of renewable water resources and the lake's water levels at an alarming rate.
Even though the climatic change has had an unpredictable impact on the current conditions of Urmia Lake, but the most important factor in lake dryness is related to unbalanced and unsustainable development in the basin, and over-extraction of water resources especially in the last two decades. Over the last thirty years, the population in the lake basin has been doubled and the agricultural area fed by water resources of the lake basin has tripled. About 90% of freshwater consumption in the Urmia Lake basin is related to the agricultural sector. Experts have recognized this amount of consumption in the Urmia basin as a major reason for the negative balance in the basin. Irrigated agriculture increased from 150 thousand hectares in 1979 to more than 400 thousand hectares in 2006.
The American Society of Agronomy (1989) presented a definition of sustainable agriculture as an activity in addition to providing sufficient human food and improving the quality of life of farmers and the community, improves the quality of the environment and natural resources. According to water resources restriction especially in the groundwater resources, agricultural sustainability in the region and as a result the inhabitant's livelihoods will be threatened with the continuation of this trend in Urmia Lake basin.
The studies showed that future water management plans are not robust under climate change in this region. Therefore, an integrated approach of future land-water use planning and climate change adaptation is therefore needed to improve future water security in the basin. The IWRM is the platform which could support the idea of sustainability in the region. Since the agricultural sector is the main water user in the basin, any integrated activity must be based on less beneficial and non-beneficial water consumption in agriculture (Fig. 1).

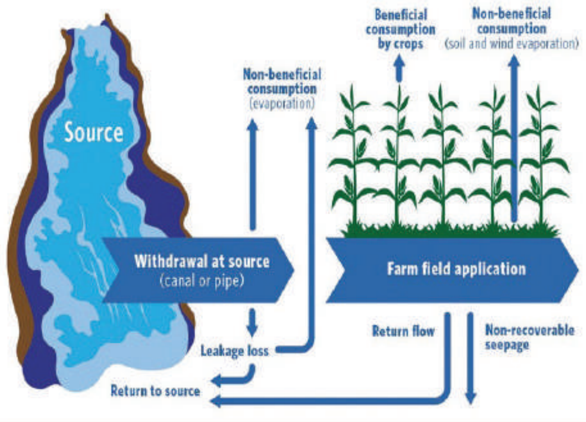


Fig 1. Beneficial and non-beneficial water consumption in agriculture.

The question is; what is the best-integrated approaches to less beneficial and non-beneficial water consumption in agriculture in a sustainable way? Irrigation management is the most important factor affecting on beneficial and non-beneficial water consumption in agriculture and here in SWM is the best technique to control it. Our data shows that most for the farmers apply irrigation water rather than actual irrigation water needed (more non-beneficial) especially in early growth stages (April and May) and they do deficit irrigation (deficit beneficial) in mid-season (June and July) when it has significant impact on crop yield (Fig. 2).

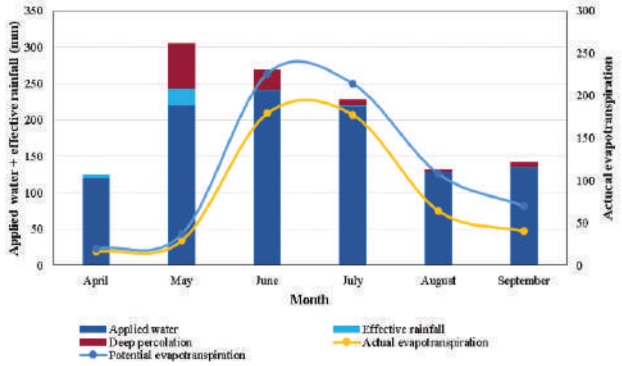


Fig. 2. Variation of applied irrigation water and actual crop water requirement in the Urmia basin for a summer crop.

Solution and feasibility:

The smart water management (SWM) in agriculture involves the use of highly interconnected sensors and information in the measurement of farm variables. This kind of precise data allows farmers to make informed decisions regarding irrigation and may other on-farm activities. Given that there are approximately 500 million small and medium-scale farmers (SSF) around the world where women are significantly are involved, enabling them to take up smart irrigation management technology could be useful to ensure the food demands and fewer resources consumption. Owing to this, the idea of AgriHydro as a simple smart technology to better agriculture irrigation management and optimum water allocation at the field scale for SSF could introduce SWM under IWMI platform to connect farms' information to irrigation network or basin in up-stream. It needs to be noted that the application of the Internet of Things would be the main tools for our goal.

Throughout the world, local irrigation agencies can be found that insist on the existing methods of irrigation distribution cannot be changed, they have been adapted for local conditions. One is told that significant change cannot be accomplished because farmers don't listen to the irrigation department. People steal water and vandalize the systems. There is little or no budget. There are too much area and too little water. Different things have been tried but only worked for a while before failing. Therefore the best approach is the "structured" approach or some other physical/social system that at least puts water out into a project. Farmers have learned to adapt, one is told, and they do their own form of linear programming optimizations of cropping patterns to minimize their risk. All of the statement above can be true but the current mode is unacceptable from a sustainability point of view. Things need to change and all of this has been considered to develop a technology user-friendly by farmers.

The idea of AgriHydro is an IWRM platform to provide the optimum water allocation at the farm scale by considering the water right. Fast, reliable, modular and scalable, empowers farmers to plan and manage the water resource in order to crop production and more optimize-able to achieve less beneficial and non-beneficial water consumption by combining the latest information of irrigation method and IoT technology, innovative scheduling and network visualization tools, advanced irrigation engineering, and an industry-standard database.

It is designed specifically for irrigation districts. The system knows about water demand such as crop's response to water factor and rotations, about delivery operations and financial analysis and about customers, and invoices. When this information is integrated AgriHydro can;

- Plans optimum crop pattern, makes smarter decisions and fewer mistakes
- Reports using meaningful performance indicators such as overall system efficiency
- Calculate volumetric accumulation and determine farmer satisfaction
- Provide the best crop pattern whiteout non-interference in water allocation. So that leads to the maximum financial return.
- Provides irrigation scheduling due to daily changes in the weather and the principles of regulated irrigation. Then allocates the water to crop pattern optimally.

Before the start of the growing season, the optimal crop pattern is pointed out to a farmer. Irrigation scheduling is improved via soil moisture monitoring and automatic meteorology station that is established in the field by WMO standard. Optimum real-time dynamic irrigation also demands robust, reliable 24 x 7 operation, with alarm escalation and notification by phone and text message or internet. Having 24 hours of Interactive Voice Response (IVR) and web access helps farmers in their interaction with the district when and where they need it.

Infield tools like mobile internet to manage water deliveries and smartphone apps for meter reading are also essential for efficient management. Hundreds of devices providing real-time information covering hundreds of customers' farms can add up to a data explosion that your system needs to handle. AgriHydro turns that data into for future planning.

Wireless internet of things (IoT) enables farmers to improve safeguards, reduce costs and enhance control of the network with real-time remote management of meteorology station and other equipment. A comprehensive suite of remote device monitoring tools and sophisticated alarms can transform farm operation by giving the detailed real-time performance information they need to rapidly respond to issues before they become problems and without having to travel to the site.

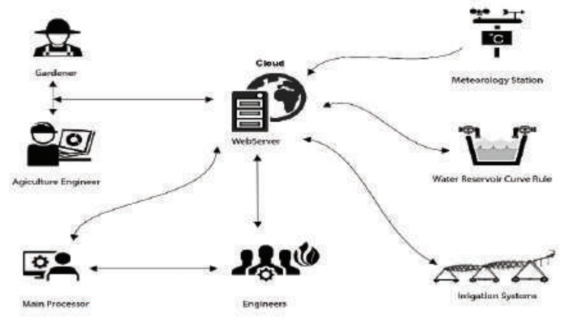


Fig. 3. IWMI platform for smart water management.

Field Embodiment

The field embodiment function pack provides a visual, schematic representation of the entire irrigation of field so that operators have an intuitive 360o, high and low-level feel of total field behavior. The innovative real-time dynamic analysis provides a visual summary of actual demand and flows at any point in the network, and future demand when used in conjunction with the Automatic Delivery function pack. Farmers can quickly navigate to any part of the field and drill down to individual parts for more details. The simple configuration lets you add and remove infrastructure "on the fly".

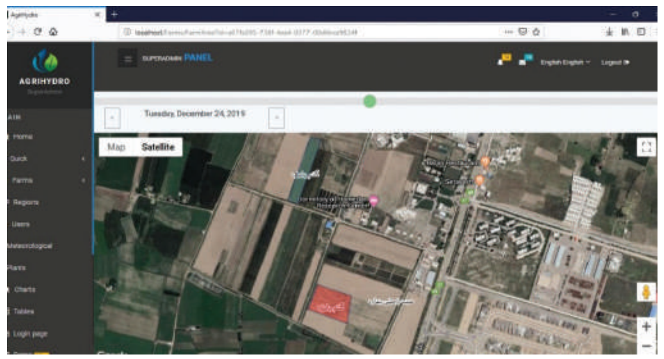


Fig. 4. Field Embodiment by farmers

Impact assessment:

The idea was applied to different farms incorporation with the farmers (Fig. 5). The farms were selected in a selected sub-basins with less beneficial and more non-beneficial water consumption. Those specifications were estimated using Rapid Water Accounting assessment (RWA+) methodology (Fig. 6). The cultivated crops in the selected farms were grape, sugar beet, and tomato.

Fig. 5. Farm selection in cooperation with farmers and setup soil moisture and weather information sensors in a grape farm.

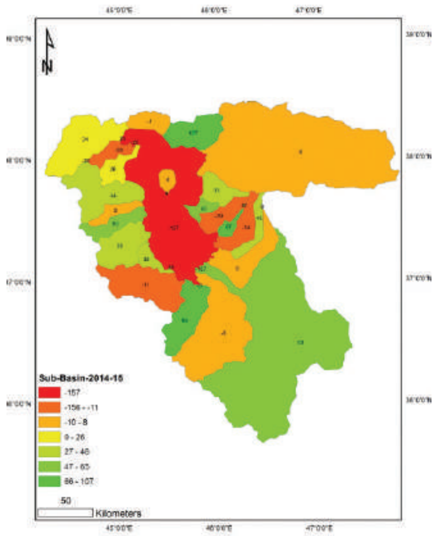


Fig. 6. The sub-basin in the Urmia basin with less beneficial and more non-beneficial water consumption recorded.

The results of irrigation management in a selected grape farm is presented in Fig. 7. As results, the number of irrigation event increased in treatment farm where irrigation has been announced by AgriHydro, but the total applied water was significantly less. Total water applied to the treatment farm until 09.07.2019 was 757 m3 per hectare while it was 1433 m3 per hectare in control where the farmers applied based on his experience. Accordingly, water consumption decreased by about 47% while allocated water meets the demand more accurately. By increasing applied water we may expect less water productivity, less income due to the increased water and energy cost and also labor. More water application has a negative environmental impact in the basin. It is estimated 200,000 Tons of fertilizer and 4,000 Tons of pesticides and herbicides are applied annually in the region. By more water application, residues of these chemicals when transferred to the water resources seriously impact their quality and ecological attributes. The results also indicated the improvement of agricultural yield and water productivity. Sugar beet water productivity increased 25% mainly due to the better water allocation based on crop development. After successful results from the on-farm evaluation of AgriHydro, we are going to move for water allocation based on crop demand in Mahabad irrigation network with 13000 ha in the south of the basin (Fig. 8).

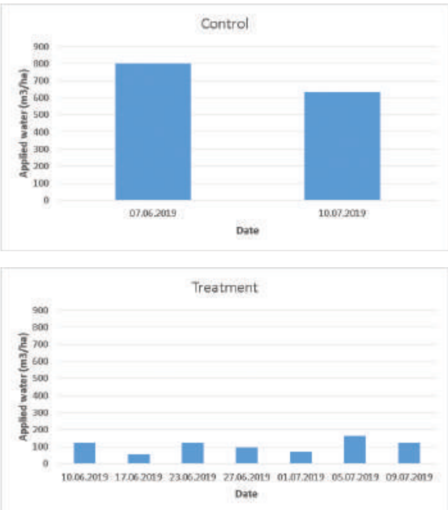


Fig. 7. Irrigation date and amount of applied water under grape control farm and treatment (AgriHydro).

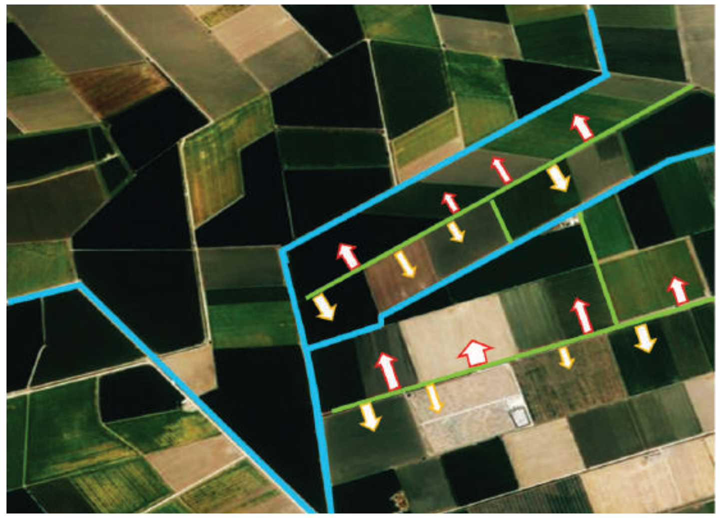


Fig. 7. Mahabd irrigation network in south of Urmia Basin.

References:

Dehghanisanij H. 2019. Development and application of moisture sensor and application model for reduction of water flow into the farms for support restoration of Urmia Lake. AREEO. Iran. 55pp. Research Report in Farsi.

Abolpour B. and Dehghanisanij H. 2019. A coequality approach to schedule the frequency and duration of crop irrigation based on a fuzzy inference system. Under review.

World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 1

Efficient Water Management

Challenge

Integrated management of diversified water resources

Solution

Sponge – An innovation in irrigation for sustainable farming

Mr. Sanjay Prasad
Project Leader, IVL-The Swedish Environmental Research institute, INDIA

Solution

SPONGE- An innovation in irrigation for sustainable farming

Sanjay Prasad

Summary

In the eastern Himalayan Range, issues such as sandy/stony soil with poor water capturing capacity, intermittent/seasonal access to water, and both labor- and cost- intensive processes hamper food production and traditionally exclude women and poor groups from the local economy. The need for mitigation is underlined in the Nepal National Water plan, Bhutan Water Policy and by the West Bengal Government Agricultural Plan. The current situation is further perpetuated when climate change impacts are considered. The current water management practice is under considerable stress and requires solutions with a great up-scaling potential. SPONGE can be quickly distributed and installed.

SPONGE is an innovative irrigation technology designed to involve women and strengthen marginalized groups.

- A techno-biological system — that greatly improves water utilization and supply. Using water from fog and dew, SPONGE increases reliability in a region with abundant but highly intermittent water availability, improving soil moisture content — while reducing technical maintenance and operation of machinery.
- Soil moisture content is increased and kept at optimal levels through a cascading system of buried SPONGEs (coco pith /cotton units), supplied with water from fog and dew harvesting is applied in gauged volumes and recycled, minimizing water loss up to 50%.
- It is an easy-to-install-operate, robust water-storing/soil-moisturizing system that enables cultivation on marginal lands and provides better opportunities for poor communities and involvement of women headed households.

SPONGE is environmentally friendly and sustainable alternative to current farming

- Decreasing dependency of ground and surface water (harvesting fog and dew);
- Promoting bio-fertilizer;
- Preferring designated supplementary crop choice over pesticides;
- Using inert and/or organic materials (foam and cotton); and
- Reducing machinery operations adopting more women farmer entrepreneurs.

Results from the pilot study demonstrate significant conclusions:

- 50% reduction of water consumption
- Successful harvesting of water from fog and dew collection systems due to the relatively high humidity and reduced ground surface temperatures that are typical of the pilot area.
- 50% reduction of fertilizer costs associated with decreased run-off loss and use of bio-fertilizers like vermi-compost, cow dung, etc.
- Production of crop yields increased by 10%, which were attributed to improved availability of water resulting in increased soil moisture maintained at optimal levels through a cascading system of buried sponges.
- Water was applied in gauged volumes and recycled, which minimized water loss.
- The planting of specific plant varieties, like Neem (Azadirachta Indicia)Tulsi (osmium tenuiflorum) and turmeric (curcuma long)a, were incorporated to control bacteria/fungus in combination with bio-fertilizers, thus forming a techno-biological system.

While analyzing **the Game Changing** fact of this Sponge innovation, it is quite clear that in traditional agricultural practice the lack of water is tackled by large-scale distribution networks from downhill rivers very costly, vulnerable to earthquakes, inflexible and where as low efficiency is tackled by drip irrigation with Costly machine installation and high maintenance.

On the other hand Sponge offers:

- Improved and stable water/crop-exchange
- Reduced ground and rain water dependency
- Low capital investment combined with reduced water and fertilizer costs for operation
- Can be applied virtually anywhere, no change in practice or crop and handled by women folks easily.

Currently with **Secure water for food award from USAID** the Sponge project is on up scaling mode planned for three years for three demonstration sites measuring 4 hectares in India, Nepal and Bangladesh.

Solution Description

Previous Application SPONGE: An innovation in irrigation for sustainable farming

Organization country
India, Sweden
Country (ies) of implementation (please select all that apply)
Bhutan, Bangladesh, India, Nepal

SPONGE is an innovative irrigation technology, greatly improving water utilization and supply. Using water from fog and dew, SPONGE increases reliability in a region with abundant but highly intermittent water availability, improving soil moisture content - while reducing technical maintenance and operation of machinery. It can be applied on existing fields as well as on marginal, rocky or sandy soils unsuited for conventional farming - and even where reliable springs or wells are lacking.

If your innovation is a technology, provide technical specification on how your innovation works; if a business model, what is innovative about it?

Soil moisture content is increased and kept at optimal levels through a cascading system of buried SPONGEs (coco pith/cotton units), supplied through fog and dew harvested water. Water is applied in gauged volumes and recycled, minimizing water loss. To ensure sustainability, SPONGE applies a specific selection of plants to control bacteria/fungus in combination with bio-fertilizers, thus forming a techno-biological system. SPONGE is designed to involve women and strengthen marginalized groups.

Where and when was this innovation piloted? What were the results of the pilot?

SPONGE was successfully piloted November 2014–February 2015 in India (Bangladesh Border at the Himalayan Foothills),
Results from the 4 hectare potato field include:

- >50 % reduction of water consumption
- All water harvested from fog and dew.
- >50 % reduction of fertiliser cost, due to decreased run-off loss and use of bio-fertilizers.
- Facilitated involvement of women and less educated farmers

Who are your expected end-users? NOTE: If your target customer/end-users is farmers, please be sure to include information on their gender, average farm size, average income, and the general locations/ geographies in which your project will be implemented.

Primary end-users are local farmers incl. tribal communities in the the rural target region. Approx. 70–90 % of the workforce in the agricultural sector. Individual private farming is the most common form, with different co-operations also present. Atypical farm is approx. 1 hectare, with a yearly profit of approx. Rs. 25,000. Current practice is very traditional, relying on manual labour. Mostly men farm, using cows or tractors to plough. Surface and/or ground water for irrigation.

What's at stake for the end user if the problem as they describe it is not addressed?

- A growing population and increased demands on living standard, together with climate change effects leads to competition and conflicts between different water needs within the families and among different actors.
- Today many household has insufficient possibilities to provide for themselves, lacking arable land/access to water and capital.
- Miss-use of underground water and waste water is common, worsening the water/food-ratio from farming.

How much does your product actually cost (this amount should include the full costs of management, maintenance, and replacement in developing or emerging markets?

Production cost for 1 hectare is approx. 11,000 USD, with a recurring cost of 700 USD/year. This gives a feasible pay-off time, as the recurring cost is significantly lower than for current practice. SPONGE is a fully scalable concept, which will be sold in "area units" rather than itemized units. In order to be able to offer affordable installations to vulnerable households as well, we will likely strive for accumulating sufficient number of orders in the same region before installing SPONGE.
How does your innovation uniquely solve your customers' problem compared to the alternatives? What are the alternatives you have considered and why is your innovation more suitable for your customers? What is transformative or "game-changing" about your innovation in this context?

Alternatives:

- Lack of water is tackled by large-scale distribution networks from downhill rivers. Very costly, vulnerable to earthquakes, inflexible..
- Low efficiency is tackled by drip irrigation. Costly installation, high maintenance.

SPONGE offers:

- Improved and stable water/crop-exchange
- Reduced ground and rain water dependency
- Low capital investment combined with reduced water and fertilizer costs for operation
- Can be applied virtually anywhere, no change in practice or crop.

Value Proposition

An alternate system for irrigation designed for short-root vegetable crops, growing in difficult terrains (mountainous, water scarce etc.) that helps farmers achieve higher incomes by

- Extended Crop Season, extended income season
- Increases soil moisture, Better quality & quantity of produce
- Reduction in the cost of operations in the long term
- Water savings, More water for livestock
- Involvement of women in farming activities

Key Activities

- Mobilization and demand generation
- Community trust building & organization
- Sales and financing
- Installation & set-up
- after sales service
- Farm advisory.

Key Resources

- SWFF Grant
- Technical expertise of the innovation / intellectual property of SPONGE
- Partnership with universities such as Uttar Bangla Krishi Vidyalaya (Agricultural University)

Key Partners

- Funding Partners:
  · USAID (SWFF)
  · VL grants
- Operational Partners: Raw material & transportation Vendors
- Mobilization partners: agri-input dealers, NGOs; Representatives of agricultural universities
- Financing partners: MFIs, local bank

Expected targets as Major Milestone

1 - Expected Adoption: 450 of poor farmer households or (2000 end users), benefitting from or directly involved in the Sponge Project innovation.

2 - Percentage increase in crop yields in dry-land cultivation by 10%: There will be an increase in yield because the availability of water will be ensured during the whole cropping activity period involving sponge installations and water storage.

3 - Total volume of water reallocated to food value chain from this Sponge innovation (1760000 L/year). The Sponge system will catch water from rainfall, dew, fog in surplus from what is required for agriculture activity and thereby will save water from underground and surface.

4 - Volume of produce grown in the tune of 252 tons. This milestone can be achieved well as we have the experience from our pilot installation and subsequent measurement of data and statistics in this regard.

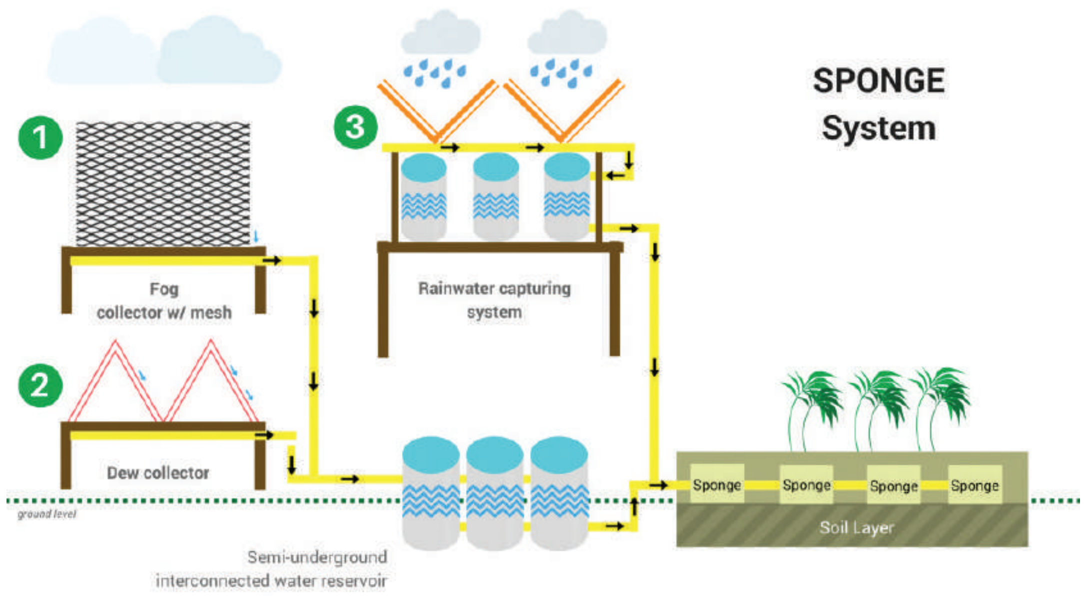
5. Hectares under improved cultivation. 4 (FOUR)

6- Expected Number of three partnerships in the Project period leveraged to improve the availability, distribution, and utilization of the product and partners in the form of Distributors and Dealers, Business Development agencies, Sales and marketing agencies , communication and branding.

Budget and funding

The co-funding option is very bright as the project has been endorsed by the local government and was also one of the stakeholders of the project. We have received co funding from the Swedish Environmental Research Institute for piloting the idea and the demonstrated results are promising. USAID is also supporting this idea with a business development approach. The Sponge project is also listed under next generation project of European Union and possible will receive some co funding as well. We have also approached Sikkim Government with our Sponge project to fulfill the organic mission of the state and discussion is on in this regard.

The Sponge project also expects to garner possible co-funding from CSR foundations like banks for water and soil conservation, Water Shed Organisation trusts helping poor farmer community. Government agencies like Ministry of Small and medium enterprises Government of West Bengal, Technology development board Government of India, DFID UK, Agri-input Optimization providers (FAIDA) can also be potential co-founders.



World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 1

Efficient Water Management

Challenge

Innovating financing for local water solutions

Solution

A water kiosk at school

Mr. Venuste Kubwimana
Secretary General, International Transformation Foundation, RWANDA

Solution

A water kiosk at school

Venuste Kubwimana

Summary

Inspired by personal experiences growing up in communities, where school-going children walk long distances to secure water for their families before/ after going to school causing absenteeism resulting to school drop-outs.
In 2013 International Transformation Foundation (ITF) members worked together on research project about sustainable clean drinking water system. One of the main insights gained is that all communities wish to improve their water system. Some communities do not have a working water system at all, prompting school-going children and women to walk very long distances to secure water from neighboring communities' wells/ rivers. The problem with current water projects in Kenya's communities are:

1) the water system with the technical components to get groundwater to the tap and
2) the paying system that describes what to pay for, how to maintain the system and how the business is set up; the social system.

A Water Kiosk at School is a (primary) school-based and students-managed business selling clean tap water to community residents at an affordable price. It consists of financing a community school to set up on-site water kiosk with sustainable products for the students to transport tap water from school to their homes. It is both an educational and profitable business teaching the students business and entrepreneurial skills, and generating much-needed income for schools. It provides practical education bridging the gap between school and work. And contribute to further development of the community with a school which is able to support itself.
A water kiosk at school is characterised by the following environment friendly products:

1. **Water Saving Tap Station -** Our water stations not only provide clean drinking water but also saves water. No water is wasted with our auto-stop tap!
2. **DRIP TAPS For Hand Washing Facilities -** We build toilets and hand washing sinks to prevent waterborne illnesses to spread. Drip taps technology reduces 90% of water usage!
3. **Water Bottles -** We provide refillable water bottles for the children to drink from made of BPA-free plastic.
4. **Jerry Carry Karts -** reduce the physical injury from constant lifting and carrying heavy loads of water on heads of the children.

Setup at a school located in a rural community with no working tap water system. where it will be the main source of clean water for all households, not only by providing them clean tap water, improved sanitation and health but also its social business model that develop communities' solidarity, developing local education and an entrepreneurial spirit.

To date, we have:
- Built 12 water kiosks at 12 schools in Kenya and Rwanda consequently
- 6557 school children no longer have to absent themselves from school to secure water for their families.
- 120358 people have access to clean tap water at affordable price within their communities.

By financing a school to set up the kiosk, within 36 months, the school earns enough money from selling water to community residents at affordable price and are able to repay the set-up cost which is then redeployed to an additional school/community.

Solution Description

Short abstract:

The Water Kiosk at School is a rural community (primary) school-based and students-managed business selling clean tap water to community residents at an affordable price. It consists of financing a community school to set up onsite water kiosk with sustainable products for the students to transport tap water from school to their homes. A water kiosk at school is both an educational and profitable business teaching the students business and entrepreneurial skills, and generating much-needed income for schools. It provides practical education bridging the gap between school and work. And contribute to development of a community with a school which is able to support itself without relying on subsidies.

Explanation of the problem and context

In Kenya, it is estimated that only a ⅓ of the population has access to safe drinking water close to their homes, at an affordable price. Therefore, school-going children have to walk long distances (at least 4km) so as to secure water for their families before/ after going to school causing absenteeism and resulting to school drop-outs.
In 2013 International Transformation Foundation members worked together on country wide research project about a sustainable clean drinking water system. One of the main insights gained is that all communities wish to improve their water system. Some communities do not have a working tap water system at all, prompting school-going children and women to walk very long distances to secure water from neighboring communities' wells/ rivers. Other communities especially in per-urban areas have a small number of taps within and would like to increase this number.
The problem with current water projects in communities in Kenya are:

1) the water system with the technical components to get groundwater to the tap and
2) the paying system that describes what to pay for, how to maintain the system and how the business is set up; the social system.

Our solution:

A WATER KIOSK AT SCHOOL was created as a rural community (primary) school based and students managed business selling clean tap water to community residents. With belief that education fashioned to provide a financially sustainable education while directly solving community's challenge is the key to tackling youth unemployment and contribute to development of a community by providing them clean tap water, improved sanitation and health but also a social business model that develop communities' solidarity, developing local education and an entrepreneurial spirit.
In this context we work with community schools to set up onsite water kiosk with sustainable products for the students to transport tap water from school to their homes. A water kiosk at school is both an educational and profitable business teaching the students business and entrepreneurial skills, and generating much-needed income for schools.
Managed by the students, it provides practical education bridging the gap between school and work. And contribute to development of a community with a school which is able to support itself without relying on subsidies and yet is able to afford the best facilities and the best teachers.

Setup at a school located in a poor/rural community with no working tap water system. In a community, it set to be the main source of clean water for all households. A water kiosk at school is characterised by the fellowing environment friendly products developed in partnership with Join the Pipe Foundation:

- **WATER SAVING TAP STATION -** Our water stations not only provide clean drinking water but also save water. No water is wasted with our auto-stop tap! They are also vandal resistant
- **DRIP TAPS for HAND WASHING FACILITIES -** We build toilets and hand washing sinks to prevent waterborne illnesses to spread. Drip taps technology reduces 90% of water usage!
- **WATER BOTTLES -** We provide refillable water bottles for the children to drink from. Our refillable bottles are created specifically to symbolize different sections of a water pipe. They are made of BPA-free plastic .
- **JERRY CARRY KARTS -** These Jerry Carry Karts reduce the physical injury from constant lifting and carrying heavy loads of water on heads of the children.
  Watch here: https://youtu.be/TVK5sZnLQ9Q

Below are activities that are carried out (chronologically) in setting up a Water Kiosk at School:

- **The school's expression of interest** to adopt A Water Kiosk at School. The expression is made by filling an application form documenting the school; community background and water situation in the school and around the community.
- **The community involvement & cost estimation.** ITF, the school and community residents work together to estimate the set-up cost within community resources context. This way, the school will be able to sell water profitably yet affordable to the community and return the set-up cost.
- **Financing.** ITF sources for funding to set up the kiosk.
- **Legally binding agreement.** An agreement is signed allowing ITF to place the kiosk management to the school and community residents. In the case that the school violates the kiosk principles, the school is held liable.
- **Permits & Licenses:** The School requests and obtains kiosk construction and water connection permits and related licenses from relevant authority.
- **Kiosk construction & water connection:** An ITF technician with help from the community residents set up the kiosk at school.
- **Kiosk launch.** The kiosk is opened to the public after training students & teachers how to run the day to day operations of the kiosk.

- **Monitoring & evaluation:**
  Day to day operations & records: A Water Kiosk at School is managed by 2 students per day with 2 roles. One receives money and does the book records. The other one is responsible for assisting customers at the tap. The book keeper records include time, buyer name, quantity purchased and paid amount . The book keeper also records any expense if any. At the closing of any business day, both kiosk operators sign and submit the records book to the responsible teacher.
  Weekly and Monthly report: The information recorded every day in the records book is used to compile a weekly and monthly report prepared by students with support of a teacher. The report is sent to ITF and essentially contains information such as: The number of students and non-students that used the kiosk, the amount of water purchased and money spent, names and details of students that managed the kiosk, etc.
  Monthly Kiosk Visit: The ITF project coordinator visits the school /kiosk to review the day to day book records.
  User Survey: This is done every quarter to get user feedback.
  Repayment: The school repays the set-up cost on a monthly basis.

Impact:
Setup at a school located in a community with no tap water system. Where it will be the main source of clean water for all households providing clean tap water, improved sanitation and health. Its social business model develops community's solidarity, developing local education and an entrepreneurial spirit. The multiple benefits associated with a water kiosk at school for students, school and community residents include:

Financially :
- The microcredit project for schools with a sustainable business model, creating money for WASH activities in school.
- A repaid loan system that allows funds to be redeployed to additional schools in need, thus reducing the need for subsidies and dependency.

Improved Sanitation And Health :
- All sanitation facilities are improved around the school, the money from the water kiosk is used to purchase soap and toilet paper for the school children.
- Jerry carry karts reduce the physical injury from constant lifting and carrying heavy loads of water on the heads of the children.

Education And Capacity Development :
- Increased school attendance as children no longer need to absent themselves from school to secure water for their families.
- Work experience for students through the running the water kiosk. They learn about teamwork, commitment, leadership and responsibility.

Socioeconomic Opportunity:
- Children are able to transport water to their own homes straight from school.
- Increased safety as children do not have to go to remote and dangerous places to fetch water.

Impact in Kenya: Since the project launch in 2014, we have successfully built 11 water kiosks across 11 schools/ communities in Kenya directly serving 5655 students (6-14 years old) and over 75587 people living around these communities.

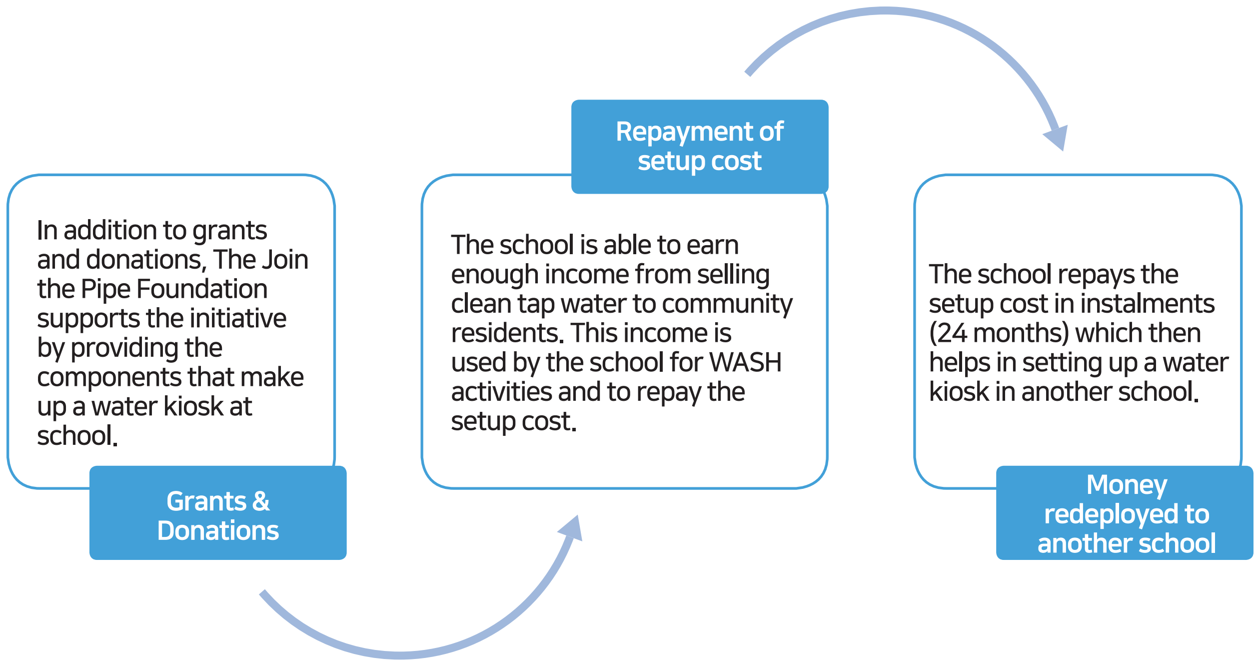
Impact in Rwanda: This August, we are set to launch our second water kiosk at school in Rwanda. After a successful pilot project at Rubugurizo primary school which is directly serving 902 students and over 44771 general community residents in Muhanga District (southern province). This is after receiving an invitation from the Government of Rwanda and consequently signing a memorandum of understating with the Ministry of Education on behalf of the Republic of Rwanda to replicate the water kiosk at school to help Improve quality and learning outcomes across primary and secondary education in the country in December 2017.

Recognitions:
The Water Kiosk at school Project has also won various Awards:
1. The Spindle's (Third prize) -Best Innovation in development Award 2018.
2. Exhibited as Africa's Top 50 Innovations at 2018 Africa Innovation summit.
3. Youth4South solution awareness, United Nations office for South to South Cooperation, 2017
4. ESD (Educational Sustainable Development) Okayama Award 2016 – Global Prize.
5. Global awards for Fundraising 2015 - Big Impact Small Budget award category.
6. Pan- African Award for Entrepreneurship in Education 2014.

Financial:

Setting up a water kiosk at school model costs $10,000-15,000. We have designed a sustainable financing model that ensure a replication in other communities. Since rural community schools do not have the money for the large investment, ITF directly or through a partner or any other social impact investor make the initial investment to set up the water system at a school. The school then, through selling of water to the students and members of the community at an affordable price (decided by community residents), Proceeds are used for sustainability of the water system.

The other part of the money that is made from the water kiosk goes into supporting WASH activities in the school and paying off the initial investment to ITF which is then redeployed to an additional school/community.



World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 2

Resource Recovery from Water and Wastewater System

Challenge

Energy Efficiency in sewage, wastewater, and sea water recycling and reuse

Solution

Novel Fertilizer Production from Human Urine in Membrane Distillation Process

Ms. Ruth Habte Hailemariam
PhD candidate, University of Science and Technology (KICT School), ETHIOPIA

Novel Fertilizer Production from Human Urine in Membrane Distillation Process

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Summary

Nowadays ammonia is one of the most produced inorganic chemicals in our globe. Over 88% production of ammonia mainly goes to fertilizer production. More than 72% of our global ammonia production mainly comes from Haber-Bosch process. This technique is somehow sophisticated and requires a high amount of energy and chemical catalysts with a high carbon footprint. Researchers revealed that this process consumes around 4% of the entire energy produced on our planet. Recently there are various emerging technologies toward addressing this ammonia gas production. The Membrane distillation process was initially designed for seawater desalination but its application in the valuable resource recovery from wastewater sources was proven to be successful owing to its outstanding performance in extracting volatile molecules. In this study, human urine has been selected as the main source for ammonia for two big reasons. Firstly, it contains a very high amount of volatile ammonia to be easily recovered by MD process, secondly, it is one of the most undesirable waste contributing 80% of nitrogen,50% of phosphorous, 70% of potassium into the domestic wastewater. Diverting urine and treating it separately also significantly reduces the high energy and investment incurred for nitrogen and phosphorus removal in the tertiary treatment plant of domestic wastewater. In this study, high-grade ammonium sulfate fertilizer was produced from source-separated urban human urine in direct contact hollow fiber membrane distillation process by circulating warm hydrolyzed urine in the feed side and cold diluted acid in the permeate side. The economic viability of the process, its sustainability, and adaptability have also been evaluated as compared to the conventional production system. Accordingly, our result revealed that hollow fiber MD is a viable and economical alternative technology for fertilizer production from human urine. The study also identified the most significant parameters and their optimal operation condition. Moreover, the effect of using different acids, fouling propensity in MD, and detailed ammonia mass transfer has been addressed in detail.

Solution Description

1. Comprehension

NPK (nitrogen, phosphorous, and potassium) are the major elements that plants should get from fertilizer. Among these, nitrogen is the most essential nutrient that plants absorb more than any other element. However, gaseous nitrogen (N2) cannot be directly consumed by plants. The major sources for nitrogen in plants body consumed in the form of only nitrates and ammonium. In addition to fertilizer production, there is also a high demand for ammonium production. Nowadays ammonia is one of the most produced inorganic chemicals in our globe. Over 88% production of ammonia mainly goes to fertilizer production. More than 72% of our global ammonia production mainly comes from Haber-Bosch process. This process involves mixing of nitrogen and hydrogen from the air by a catalyst which makes it expensive, high energy demand (high temperature and pressure) and high greenhouse gas production (Ye et al., 2018). Recently there are various emerging technologies toward addressing this ammonia gas production. These methods include acid stripping, air stripping, distillation, and osmotic membrane systems. However, their efficiency is limited, extract only a small amount, not economical as they require lots of energy for aeration and heating. Moreover, these traditional methods take a long time and are liable to contamination. But membrane distillation process has various interesting features such as high effective active surface area, less chemical-intensive, environmentally friendly with less footprint, less temperature and energy requirement, and high packing density but its research application has been limited mainly to desalination and highly polluted industrial wastewater sources. In the membrane distillation process, any high-nitrogen feed can be used as a source for ammonia volatilization. The study showed that various sources have been applied for the production of fertilizers from high ammonium ion containing wastewater sources, livestock manures, and ammonium salt solutions). In this study we selected the human urine as the main source for ammonia for various reasons: human urine contains very high amount of volatile ammonia, it is easily available and cheap, it is one of the most undesirable waste causing 80% of nitrogen,50% of phosphorous, 70% of potassium into the domestic wastewater. Generally, the high release of nitrogen and phosphorous in the ecosystem favors grow of algae and disturb the natural environment and affects the health of our water systems. Hence, diverting urine and treating it separately reduces very high amount of energy and investment incurred for nutrient removal in the tertiary treatment unit of the domestic wastewater treatment plant. This is a big contribution to the prevailing global water and energy challenges. Therefore, the scope and overall objective of this study is to identify significant operating parameters, selection of optimum operating condition for maximum and economic fertilizer production, studying the economic viability as compared to the conventional method, investigating the fouling propensity and maximizing ammonia mass transfer rate in MD process. For economical operation, and in order to get high quality and highly concentrated fertilizer solution, optimizing the MD parameter has been very essential

2. Sustainability of the technology

Sustainability check is one of the most important factors to measure the viability of a certain new technology. Sustainability can generally be defined as meeting the needs of the present without compromising the ability of future generations. Establishment of sustainable technology should address four major pillars which are equally important to the well-being of the project. These pillars include socio-cultural and political sustainability, economic sustainability, environmental sustainability, and technical sustainability. A certain project setup, any construction of engineering works, or selection of a fertilizer production technology options must also address the requirement of all these pillars in order to sustainably serve the end-users.

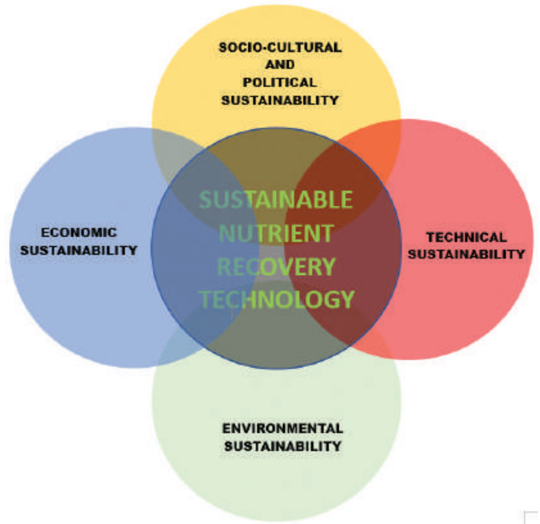

Figure1: Sustainability-based technology selection technique

These four sustainability pillars can be described based on the context of the target end-users.

Socio-cultural/political sustainability: This pillar of sustainability ensures the acceptability (adaptability) of the technology within the community and its compatibility with their indigenous knowledge, tradition, history, culture, and social norms. The sustainability of such technologies depends on the willingness of users to provide the necessary time, money and labor to keep the system functioning. The membrane distillation-based fertilizer production from urine (MDFU) project has been evaluated toward this pillar and there was no problem with the social sustainability pillar except that the psychology of the people toward using urine as a valuable resource was difficult. Better to use this fertilizer for greenery than vegetable production.

Economical Sustainability: This term refers to the sustainability of the project in terms of financial and economic aspects. It answers the question 'can the users get the fertilizer cheaper than the prevailing market price? Compare both the CAPEX and OPEX price. The optimization result in this study proved that there was an optimum point of fertilizer extraction at which MDFU was cheaper and high quality than the conventional system. See the modeling result.

Environmental sustainability: This sustainability pillar mainly ensures the carbon footprint, rate of waste generation and environmentally friendliness. The relative pollution rate, the tendency of using green energy and, gas emission in MDFU was better than the conventional Habor-Bosch process and acid stripping technology. The biggest environmental concern from this project might be the release of the brine from the feed side which actually can still be used for phosphorus recovery. Moreover, this project can be easily synchronized with renewable energy sources.

Technical Sustainability/Feasibility: With this sustainability pillar, one can ensure that the project is technically sound, scientifically proven, commercially available and can easily be installed and operated in the project area without any failure. The MDFU found to be feasible and proved to be easily implemented on urban buildings and rural setups without any problem. This kind of project has already been established as a pilot plant both in resource recovery and desalination sector. The MD process was found very feasible to completely recover all the ammonia within a short period of time. See the results

3. Feasibility

The overall sustainability report investigated over the above four pillars shows that the MDFU project can be considered as feasible project and can be upscaled both at the pilot and large scale for successful implementation in an urban and rural setup. The detailed technical matters such as the methodology, collected data, analysis tools, results, and conclusions were summarized as follows:

3.1 Methodology

The MDFU principle worked in such a way that, first the collected fresh urine was kept for a few days to hydrolyze. With this process, the aerobic bacteria degraded the urea and changed it to ammonia and the pH raised from 6 to 9 (see the equation Fig.1). Then the temperature of the hydrolyzed urine was increased and circulated by pump on the MD membrane surface. This process favors the volatile ammonia gas to pass through the hydrophobic pores. Cold Inorganic acids (e.g sulfuric acid) were selected as a receiving solution in the permeate side and circulated continuously which favored the ammonia mass transfer across the porous membrane in a vapor phase. Once the ammonia passes through the MD membrane, it turns to ammonium as the pH was small in the permeate side. The ammonium ion then reacts with sulfuric acid and form ammonium sulfate solution which can directly be utilized as a fertilizer. The detail schematics of the process was indicated as follows (see Fig. 1)

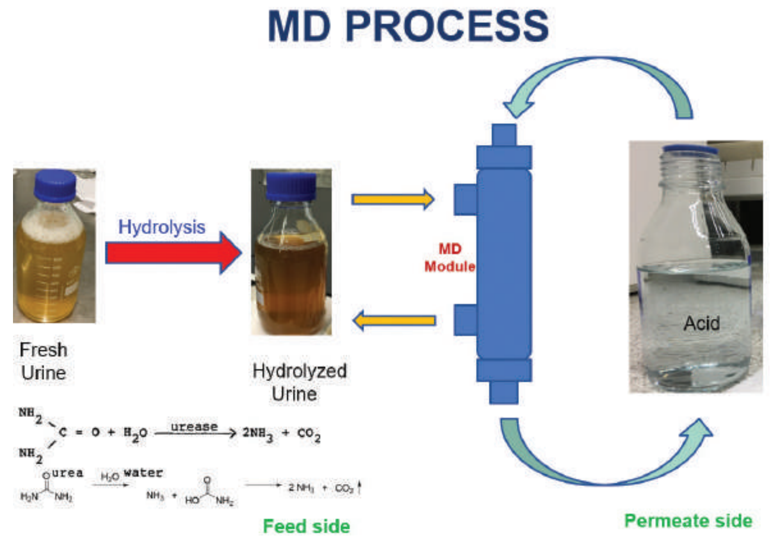

Figure1. Schematics of MDFU and hydrolysis process

A detailed optimization has been executed to select the best operating parameters for extracting maximum ammonia with small amount of investment. In the optimization work, the overall price of ammonium sulfate fertilizer produced has been compared with the conventional techniques. For the optimization, surface response method has been utilized. Some of the results were indicated as follows:

3.2 Findings

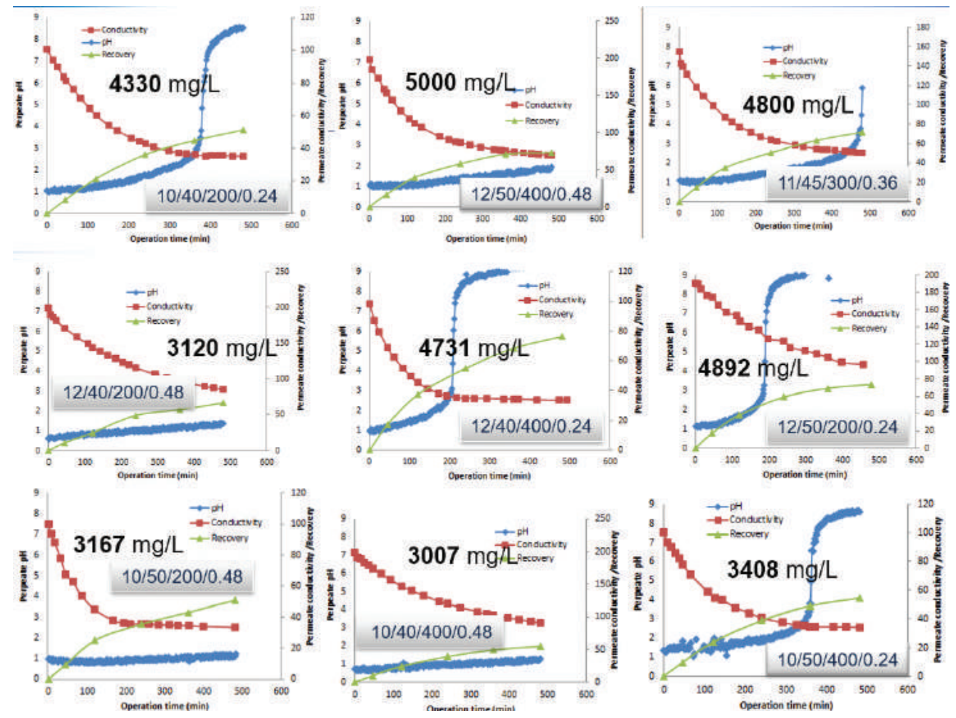

Figure 2. Ammonium production amount under different operation conditions

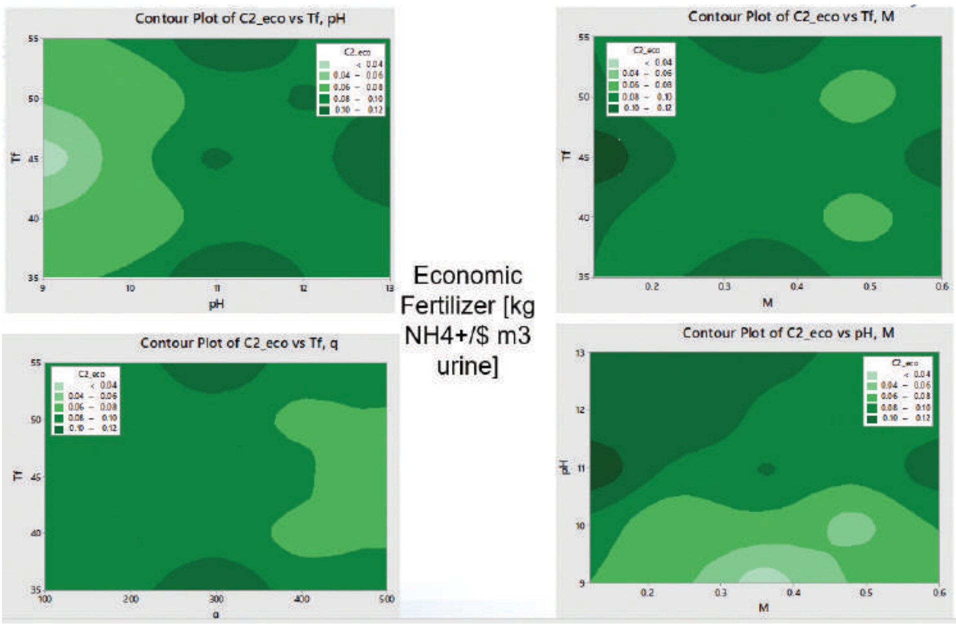

Figure 3. Response of ammonium fertilizer production amount under varying different operating conditions. Note: C2_eco = Amount of ammonium fertilizer produced per 1dollar per 1 m3 of human urine. Tf= feed temp.; M= permeate acid concentration in molarity; q=feed/permeate flow rate (rpm); pH= feed urine pH

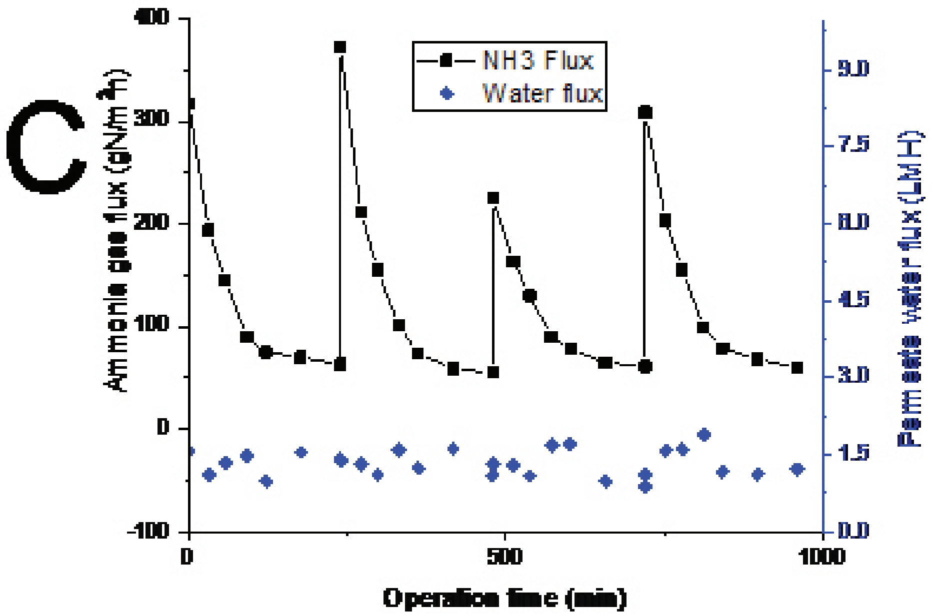

Figure 4. Ammonia gas flux and permeate water flux from real human urine in hollow-fiber MD process

4. Challenge

List of possible challenges and respective solutions proposed were organized as follows:

- Psychology of using urine product as a fertilizer for edible items was big problem. However, this project can be implanted for greenery and non-edible plant production.
- The membrane distillation process is new and not yet commercialized. However, there is very good hope of commercialization due to its application in the desalination industry. Some countries started working at the pilot level. This can be taken also for a fertilizer production project.
- The feed side brine after nitrogen recovery is a big concern. For it has pharmaceuticals, phosphorous, and microbes. However, our project is extended and now working on pharmaceutical removal and phosphorus recovery researches on the remaining brine.

5. Impact

If successfully implemented, the impact of this project is multidimensional. The project is not only aimed at providing resource recovery. It also contributes a lot to the environment willingness and reduces a lot of investment which otherwise would have been incurred in environmental protection and energy production. Some of the major impacts can be.

- Increased agricultural production (both in quality and quantity) from the use of such fertilizer greatly contributes to the food security problems and eradication of poverty.
- This project ultimately contributes at large to the environmental protection works and creating a safe and greener world for the next generation.
- Energy-saving and green energy production from the project also contributes to the mitigation of climate change impacts which reduces various natural catastrophes

6. Acknowledgment

We acknowledge UST, Korean National Research Foundation (code NRF-2017M1A2A2047369), and university of technology Sydney.

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World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 2

Resource Recovery from Water and Wastewater System

Challenge

NEXUS for efficient utilization of limited water resources and energy recovery

Solution

Improving Water Security through Water-Energy Nexus Approach in Danang city of Vietnam

Dr. Pham Ngoc Bao
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Solution

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Pham Ngoc Bao

Summary

Da Nang is the sixth most populated city in Vietnam, with an area of about 1,255km2 and a population of slightly more than 1 million by the end of 2017. The city located in middle of Central Vietnam, between Hanoi and Ho Chi Minh City. As an economic and cultural center of the central Viet Nam, Da Nang City has experienced a continual and stable economic growth, and its GDP grew at an average rate of 11% in the period 2006-2010, which is higher than the country's average. Over the last decade, Da Nang has turned itself into a rapidly growing hub for transportation, services and tourism. It has also becoming a fast moving real estate and private property development. Investment into the city also comes from tourism, with more than 4.5 million visitors in 2015 and this number is expected to continue increasing in the coming years. This situation has created a huge pressure on old water supply infrastructure due to rapidly increasing demand for water supply, not only from local residents but also for increasing number of tourists from year to year. It is anticipated that by 2030 the total water demand of Da Nang will grow more than twice amount that can currently be supplied by the city's water utility. Water demand for Da Nang city could even increase to fourfold within the next 10 years. Consequently, demand for energy consumption for water production will also significantly increase over the next decade, placing a significant risk on water and energy security for the city in the near future.

Table 1. Electricity consumption and costs for water production in Da Nang (2015-2017)

Year	2015	2016	2017
Amount of water production (m3)	73,883,879	81,172,695	87,898,547
Electricity consumption for water production (kWh)	18,383,718	21,372,577	21,922,726
Electricity costs for water production (billion VND)	30,937	36,418	36,934

(Source: Ninh, 2018)

To address the challenges and promote water-energy smart living to the city residents, a group of researchers from the Institute for Global Environmental Strategies (IGES) based in Japan has worked closely with the local government of Danang city since 2015 to investigate the problem and identify potential opportunities and solutions for addressing these challenges. There was two possible scenarios that could be considered. In the first scenario, a supply-oriented approach was employed, in which the City was required to put more resources and investment for improving the capacity of water supply through building new water treatment facilities, searching for alternative water sources··· to satisfy the present and future demand. Consequently, this scenario will lead to more intensive use of resource, require huge investment, and the most importantly this will be an unsustainable solution, both in term of economic and environment aspects. In the second scenario, a Water-Energy Nexus approach was considered for facilitating to address the problems at both micro (grass-root level through household level) and macro scale (city level through water utilities).

Micro scale: our main objective is to influence water use lifestyles and behaviours of local residents in Da Nang through participatory research, demonstration, education and trainings on both passive and active measures to reducing both water and energy consumption at household level through water-energy nexus approach.

Macro-level: our main objective is improving energy efficiency for water pumps at the Danang city water utilities. Consequently, it could bring multi-benefits to the city, including improved energy efficiency of intake and water distribution pumps, increased water safety, water security, improved water supply capacity, energy saving, CO2 emission reduction and reduction of operation costs of the water supply utility.

Solution Description

Macro-scale solution

Water supply system in Da Nang City has been managed and operated by Da Nang Water Supply Company (hereinafter referred to as "DAWACO"), a Water Supply Joint-Stock Company. DAWACO is now operating four water treatment plants (WTPs) throughout the city with a total capacity of more than 210,000m3/day.

One of the main water treatment plants is Cau Do WTP, with a total design capacity of 170,000m3/day. However, due to a high water demand from the city, most of the plants often have to operate with higher design capacity, thus total actual operating capacity of the plants ranging from 220,000 – 270,000m3/day. Most of raw water and clean water pumps are quite old and operating with very low efficiency, only about 50% for raw water pumps and less than 64% for clean water pumps, and making a lot of noise due to possible intrusion phenomenon. Again, this may create a potential risk to damage the water pumps, and consequently affecting to water security and stalely water supply safety of Da Nang city.

Fig. 1. Intake and distribution water pumps before replacement

Nexus Solutions to Address the Water Security Challenges

Since water and energy are resources that are strongly interlinkaged, because meeting energy needs requires water (e.g. hydro-power plants, cooling water needed for thermal power plants), and also, energy is needed for pumping, collection, distribution and treatment of either water or wastewater. This interrelationship is often referred to as the energy-water nexus, or the water-energy nexus. There is growing recognition that "saving water saves energy", and "saving energy helps to reduce global warming" through reducing the carbon emissions. It has been estimated that at drinking water utilities, majority of energy/electricity consumption (about 80%) is to operate motors for water pumps. Electricity costs are also the second-largest costs for operating the utilities, after labor costs, thus energy/electricity conservation and improved efficiency are critical issues that receive many attentions nowadays from managers of drinking water utilities. Opportunities for improved efficiency such as upgrading to higher efficiency water pumps (either raw water or clean water pumps or both), improving energy management, and generating energy on-site to offset purchased electricity. However, barriers to improved energy efficiency by water utilities exist, including capital costs and reluctance by utility officials to change practices or implement new technologies.

Understanding these strong interlinkages, benefits as well as potential barriers to address the challenges that the Da Nang city is now facing, the top management board of DAWACO has decided to work with the Institute for Global Environmental Strategy (IGES) and the City of Yokohama to investigate the feasibility of replacing 3 existing conventional raw water pumps and 6 existing clean water pumps with low energy efficiency by new ones with much higher energy efficiency (83% for intake pumps and 90.6% for clean water distribution pumps), which have been customized to specific conditions and requirements of the recipient plants . Results from the feasibility study showed that: (i) maximum capacity of the pumps can be increased from 18,870,000m3/year to 20,800,000m3/year for intake pumps; and from 84,000,000 to 101,620,000m3/year for distribution pumps; (ii) electricity consumption will be reduced from 1,730 MWh/year to 780 MWh/year for intake pumps; and from 16,610 MWh/year to 14,050 MWh/year for distribution pumps; (iii) electricity costs will be reduced from 2.93 billion VND/year to 1.33 billion VND/year for intake pumps; and from 28.23 billion VND/year to 23.89 billion VND/year; (iv) cost saving amounts thanks to reduced operating costs for intake pumps will be 1.6 billion VND/year; and 4.34 billion VND/year for distribution pumps (IGES et al., 2016).

Actual Benefits from the Implementation Project

The results after 1 year of actual installations of replacing pumps and operation by DAWACO (since the last quarter of 2017) has showed actual effectiveness of the project. The total electricity costs of operating pumps in 2018 has reduced about 5.77 billion VND/year; electricity consumption for water production has been reduced 3,400 MWh/year and the estimated payback period will be only around 3 years thanks to the 50% subsidies from the Japanese Government through Joint Crediting Mechanism (JCM) Financing Programme for JCM Model Projects and saving costs from reduced electricity consumption (Ninh, 2019). The payback period will increase to 6 years in case there is no subsidy from the JCM Financing Programme.

Fig.2. Intake and distribution water pumps after replacement

Energy saving achieved by replacing the pumps is estimated to contribute to reducing emissions by around 1,145 tCO_2/year (GEC, 2019). This project has also significantly contributed to improved water security, ensured stable water supply safety as well as sustainability of Da Nang city, thus it also contributes and facilitates Da Nang city in achieving the relevant targets in SDG 11 (make cities and human settlements inclusive, safe, resilient and sustainable).

This measure also contributes to SDG-6 (Clean Water and Sanitation), SDG-7 (Affordable and Clean Energy), SDG-11 (Sustainable Cities and Communities) and SDG-13 (Climate Action):

Performance parameters	Results	Relevant SDGs
Increase efficiency of pumps	Efficiency of intake pump improved from 50% to 83% and for water distribution pump from 64% to 90.4%.	SDG 6 and SDG 11
Improvement of supply capacity	Increased capacity from 18 million m3/year to 20 million m3/year for intake pumps; and from 84 million m3 to 101 millionm3/year for distribution pumps	SDG 6 and SDG 11
Electricity saving	Electricity consumption for water production was reduced by 3,400 MWh/year	SDG 7 and SDG 11
CO2 mitigation amount	Contributes to reducing emissions by around 1,145 tCO_2/year	SDG 13 and SDG 11
Reduction of operation cost	Total electricity costs of operating pumps in 2018 was reduced by about 5.77 billion VND/year. The estimated payback period is only 3 years.	SDG 11

Micro-scale solution

It has been forecasted that water demand per capita will increase from 120 litres/per person/day, at present level, to 180 litres/per person/day in urban areas and 150 litres/per person/day in peri-urban area by 2030, if no water saving measures are to be applied.

The increased demand will lead to a serious challenge, both for local residents and DAWACO. Residents will suffer from unstable supply of water, and high potential of water shortage, especially during high-demand season (e.g. summer or tourists' season). Since the hydraulic pressure from the waterworks is not enough in some parts of the city, most residential and commercial buildings in Danang are equipped with at least one large water tank on the rooftop to store water and adjust water pressure for the daily use. With the continued increase of the water demand in the hotels developing along the beachside, residents in the higher areas will experience a more frequent shortage or low water pressure. Additionally, DAWACO and Danang city government are very much concerned with the rising water demand. The increased use of water, combined with the increasing trend of extreme weather conditions affected by climate changes, will lead to more frequent shortage and degrading of water quality as well.

Actions and Impacts on the City's Water Security

Against this backdrop, a team of researchers from the Institute for Global Environmental Strategies (IGES) in

Japan) has collaborated with the Environmental Protection Research Centre (EPRC) of Danang University of Science and Technology to launch a project aiming to influence lifestyle decisions of urban residents through participatory research, demonstration, and education on measures for water saving. More specifically, the project introduced the following approaches and activities:

(i) **Demonstration of supporting measures** for the water saving behaviours was introduced to 15 pilot households. The measures included passive and active measures. Passive measures meant the instalment of devices to save water and energy associated with water use, such as water saving taps, dual flush toilets, and solar water heaters. Active measures were the introduction and training of a set of practical actions such as the habit of avoiding unnecessary use of water and energy, and keeping track of daily water and energy uses.

The EPRC's project team surveyed household water use to selected pilot households with diversity in the family structure, economy, construction types, and water usages. Their water and energy usage and the cost associated were monitored through the surveys during the demonstration phase of the Passive and Active Supporting Measures.

Fig. 3. Both active and passive measures are introduced under this project

(ii) Development of training courses and integration into the education curricula
Based on the results of the pilot measures, the project team has developed the training course targeting the University students (Engineering and Designers), and carried out training to all relevant stakeholders such as local government, water utilities, community leader, women unions and local residents.

(iii) Development of decision support tool
In particular, the project has successfully developed a decision support tool for the water utility and facility managers (DAWACO), policy makers and even local residents for identifying most effective measures available to save water usage at different levels.

In short, the project collaborated with the stakeholders including the educators, government, and water utility company toward developing the conditions where local residents of Danang have access to necessary knowledge as well as tools to save water, supported by the policies of the government and the water utility.

Fig. 4. Offering a training course for engineers, designers, water practitioners and university students in the field of water and wastewater engineering at DUT

Learning by doing, with partners

EPRC team has conducted a series of consultation meetings with relevant stakeholders throughout the project period. The discussion with the water utility (DAWACO), Danang City Government, University researchers and secondary and elementary school teachers, and piloted households, have helped the team to identify several key opportunities they were unaware.

Firstly, the introduction of demand-side water saving measures, associated with the training and awareness raising, could be more effective if the project approaches the households through a few key actors or groups. These key actors or groups could be, for instance, the Women's Union, children at the elementary or pre-school age, and the teachers working with them. Secondly, while the tourism sector leads to the increasing demand for water, it was desired that the project cooperates with them for the piloting. Thirdly, many stakeholders pointed that the design of each building and the water supply system as a whole should be improved to tackle with the water issues from the long-term point of view, while awareness and tools at households would be effective in saving water quickly. Therefore, it was desired that the demand-side actions are integrated with the long-term policies and measures for the supply-side, such as the technical design, pricing, and so on.

The project team reflected these points in the implementation and added many activities that were not originally put in their plan. They immediately started talking with a kindergarten and an elementary school to explore the plan to conduct the pilot and training courses in these facilities. In the original plan, the EPRC team intended to develop and test the curriculum targeting the University level students majoring in Civil Engineering. Such a curriculum could focus on the technical aspects, while it was also important to provide contextual knowledge such as sustainable development, climate change, and so on. However, education and training targeting children and families would require different contents and methods. Therefore, the project needed to count much on the expertise of the teachers in this regard. Demonstration in the classrooms or school facilities turned out effective in attracting the children's attention and guiding them to further talk to their parents about what they could do in their families.

They also continued the discussion with DAWACO and the city government to identify the most effective forms of inputs that they can provide the development of their long-term policies of water management. In this context, the Decision Support Tool helps the utility company and the facility managers to design and introduce saving measures were improved. The tool was developed by the EPRC with an external consultant and modified to meet the demand of these users.

Fig. 5. Demonstration in classrooms for elementary schools

Thus, through the continued discussion and adaptive implementation reflecting the points came up, the project team identified the partners. The EPRC team successfully formed an expanded group of partners collaborating toward the short-term targets (such as the demonstration and training in the classroom and households) and the long-term goals (such as the stable water demand and supply with improved awareness and skills of the citizens).

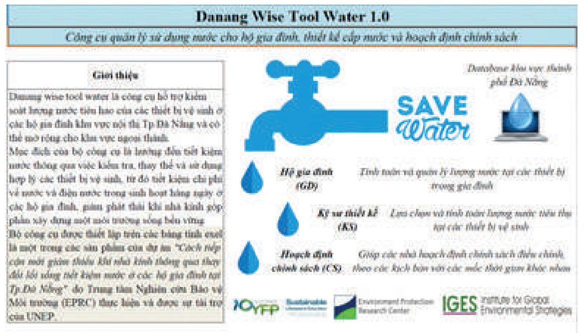

Fig. 6. Decision support tool to assist policy makers, designers and water users

Water-Energy Nexus Approach Helps to Address the City's Water Security through Water Saving Lifestyles at Household level

Based on the findings from this project, it has been found that 33% households in Danang city has water consumption higher than average, accounting for more than 50% of total supplied water. At the time of conducting the survey, due to high demand particularly during peak hours, the city is still lacking of about 7,500m3/day. Thus, in order to address this challenge, the project explored the potential of spreading water saving lifestyles through the demonstration of water saving measures (through both passive and active measures), development of trial of education curricula, and campaigns to the stakeholders.

It is expected that if all active and passive measures are properly implemented, total water consumption in daily households' activities can decrease 10 – 15%, particularly in high level of water used households. Consequently, it can save 5,500 – 8,100 m3/day. This amount of water can be used for addressing water shortage during peak hours in Danang city.

In addition, GHG emissions could be decreased up to 0.03 kg CO2/day/household (11kg CO2/year/household), and emissions from electricity could also be decreased to 0.11 kg CO2/day/household or 40 kg CO2/year/household.

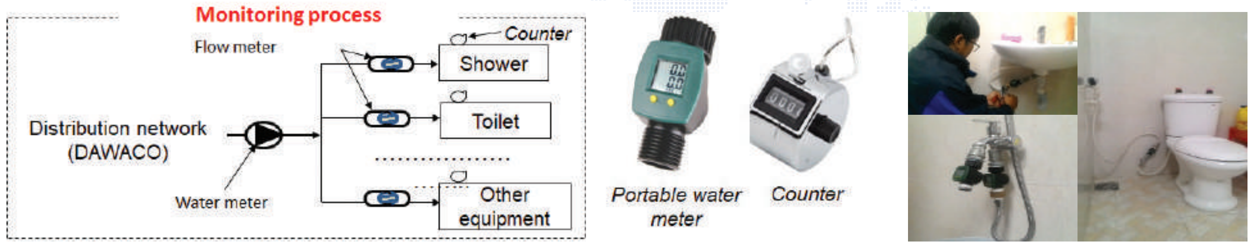

Fig. 7. Installation of monitoring devices for water flowrate and counter (flushing toilet)

Thus, if these measures were spread across the city, the city could reduce a significant amount of water use as well as achieving a significant amount of GHG emission reduction.

Furthermore, the group of partners evolved through the repeated discussion and collaborative actions will be the basis toward further scaling up of the project. The project has already carried out actions seeking further opportunities, including the training of teachers, discussion with the engineers, and with policymakers. What the project learned has been, and will be quickly reflected in the implementation and plans. For instance, the city government decided to integrate the education curriculum tested at the university into the city's programme. Additionally, the city government requested its Climate Change Coordination Office (CCCO) to start examining the long-term policy of water management. EPRC and the partners will further work on both the improvement of the actions with households, education and communication, while working on the long-term policies and exploring the partnership with the key stakeholders, including but not limited to the Women's Union and the tourism sector, toward the spread of sustainable living in Danang.

World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 2

Resource Recovery from Water and Wastewater System

Challenge

NEXUS for efficient utilization of limited water resources and energy recovery

Solution

Solar Dew – Solar Water purification and desalination for households and communities

Mr. Alexander François Marie van der Kleij
Head, SolarDew, THE NETHERLANDS

Solution

SolarDew - Solar water purification and desalination for households and communities

Alexander François Marie van der Kleij

Summary

An estimated 90 million people globally, are affected by water scarcity and the issues surrounding brackish or saline groundwater. There are currently no cost-effective solutions for desalinating water for small communities which have little or no access to infrastructure. People are in need of a reliable, robust and cost-effective solutions for producing safe drinking water from the available local water sources, whether these are saline, chemically or biologically polluted.

SolarDew has developed a unique solar water purification technology specifically for producing clean drinking water from saline or brackish water. The product looks like a solar panel, but it does not produce electricity. Instead, contaminated water is heated directly by the sun and evaporated through a proprietary membrane to produce clean drinking water, whilst leaving bacteria, viruses, chemicals and salt behind. It contains no electrical or mechanical components and as such is extremely reliable, robust and easy to use.

SolarDew has developed an inexpensive membrane (less than 2 per m2) that has a high fouling resistance. This membrane is integrated in a water purification bag which can be manufactured using roll to roll using technology from the packaging industry. These two technical innovations ensure that ultimately the water price is in the range of only 1 to 2 cents per liter which can be as much as 5x lower than water trucked to these communities.

The technology can be used in a variety of products, for example, as a compact, inflatable product in and can be rapidly deployed in the aftermath of a natural disaster or as a permanent long-term source of drinking water.
The unique aspects of the technology are

1. Drinking water from any source
2. Solar
3. Low water price
4. Low maintenance

From a technological perspective the innovations lie in the:

5. Low cost membrane with high fouling resistance
6. Roll to roll manufacturing
7. Proprietary supply chain

Solution Description

SOLARDEW®
CLEAN WATER SOLUTIONS

In the future will there be enough drinking water for us all?

Everyday 850 million people have to worry about how they are going to provide clean drinking water for their families. The water available to them will become increasingly contaminated or saline and there are currently no cost-effective solutions to these enormous problems. This is not only the case in rural areas but also in fast growing cities, both in developing and developed countries. This situation is only getting worse. Water scarcity due to pollution, climate change, and population growth all mean that our traditional water sources are disappearing quickly with the result that people's lives are ruined and their livelihoods destroyed. This is expected to affect 5 billion people by 2050. Buying water of unknown quality or producing more bottled water, than the 500 billion water bottles we are already producing each year, cannot be a sustainable solution to our drinking water problems.

FIGURE 1 - LEFT - PEOPLE IN INDIA HUDDLING AROUND THE ONLY LOCAL WATER SOURCE.
RIGHT - PEOPLE IN CHINA BUYING BOTTLED WATER BECAUSE THEY DO NOT TRUST LOCAL SOURCES.

A new source of clean drinking water – SolarDew

People are in need of a reliable, robust and cost-effective system for producing safe drinking water from the available local water sources, whether these are saline, chemically of biologically polluted. Hence, SolarDew assembled a diverse team of experts in the fields of business development, water management in developing countries and industrial design to address this growing need. Supported by well-known and first class rated university professors specializing in the fields of membranes, polymers, solar and water technology, SolarDew has developed a unique solution, **a water purification and desalination product that can produce clean water using only solar energy.** The product is easy to use, robust and extremely low in maintenance. It eliminates the need to transport water over long distances in order to obtain clean drinking water.

"SolarDew offers clean drinking water for less than 2 cents per liter"

SolarDew - Simple, Affordable and Reliable.

In essence, the technology allows saline or contaminated water to be heated by the sun and evaporated through a proprietary membrane to produce clean water, whilst leaving bacteria, viruses, chemicals and salt behind. This process, called membrane distillation, takes place inside an extremely simple water purification bag (SolarDew's core technology). The bag is placed inside a protective housing with a transparent cover. SolarDew has brought together leading manufacturing companies to create a proprietary manufacturing supply chain.

Whether people require a compact, inflatable product which can be rapidly deployed in the aftermath of a natural disaster or a system that provides a reliable long-term source of drinking water to individuals or communities, **SolarDew has the solution.** SolarDew systems are designed for small scale, point of use applications that purify 8 to 5000 liters of clean water, daily.

FIGURE 2: LEFT- SOLARDEW WATERSTATION FOR COMMUNITY, INDUSTRIAL AND AGRICULTURAL APPLICATIONS, AND RIGHT - SOLARDEW LIFELINE FOR DISASTER RELIEF.

The growing market for point of use desalination

SolarDew's market is found in all regions of the world with an average to high level of sunshine and where local (ground) water sources are either saline, brackish or contaminated. The estimated market size for point-of-use desalination is 90 million people which translates into a market with a turnover of more than 2 billion per year. Other niche markets exist in the areas of emergency relief, industrial applications and healthcare.

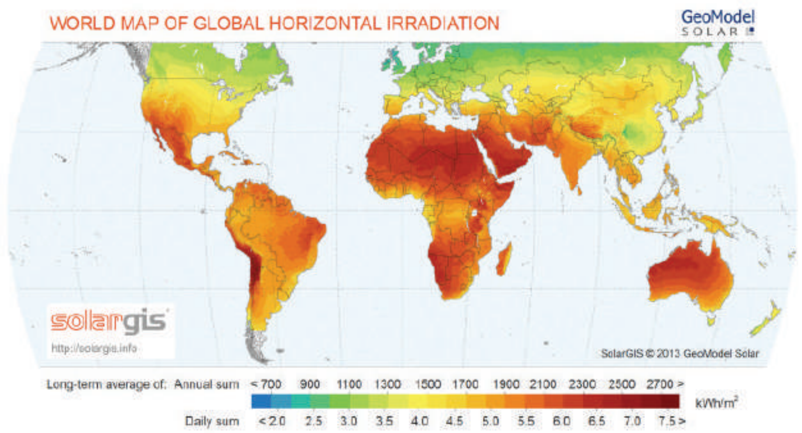

FIGURE 3: GLOBAL SOLAR RADIATION. AREAS WITH HIGH SOLAR RADIATION ARE PREDOMINANTLY ARID OR SEMI-ARID AND CAN HAVE ISSUES WITH SALINE WATER.

No solution on the market

There are simply no affordable products in this enormous market. Reverse Osmosis is expensive for small scale applications, requires high maintenance and is difficult to operate by just anyone. Some solar desalination technologies carry a high water-price due to lower productivity and short lifespans, whereas others require high initial investments.

SolarDew's products are unique in offering clean drinking water from any source at an affordable price of 1 to 2 Eurocents per liter (OPEX + CAPEX). This is lower than the local price set by water re-sellers, even in in developing countries.

Building strong relationships with partners and customers

Initially, SolarDew will focus it sales on two stepping stone markets, Chile and Oman, which are also gateways to a wider region. SolarDew will take a project-based approach to sell products to larger clients such as NGO's, governments and disaster relief organizations which are looking for desalination solutions for their communities.

SolarDew will be active in these markets through a network of dedicated local partners/distributors and aims to stimulate local economic development by manufacturing and assembling locally, where possible, whist ensuring that the product is adapted to the needs and requirement of the local customers. Corporate interest in SolarDew's technology from large water service suppliers and personal water purification equipment manufacturers has been rapidly growing, given the shift towards desalination, sustainability and point of use water supply. Together with interested parties SolarDew is discussing several strategic partnerships.

Bringing SolarDew to the market in 2020

In 2017/2018 the technology has been validated by an independent laboratory with ISO certification. In september 2019, prototypes will be tested in the field to demonstrate the performance of SolarDew's products. The first demonstration project for a launching customer be launched in the 1st half of 2020 following with manufacturing and market introduction of the 1st series at the end of 2020.

Improving the lives of One million people by 2030

SolarDew wants to provide one million people by 2030 with clean drinking water. In line with the United Nations Sustainable Development Goals, SolarDew will look to:

- Save 1200 children, under 5 years of age through consumption of safe water.
- Reduce emissions up to 3700 tons of CO_2 per year
- Reduce the number of plastic wastes by up to 350 million bottles/year
- Significantly reduce the daily time spent fetching water for 140,000 women

Conclusion

In the coming years our drinking water sources, like our energy sources will become more and more decentralized. SolarDew aims to have a positive impact on people's daily lives whilst minimizing the effect on our environment and our planet. SolarDew's vision is:

"Drinking water is not only a global problem to be solved but an opportunity for creating a new, sustainable business"

World Water Challenge 2019

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Main Topic 3

Water and Natural Disasters

Challenge

Urban flood prevention and management for sustainable water cycle and urban regeneration

Solution

Exploiting the synergies between sustainable urban drainage systems(SUDS) and urban farming in Vinh Yen City, Vietnam

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Mr. Hoang Anh Duc
Project Engineer, Ministry of Construction (MOC) - Vietnam Institute for Urban and Rural Planning (VIUP), VIETNAM

Solution

Exploiting the synergies between sustainable urban drainage systems(SUDS) and urban farming in Vinh Yen City, Vietnam

Bui Thi Hong Hieu, Hoang Anh Duc

Summary

The project "Exploiting synergies between Sustainable Urban Drainage Systems (SUDS) and urban farming in Vinh Yen City, Vietnam's pilots the synergies between handling rainwater through SUDS and using SUDS for small scale urban farming".
The project is implemented in the city of Vinh Yen, which is located approximately 50 kilometers North-West of Hanoi with a population of about 108,327 people. The city has long been prone to flooding and the project seeks to demonstrate one potential decentralized solution of establishing SUDS to retain some of the rain water.
SUDS covers the handling of rainwater on the surface and is often co-designed with urban green infrastructures. In several cities in Vietnam people (mainly women) have begun to grow vegetables etc. on roof tops and in back yards. There is thus a potential to combine SUDS with urban farming elements and educate the users in maintaining the system while they use it for urban farming.
The objective of the project is to implement concrete SUDS designed with small scale urban farming elements, that besides making the urban area more resilient towards flooding, also will benefit a local community's social resilience by providing the local people (mainly women) the opportunity to grow crops such as vegetables, herbs and spices. The local women are empowered when the crops are either used as household supplements or as products to be sold at a local market. Furthermore, will the social elements of meeting other locals increase the social resilience of the community?
The project will evaluate SUDS effectiveness in mitigating impacts in floods, define which crops can be farmed in different types of SUDS, evaluate small scale urban farming's financial contribution to households, and evaluate urban farming's contribution to creating social resilience.
Text book guidelines on SUDS and small-scale urban farming for urban planning, as well as training and awareness raising material for other Vietnamese cities is developed during the project, and will be distributed by the Ministry of Construction (MOC).
The project is a result of collaboration between the Nordic Development Fund (NDF), NIRAS, the city of Vinh Yen, Vietnam Ministry of Construction (MOC) and Vietnam Institute for Environmental Planning, Urban Rural Infrastructure (IRURE). The project was implemented with significant finance from NDF. The project ran for 2.5 years and has a budget of approximately 500.000 EUR, of which 63.000 EUR will be allocated to constructing the pilot project.

Solution Description

Project name:
Exploiting synergies between sustainable urban drainage systems (SUDS) and urban farming in Vinh Yen City, Vietnam' pilots the synergies between handling rainwater through SUDS and using SUDS for small scale urban farming.

Region:
Vinh Yen City, Vietnam country

Budget:
EUR: 480,000 from NDF, total budget EUR 620,000

Period:
The duration of 30 months, start date is from 1st February 2016 to 1St August 2018.

Background:
Within the Vietnamese cities there is currently a trend where people (mainly women) grow vegetables on roof tops and in back yards, because they do not trust the quality of the commercial products and to save money. This movement is comparable to citizen driven small scale urban farming. Supporting this movement can increase environmental as well as social resilience. The latter by the creation and strengthening of social relations in a neighborhood especially among women and elderly people. The yield can either be included in the household as food or be sold. SUDS combined with small scale urban farming, in a Vietnamese context, will add dimensions of financial contribution to the household, empowerment of women and increased social resilience of the community. The project also includes the technical capacity of the SUDS implemented. Whereas the project will monitor and evaluate the retention effect of the SUDS that is the amount of rain water (m3) retained or delayed. This will indicate the SUDS effect in flood prevention and its effect as a measure in urban climate change adaptation planning.

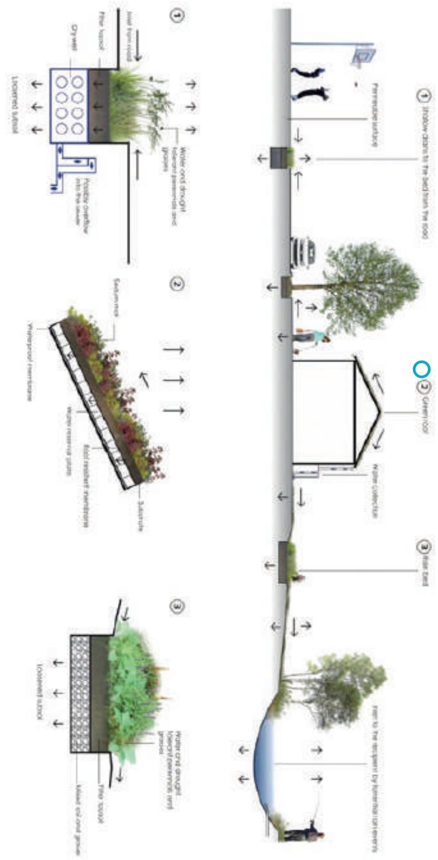


Figure 1: Illustration of SUDS in an urban area.

Objectives:
The overall objective is to expand the usage of SUDS in Vietnamese cities to increase climate resilience and social resilience. SUDS prevent flooding of livelihoods and critical infrastructure and combining it with urban farming will support the combat of poverty and empower locals (mainly women), when they can use the crops for cooking or sell them at the local market. Indirectly, urban farming as an integrated element of SUDS may also reduce the maintenance costs of SUDS. Despite the lower construction costs of SUDS, the maintenance costs are often hindering implementation.

Purpose:
The project has a twofold purpose:
1) To analyze, demonstrate and test the effectiveness of SUDS in mitigating impacts of floods and inundation.
2) To define crops suitable for urban farming in synergy with SUDS, to test the usability, and to evaluate local women's financial and social benefits.

Innovativeness:
SUDS is a gradually more practiced approach for managing the increasing threat of pluvial floods. The SUDS practices are designed to retain, infiltrate and/or evapotranspiration storm water, and reduce the amount of water that runs off the surface.
SUDS includes varies elements and technologies: e.g. like rain barrels to collect water from roofs, swales to facilitate infiltration to manage pollution and runoff, green roofs, permeable pavements, etc., that can be modified to suit the specific site conditions and other factors like affordability and social acceptance. A key feature of SUDS solutions is that they attempt to mimic nature that is to move the hydrological response of the urban area towards the pre-urbanized state.
The SUDS are thus already designed as a measure to prevent floods. The novelty of this project is to further design the SUDS to also be used by locals as urban farming elements, whereas the urban farming element is to be designed to be applicable without reducing the water retention effects of the SUDS. Furthermore, the locals are trained to also maintain the SUDS, so the systems' retentions effect will stay effective. The training will also create awareness of climate change. Many SUDS provide benefits other than flood and pollution control, for example SUDS have synergies with urban farming simply because they provide a place to do farming. Further they can add value to urban spaces by providing multifunctional green-blue spaces. These added benefits are also often termed 'ecosystem service value' are often ignored when drainage projects are budgeted. The innovation of this project is to exploit the synergies of SUDS as a flood prevention measure that besides contributing to urban green infrastructure and urban quality also contribute to citizen driven urban farming.

Relevance Climate change:
To avoid flooding in dense urban areas, it is necessary to mimic nature's natural retention abilities, whereas climate change adaptation means such as SUDS and green infrastructures are integrated into urban development. Increasing the green elements will also have a cooling effect on the city by reducing the urban heat island effect, which in the long term may reduce the usage of air conditioning and thus reduce greenhouse gas emissions. Furthermore, by strengthening cohesion in a neighborhood, social resilience is increased which may benefit in many situations, not only in cases of flooding.

Adaptation impacts:
Annual rainfall is projected to increase from 1.0 – 5.2% (low emission scenario) and 1.8 – 10.1% (high emission scenario) by 2100, and Vinh Yen City, as many other Vietnamese cities, already experiences inundation in the city center when heavy rain occurs. However, flood maps are not available and thus the local authorities do not have full insight in flow patterns as well as actual and potential risk areas. This knowledge contributes a solid analytic basis for developing a climate change adaptation action plan and implementing adaptation actions in the future.
Implementing SUDS instead of grey infrastructure, such as underground retention basins, are cheaper solutions that also mimic nature's retention abilities and retain rainwater where it falls. Urban green infrastructures and SUDS are well known to have a retention effect on rainwater, it is also well known that gardens are among the green infrastructures with the highest retention effect. A green roof designed as a garden can retain up till 90% of the water runoff from the roof.

Outputs:
1) Flood risk analysis of an urban area in Vinh Yen
2) Implementation of a SUDS integrated with urban farming
3) Engagement of local citizens (mainly women) in using the SUDS for urban farming
4) Test results of SUDS
5) Textbook guidelines to be distributed to other cities

Description:
This project pilots the implementation of actual investments in SUDS and its synergies with urban farming in Vinh Yen City. Vinh Yen is chosen because it plays a key role in Hanoi capital region and in the Northern economic region and is a city that experiences growth in the industrial sector and tourism sector. The industrial sector counts for 60 % of GDP and Vinh Phuc urban master plan to 2013, and vision to 2050, lays out 318.6 km2 of new land. Vinh Yen City and Vinh Yen Province experience high degrees of urbanization and industrial development, which degrade environmental quality and decrease agricultural land, and on the same time turn permeable surfaces into impermeable surfaces and thus degrade the land's natural rainwater retention.
Especially the poor are vulnerable to flooding and the related health issues, however, also critical infrastructure such as hospitals and main roads are at risk. To avoid flooding it is necessary to mimic nature's natural retention abilities and include climate change adaptation such as SUDS and green infrastructures into urban development. Increasing the green elements will also have a cooling effect on the city by reducing the urban heat island effect, which in the long term may reduce the usage of air conditioning and thus reduce greenhouse gas emissions.
The potential project site is located in the old city center at the conjunction between Ba Trieu and Me Linh streets (named Residential zone No. 1) (see figure 2). Some small parks (open space) are available. This site has experienced inundation when heavy rains occur (level of inundation: 50-70cm).
The project has implemented five small-scale pilot projects, four in private gardens and one in a kindergarten.

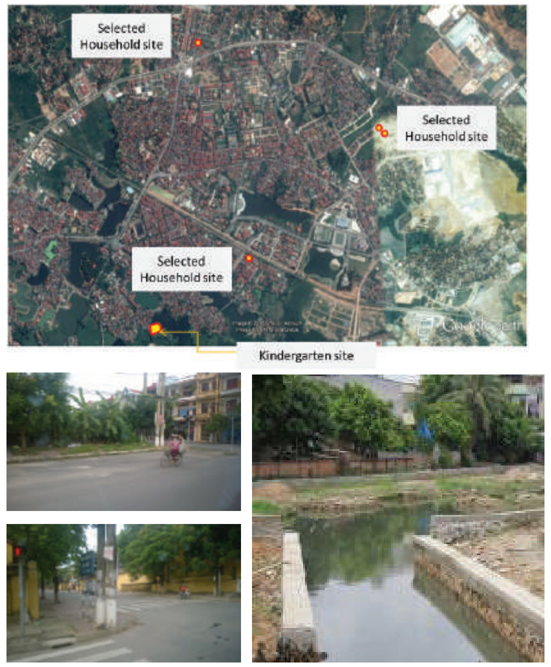


Figure 2: Pictures of the 5 potential project sites.

The activities and final outcomes:

1) A focused review of existing knowledge and gathering of formal requirements. An identification and description of the crops suitable for SUDS in Vietnam. Clarifying all relevant legislation and regulation related to selling the crops.

2) A flood risk analysis and selection of pilot area. Flood risk analysis and selecting pilot area. The activities include creating flood risk maps of Vinh Yen City (see Figure 3), consultation with main stakeholders on key local issues to be considered prior implementation, setting up criteria for pilot area, developing a spatial analysis of pilot area incl. availability of open space, roof tops and household gardens, reviewing SUDS suitable for urban farming, selecting pilot site.

3) Awareness rising and training. The activities of this work package continue throughout the project period. A study trip to Copenhagen for officials and a workshop


Figure 3: Flood Risk maps.

with Copenhagen officials on SUDS. Development of awareness rising and training workshop plan; engagement with local citizens on developing urban farming combined with SUDS; training of urban planners from the City of Vinh Yen and local NGOs, development of text book guidelines and training materials.

In the Vinh Yen project, workshops across the different stakeholders were the preferred method for involvement. Furthermore, training sessions of local government professionals and citizens were also applied (see Figure 5). In regard of defining the site areas for the five pilot projects, the main emphasis was placed on stakeholders with potential to be great ambassadors for the projects to showcase the benefits of combining SUDS with urban farming.

Figure 4: A study trip to Copenhagen.

Figure 5: Workshop for presenting and discussing guidance.

3) Implementation of SUDS: A significant effort will be allocated to describe and agree all issues which will support the actual implementation. The pilots showcase how climate change adaptation, urban farming and SUDS can be combined to provide a way of retaining water and at the same time produce crops. The project involves the construction of five pilot projects, one SUDS and urban farming system in a kindergarten and four pilots at rooftops and backyards in private households. The project site in the Kindergarten is additionally meant to teach the children, and subsequently their parents, about climate change and the need for climate change adaptation as well as grow organic vegetables that the kindergarten can use to cook (see Figure 6-a). In the four remaining pilots, the intention is to enable households to grow vegetables to cover their own need, and then establish an extra income source by selling any surplus produce. Additionally, when the project is scaled up, it will work as a water retention system, delaying the runoffs from the roofs to the sewers during rains (see Figure 6-b).

Figure 6-a. The SUDS's design drawing and the achievements of the Kindergarten.

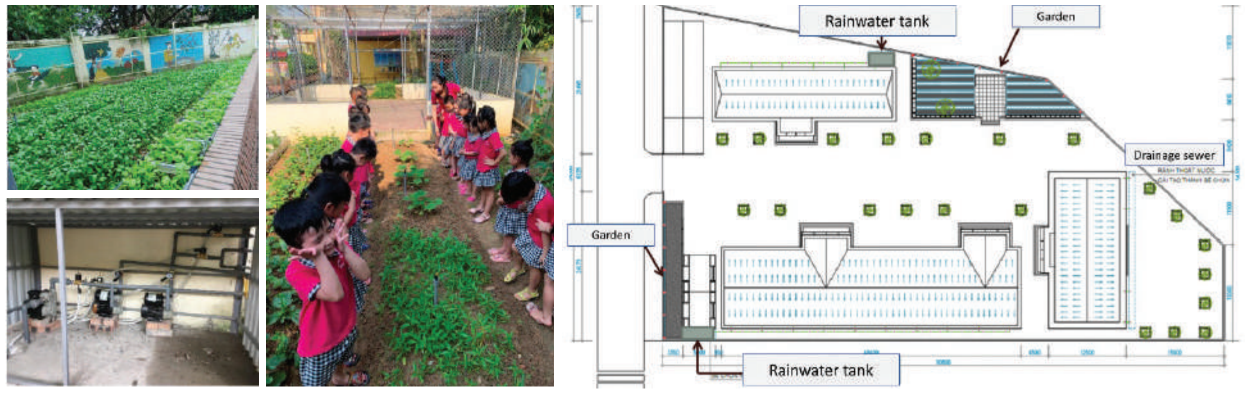
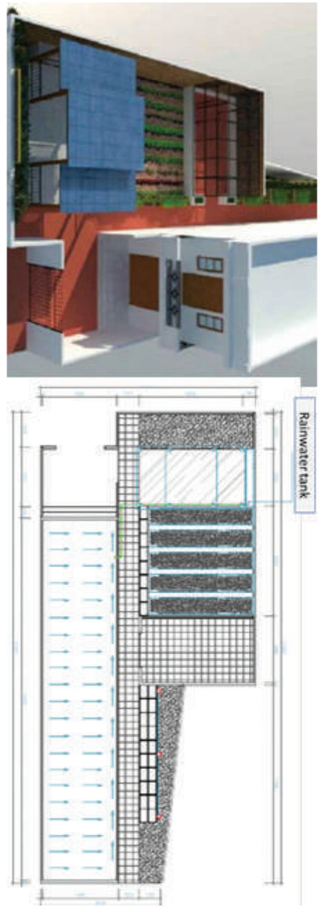


Figure 6-b. One of the four private gardens established with the SUDS.

4) Testing, monitoring and evaluation: Monitoring the retention effect (volume of rainwater) of the different SUDS, monitoring the effectiveness in mitigating flooding impacts, interviewing local women on their practical, financial and social experiences with using the SUDS for urban farming. The Vinh Yen pilots are integrated in the SUDS guidance as an example of small-scale SUDS with synergies to the interests of private households and with a teaching potential. Furthermore, an important aspect of the project was the success of the pilots and how they also functioned as Urban Farms in addition to collecting rainwater through the SUDS. The stakeholder feedback from the pilot projects has been overly positive. Two families expressed that they through the pilot cover their own consumption of vegetables, and still have some to spare. This surplus produce they give away. Additionally, due to connecting the SUDS to a gardening system, the inhabitants that usually used tap water for watering plants, now save money on their water bill. The evaluation from the kindergarten shows that the garden has successfully harvested three times within a seven months period. Children from the ages of three and up are participating in learning about climate change, and are planting vegetables and flowers at the kindergarten. The parents are also positive about the potential for the children to grow vegetables and flowers.

Landscape of the Kindergarten (Figure 6-a)

Landscape of the private household (Figure 6-c)



Landscape of the private household (Figure 6-d)

Landscape of the private household (Figure 6-e)

World Water Challenge 2019

Date September 5, 2019

Venue #320 EXCO | Daegu, Korea

Main Topic 3

Water and Natural Disasters

Challenge

The depletion and pollution of water caused by climate change

Solution

Rejuvenation of Lake Mahadevapura using Nature Based Systems

Mrs. Rohini Pradeep
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Solution

Rejuvenation of Lake Mahadevapura using Nature Based Systems

Rohini Pradeep

Summary

Mahadevapura lake rejuvenation is a very recent effort by CDD Society in collaboration with like-minded entities. After studying multiple cases of lake rejuvenation across the country, we zeroed in on using DEWATs, a nature-based technology to treat wastewater for rejuvenating a lake in Bangalore. DEWATS is a nature-based treatment system which has been implemented in India in such a large scale for the first time.
The system serves as a pilot project for us, at CDD, to understand the effectivity of the nature-based systems that have treated household wastewater for years, in treating wastewater for rejuvenation of lakes and natural water bodies. The project also uses passive treatment systems such as gabions and artificial floating wetlands to treat water further. Though commissioned very recently, this project spurred the organization to undertake multiple R&D activities, to improve multiple aspects of treatment system implemented in Mahadevapura lake.

DEWATS is both a product and approach which can solve the problem of wastewater management. By providing an enduring solution to wastewater management, DEWATS enables CDD Society to work towards its mission of preserving the environment, securing water resources and improving health and hygiene. This project is specifically very important for CDD Society as this involved DEWATS plant being able to treat such high volume of wastewater every day which otherwise would have flown into some water body.

The overall Mahadevapura lake project is an initiative which is in its initial stage and the DEWATS plant needs to get acclimatized with time to give the best results which adheres to the general effluent standards issued by Central Pollution Control Board.

Solution Description

About the lake:

Mahadevapura lake is situated in the eastern part of the city of Bengaluru. The lake has a large catchment area which includes residential and official buildings. The lake is a part of the Varthur lake series that drains southward to its downstream lakes. Like many other lakes in the city of Bengaluru, Mahadevapura lake's condition was dilapidating until the year 2016, when the city corporation realised the situation and started working towards the lake's restoration through basic interventions - such as desilting and deweeding the lake followed by constructing and improving inlet and diversion structures. The city corporation built all the necessary hydraulic structures to divert the wastewater entering the lake water body.

Eventually the responsibility of maintaining the lake and its surroundings was given to the community based not-for profit organization, United Way Bangalore (UWB), the Bangalore chapter of the United Way Worldwide. UWB helped in sourcing in the fund for improving the water quality of the lake by teaming up with companies (Mphasis, Amazon, Dell Technologies, HTC) through their CSR funding. This team selected CDD Society, Bangalore for providing technical expertise in design and implementation of a treatment solution for the inlet water into the lake.

The lake is spread over an area of 26 acres including its surrounding shoreline area. The water spread area of the lake is approximately 19 acres and has an average depth of 3.5 meters. The lake has four inlet sources. The sources being - a technology park housing IT offices, stormwater drains, upstream lake and residential area brings in a lot of pollutants into the lake. Inlet 1 brings in wastewater from the nearby Technological park building area which is diverted through the lake diversion channel to the downstream lake. The inlets allowed wastewater from residential areas and office complexes into the lake, other than the excess water channeled through storm water rains during heavy rains. The source of residential and commercial area wastewater flow to the Sewage treatment plant comes in through an improved earthen drain which was previously not having any direction. CDD Society intervened and constructed a channelized earthen drain to prevent the flow from getting deviated and ensure the wastewater entered the treatment system.

The sewage treatment plant designed and implemented by CDD Society is a nature-based solution. The treatment system is minimally dependent on electricity and is a chemical free solution. The treatment system - Decentralized wastewater treatment system (DEWATS) - is based on anaerobic processes which aim to mimic natural processes by providing ideal conditions for the microbial growth and activities. After treatment in DEWATS, the treated water is passed through gabions and constructed floating wetlands for tertiary treatment before flowing entering the lake body.

Introduction to DEWATS:

DEWATS, which stands for Decentralised Wastewater Treatment Systems, is both a product as well as an approach, which can solve the problem of wastewater management. It recommends a decentralized approach i.e. building many smaller systems to treat wastewater close to the point of generation. This also enables beneficiaries to maximise on resource utilization by reusing the treated wastewater, for example, in this case the treated water served to refill the lake body, thus recharging the groundwater level in urban areas, where groundwater level is reducing. Simply-designed using natural bacteria, plants and gravity instead of electricity, machines and chemicals, is what makes it ideal for developing countries like India. It is also very easy to integrate aesthetically into built environments and is adaptable to treat many types of wastewater. By providing an enduring solution to wastewater management, DEWATS enables CDD Society to work towards its mission of preserving the environment, securing water resources and improving health and hygiene.

DEWATS was first conceptualized and implemented in 2002. At the time, few technologies were available for wastewater treatment systems making these systems expensive to build and maintain. Hence, only large cities in India (e.g.: Mumbai) had primary treatment plants. As a result, dirty water and sewage would invariably end up in drains, rivers and lakes damaging the environment as well as people's health. The situation is not very different today. Even today, only about 250 cities (out of 7,000+ towns and cities in India) have partial sewerage networks and only 12-14% of urban sewage is treated, meaning India's cities alone discharge over 50 billion liters of untreated sewage daily.

A 2015 Government report revealed that 68% of municipal STPs did not meet discharge standards/were not functioning. There are several reasons for this – funds are not available, skilled manpower is hard to find, and

electricity supply in many parts of the country is intermittent or water supply isn't adequate for a sewer system to function optimally. Thus, wastewater is being dumped indiscriminately into the environment polluting even (once) clean waterbodies.
In a country facing rapidly worsening water shortages, this is doubly crippling — fresh water sources are becoming polluted and unusable, and wastewater which could be treated and re-used, is being wasted. Thus, an alternative requires not simply value engineering the modern STP, but re-examining and building new systems that are cost effective, easy to manage, less energy dependent, and that can locally re-use treated water. DEWATS meets all these criteria and thus has potential to have a huge impact on public health and environment. Till date, it has been accredited by a committee set up by the Prime Minister's Office to recommend clean technologies in India. It has also been mentioned in the Central Public Health and Environmental Engineering Organization's manual on Sewerage and Sewage Treatment.
We apply the adage, what cannot be maintained, shall not be built to our solutions. DEWATS thus has potential for mass implementation and the potential to provide improved sanitation across India – which is the project's main objective. Through DEWATS, the project provides an enduring solution to wastewater.

Systems installed for wastewater treatment for the Lake

A **DEWATS** has been set-up in northern part of the lake shore on 0.6 acres of land allocated by the city corporation. The cost of the entire initiative was INR 2 crore and the capacity of the treatment plant is 1 Million liters per day. In the design and implementation of the treatment plant following are the modules included:

Upstream diversion (USD) structure: USD structure set up in an area of 26 m2 is used for collecting water from the surface sources i.e. the 85-meter length earthen drain and conveying it further to the treatment plant.
Primary treatment: The open channel carries lot of grit/silt and solid waste from upstream area, which need to be trapped in the beginning for proper functioning of operational of plant. The screens are fixed to trap the solid waste. Grit/silt are trapped in the sedimentation basin with retention time of 0.5 hr. The overflow from silt trap is collected in the balancing tank for the purpose of the pumping of wastewater into secondary treatment. The pumping is be operated for 16 hrs/day.
Diversion channel: A diversion channel is a structure that conveys wastewater in an environmentally safe manner from the intake structure to the modules of Treatment plant. It has been built in a 20 m2 area.
Sedimentation tank: A sedimentation tank of volume 34 m3 allows suspended particles to settle as water or wastewater flows slowly through the tank, thereby providing some degree of purification. A layer of accumulated solids, called sludge, forms at the bottom of the tank and needs to be removed periodically.
Balancing tank: A balancing tank of 135 m3 volume is sufficient to permit a non-uniform flow of wastewater to be collected, mixed and pumped forward to a treatment system at a more uniform rate. Pumping is controlled by level sensors and its rate varies according to the depth of liquid in the balancing tank.
Secondary treatment system:The primary treated water will consist of organic matter which are in both suspended and colloidal solids, which is treated in combination of Anaerobic Baffle Reactor (ABR) with Anaerobic filters (AF). The ABR has a series of 5 up-flow chambers followed with the 2 chambers with filter in it having a total volume of 1437 m3. There are 5 such series. As wastewater flows through these chambers and filter, particles are digested by anaerobic microorganisms and reduce the organic load by 85-90%.
Anaerobic baffled reactor: Baffle reactors ensure anaerobic degradation of suspended and dissolved solids by mixing wastewater with active sludge blanket – these are naturally occurring bacteria that accumulate in the bottom of each chamber. The baffle reactor is suitable for all kinds of organic wastewater and its efficiency increases with more organics in the water (the dirtier the better).
Anaerobic filter: Anaerobic fixed bed filters make use of anaerobic digestion process with fixed film bed filter over cinder materials in the chambers. Active bacterial mass grows on the filter material (carrier). These units treat whatever is dissolved in the wastewater by bringing it in close contact with active bacteria mass. The filter media can be cinder, rock aggregates, slag, or specially designed plastic material etc. The filter media used in the treatment process is Cinder. These units are ideal for wastewater with low content of suspended solids.
Tertiary treatment: Combination of series of Gabions and floating wetlands are used as tertiary modules.
Gabions: Two gabions each of dimensions 26m by 1m spread over an area of 53 m2 are installed on the way of outlet from treatment plant to the lake. As water enters the gabions it breaks up into small streams due to the flow through the space between gravels. The water moving in small stream gets exposure to the air causing good aeration. The base of the gabions is held by geotextile. The geotextile helps in holding the loose soil below the gabions, Pond liner stop water from penetrating the soil below the gabions.
Floating wetlands: Twenty number of wetlands of dimension 5 m by 2 m, provide a floating mat of vegetation that floats up and down with the changing level of a water surface. The floating wetlands are utilized as a floating mat for the plants which float with changing levels of the water surface. The plant roots grow down through the buoyant structure made of 4 "PVC pipe, plastic mesh and coconut coir as the wetland medium into the water. Microbial growth occurs on the roots of the floating plants and transform the carbon and nutrients into simpler compounds.
Though there is a huge reduction in the pollutants which are of concern as stated by the PCB standards, still there is a need for even more improvement in the treated water quality in terms of nutrient reduction. As the system is just 4 months old, it is believed to get acclimatized and produce better quality result with time of 6-8 months. A re-evaluation of the water quality parameters after this duration of time will represent a better picture of the treatment efficiency of the STP. The wastewater treatment plant is being operated and maintained by CDD Society through an O&M contract for two years.

How is DEWATS different from other technologies and its application in other places:

The modules are designed for 3 levels of treatment, purifying the water further at each stage - primary, secondary and tertiary – till standards are reached.
Its costs and economic benefits can be understood by comparing with two alternatives — large scale centralized sewage systems, and small-scale sewage treatment plants that use traditional electro-mechanical systems.
Large-scale, centralized treatment plants require high capital investment to build pipelines, pumping stations and treatment plants. They thus require digging and can be disruptive taking 3-10 years to implement. Typically, initial costs are in the range of Rs. 14,000-25,000 per citizen. Additionally, operating these systems can cost Rs. 3,000-5,000 per person per year for continuous power, skilled operators, chemicals etc. (Due to this complexity, very few centralized treatment systems in India have been successful).
Other decentralized technologies such as SBR, MBBR cost about the same as DEWATS to build but operating costs are typically 4-6 times higher as they need electricity, 24x7 trained operators and chemicals. (This is why many buildings shut down their small-scale STPs to save cost but as a result, the sewage leaves the system untreated.)
DEWATS, in comparison is de-centralized and recommends the set-up of small systems, which in-turn require less pipelines. The initial capital investment may be Rs 6,000-8,000 per capita while operating costs are very low, about 90-95% lower than centralized systems.
When compared to both alternatives, on a lifecycle cost basis, DEWATS wins hands down.
The scope of DEWATS is pretty wide. We have set up DEWATS for housing complexes, hospitals, schools, slums, universities and other communities that need to treat their sewage, but where the municipality does not have sewerage networks. Many urban and peri-urban areas are becoming water stressed, especially in summers. DEWATS allows re-use of the treated water, thereby protecting fresh water supply and reducing water costs.
Specific examples of the scope of our DEWATS in India include:

(a) Aravind Eye Hospital in Pondicherry (Tamil Nadu) (which receives about 5,000 visitors a day) has saved over 100,000 m^3 of fresh water through recycling and re-use

(b) VBHC Value Homes Pvt. Ltd. (Karnataka) - first instance of a large housing complex implementing DEWATS in India

(c) In Nagpur (Maharashtra), the DEWATS set up at the weekly market now disposes only treated water into the lake preventing further degradation

(d) In Gorakhpur (Uttar Pradesh), we set up a DEWATS in a peri-urban area where due to lack of proper irrigation facilities, small and marginal farmers were using wastewater for irrigation - risking diseases caused from the consumption of vegetables grown with this water.

(e) In the case of the 2004 tsunami, 22 DEWATS were set up for 225 houses built for those displaced by the tsunami. During emergencies, the risk of an epidemic is high and these DEWATS provided much needed post-disaster sanitation relief.

World Water Challenge 2019

Date September 5, 2019
Venue #320 EXCO | Daegu, Korea

Main Topic 1

Efficient Water Management

Challenge

Integrated management of diversified water resources

Solution

Smart Technology for Integrated Management of Diversified Water Resources

Ms. Wala'a Mhammad Khalaf Bani-Mostafa
Researcher, Water Authority of Jordan, JORDAN
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Solution

Smart Technology for Integrated Management of Diversified Water Resources

Wala'a Mhammad Khalaf Bani-Mostafa, KukHeon Han

Summary

One of the biggest challenges in the 21st century has been securing of adequate water supply for the urban cities in the world. Furthermore, it is not enough to simply use only freshwater, which is already limited, for the rapid growing and urbanized population of the world. The ever-changing climate also impacts the availability of water, creating high water stress during the dry seasons. The concept of using multiple sources of water which includes dam, lake, and ground water, but also non-conventional water such as seawater, rainwater, and reclaimed water is called diversification of water resources. By the implementation of diversification of water resources, the problem of water stress can be managed in a sustainable way as well as meet the ever-growing demand. Multiple sources can supplement each other and help reduce the overall water stress even in the harshest of climatic conditions. In order to facilitate such diversification and to meet the current as well as future demands of the urban cities, proper identification and management of locally available water resources is also very necessary. In this regard, we have proposed the solution, which is **"Smart Technology for Integrated Management of Diversified Water Resources"**, and have applied it to Jordan and Korea. The proposed solution is expected to guarantee the sustainability in supplying water by using all available water resources.

Solution Description

1. Selected Problem

Among given 10 challenges, the following one is selected:
"Integrated management of diversified water resources"

2. Challenges to Be Addressed

Conventional water management has shown limited capability for providing ongoing fresh water supply to people. This is attributed to the fact that the conventional systems rely on using only one type of water resource, leading to an increase in risk of the water imbalance.
There are two examples of the challenges on the water management:

- **Jordan:** The water source of the northern region of Jordan is mostly underground water, and some of it is springs and discharged water from a sewage treatment facility. Currently, Irbid and Mafraq provide an amount of water to Jerash and Ajloun. The water supply ratio in 2015 was above 90%, while the per capita water supply quantity and consumption quantity per person (less than 80 lpcd) is lower than the average value in Amman and Jordan due to the high NRW (average 52%) water ratio and the increased leakage ratio caused by the deterioration of facilities and intake various kinds of water sources.

- **Korea:** Yeongjong Island, which has the Incheon International Airport, relies on the single water resource (Han River- Gongchon WTP) and does not have any alternative options that may be required in case of equipment failure, drought or accidental pollution. Therefore, if an accident occurs along the main water pipe in the sea, no other water alternative is available on this island. This will also lead to a catastrophic impact in the operation of the airport.

To achieve more resilient water management, it is essential to diversify water resources. In fact, there are various sources of fresh water, including surface water, ground water, harvested rainwater, desalinated seawater, and reclaimed wastewater. The integrated management of diversified water resources is a key to success in efficient water management.

Hence, the key words/challenges for the "Integrated Management of Diversified Water Resources" can be summarized as: Vulnerability, uncertainty, resilience, climate change adaptation, risk management (decentralization) and marginal water quality of supplied water.

3. Proposed Solution & How it works

An innovative approach that has potential to solve the problem associated with the selected problem is: "Smart Technology for Integrated Management of Diversified Water Resources". This technology consists of two key enablers:

- **Water Demand Monitoring and Demand Forecasting**
  To facilitate the diversification of water resource, it is critical to understand how much water is currently and will be required. This can be done by : 1) Real time demand pattern analysis and monitoring by utilizing the AMI data for demand forecasting (figure 1 & 2) and 2) Planning and simulating for optimal sizing of water systems in newly developed cities using the demand patterns.

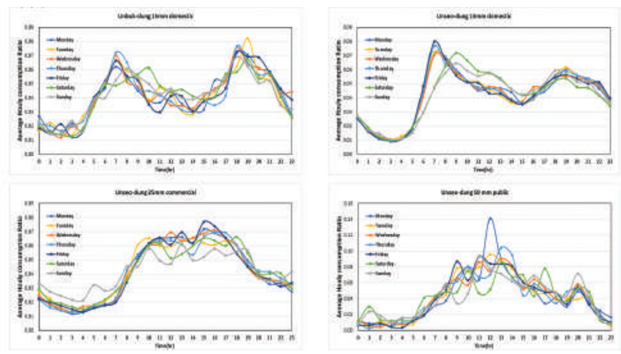

Figure 1. Demand patterns of different types of water use

Figure 2. Real-time smart water monitoring gadget (AMI)/ water meter/sensors

- **Demand Based Integrated Management of Diversified Water Resources**
Smart real-time platform for "Integrated Management of Diversified Water Resources", that we developed consists of six SWG analytics i.e. SWG-STAT, SWG-DSM, SWG-DSS, SWG-HyNet, SWG-DBM and SWG-App. It integrates the AMI data and reference layers in a single platform as shown in figure 3.

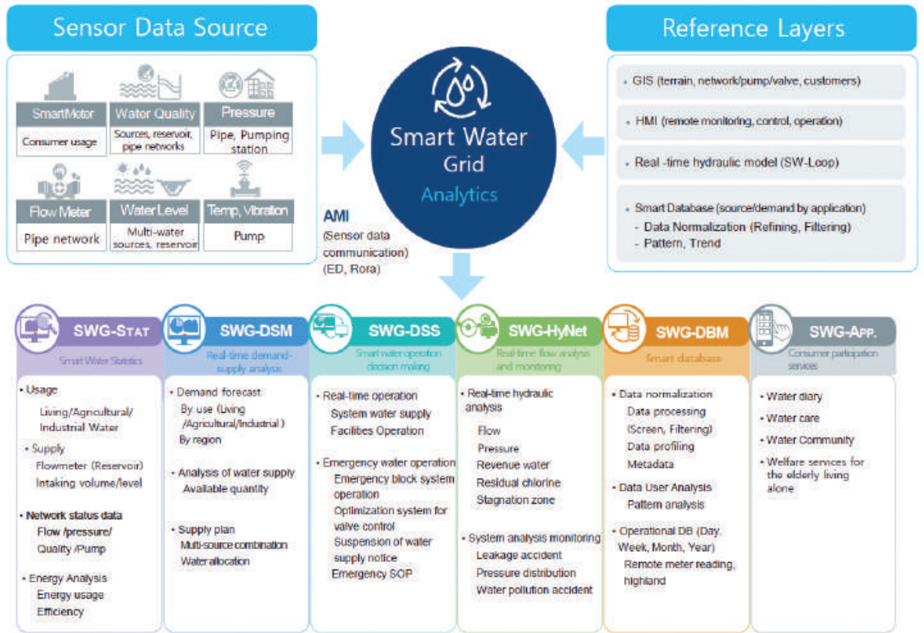

Figure 3. Smart real-time platform for integrated management of diversified water resources

One of the key technology of SWG is the real time demand and supply management as shown in figure 4 for securing water with efficient water management. It integrates real time multi-sources water and real time multi-water demand with the use of ICT to solve the water shortage problem.

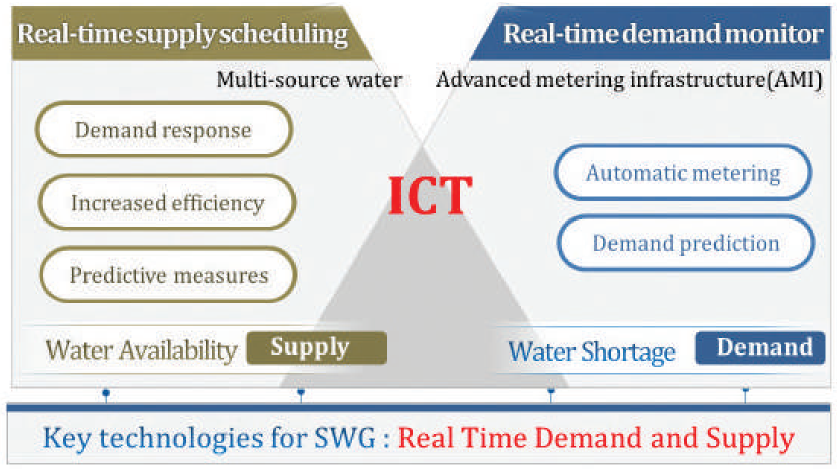

Figure 4. Securing water with efficient water management

We also have developed SWG & LID linkage intelligent urban water resource management as shown in figure 5. For optimal water intake from diverse water sources to satisfy the multi water demands, we have developed the optimization framework as shown in figure 6.

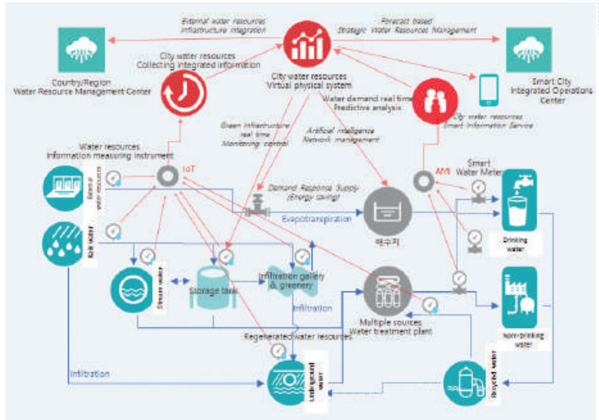

Figure 5. Conceptual diagram of SWG + LID linkage for intelligent urban water resource management

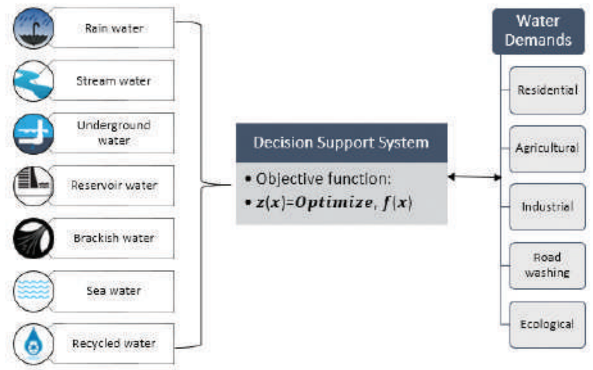

Figure 6. Optimization framework using multi-sources water and multi- water demands

4. Statement of Justification

The proposed solution has the following key points:

- **Contribution to "Sustainability":** Smart Technology for Integrated management of diversified water resources Water sustainability could be defined as supplying or being supplied with water for life or, perhaps more precisely, as the continual supply of clean water for human uses and for other living things. In this context, it is evident that the proposed solution can guarantee water sustainability by using all available water resources with reduced electricity consumption.

- **Feasibility:** Smart water technology for integrated management of diversified water resources have been developed since 2012 and now they are ready to practical implementation. The technology has also been demonstrated in pilot and full scales in Incheon city since 2016. The technical, economic, and legal feasibilities have been fully confirmed in Korea and they may be also done without any serious problems in other countries.

- **Challenge:** The proposed solution is a cutting-edge technology based on the convergence of information and communication technology (ICT), which allows the seamless integration of various water resources. Accordingly, the challenges posed by the selected problem can be overcome by adopting this solution.

- **Impact:** The application of the proposed solution reduces the uncertainty associated with water supply, thereby promoting the efficient water management. In addition, an excessive use of fresh water resource will be prevented. This will bring mutual benefit for ecosystems and human beings.

5. Case Study: Implementation of the proposed solution in Jordan and Korea.

5.1. Smart Water Management Plan for Qeerwan Water Supply System, Jordan

Qeerwan area of Jordan is in huge water shortage problem and the limited water supply is inevitable due to high water leakages and the seasonal volatility of the water sources. There are small and medium sized multi-sources water available in the Qeerwan. Some of them are Mastal Fisal well fields, Qeerwan spring water, Mafraq (Zatary well field), Jerash reservoir, sea water and brackish water (figure 7).

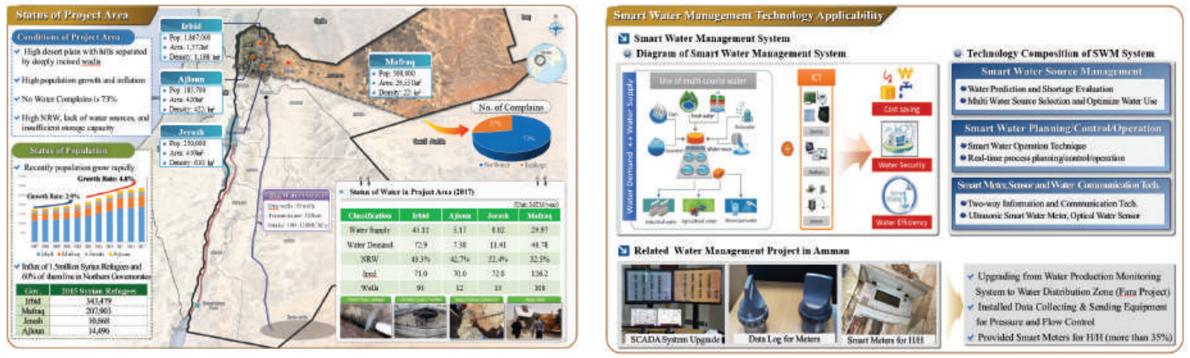

Figure 7. Smart water technology applicability in Qeerwan, Jordan

So, the use of diversified available water sources together with following techniques can solve the problem.

- Rehabilitation the Qeerwan treatment plant with intelligent water source management.
- Installation of Smart meters, sensors and communication technology.
- Development and application of smart water information integrated operation system.
- Prioritization on withdrawal among multi-sources considering sustainability of aquatic ecosystem.

The water supply service quality can be dramatically improved by introducing energy saving measures and a systematic monitoring and control system as shown in figure 7 & 8. Application of smart water technologies along with diversification of water resources in Qeerwan area provides mainly the following types of benefits:

- Reduction of water production cost.
- NRW reduction and increase in energy saving as expected in the figure 9.

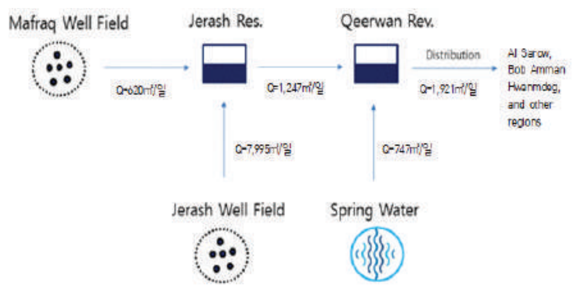

Figure 8. Diversification of water sources.

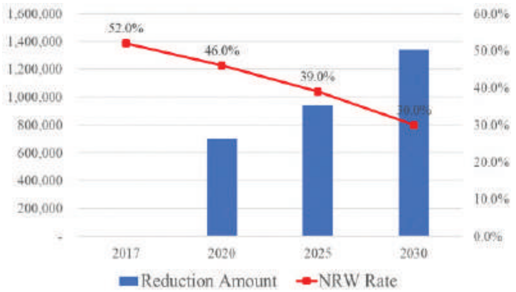

Figure 8. Project benefit with reduction of NRW

5.2. Optimized Water Intake from Multi-Sources in Yeongjong Island, Rep. of Korea

There are 7 possible alternatives locally available, small to medium sized multi-water resources in Yeongjong Island, Korea. They are brackish water (3-reservoirs), ground water, stream water, reservoir, sea water, rain water harvesting and recycled water. Here, we developed a multi sources water selection model for the optimal selection of locally available multi water sources, one of the key technology of smart water grid (figure 10). Generalized Reduced Gradient (GRG) and Genetic Algorithm (GA) are used to solve the applied model. The model is tested in the Yeongjong Island of South Korea and is able to address the problem during the emergency optimally.

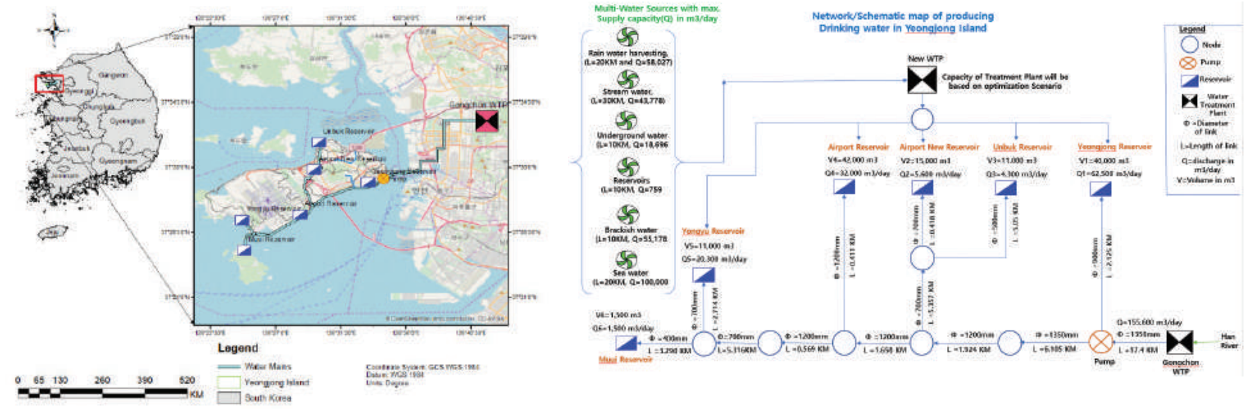

Figure 10. Existing water supply system and proposed system with diverse water sources.

The diversification of the water resource in Yeongjong island provides three types of benefits:

1) Benefits to water customers due to the introduction to smart water metering;
2) cost reduction in water production by approximately 10 %; and
3) lower incidence of leaks by up to 5 %. The result of the economic analysis is summarized in Table 1.

Table 1. Economic analysis for diversification of the water resource in Yeongjong island

Classification	Current value (Unit: 10^6 won)
Consumer benefit	407.0
Cost reduction in water production	4,903.6
Lower incidence of leaks	3,251.3
Total	**8,561.8**

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