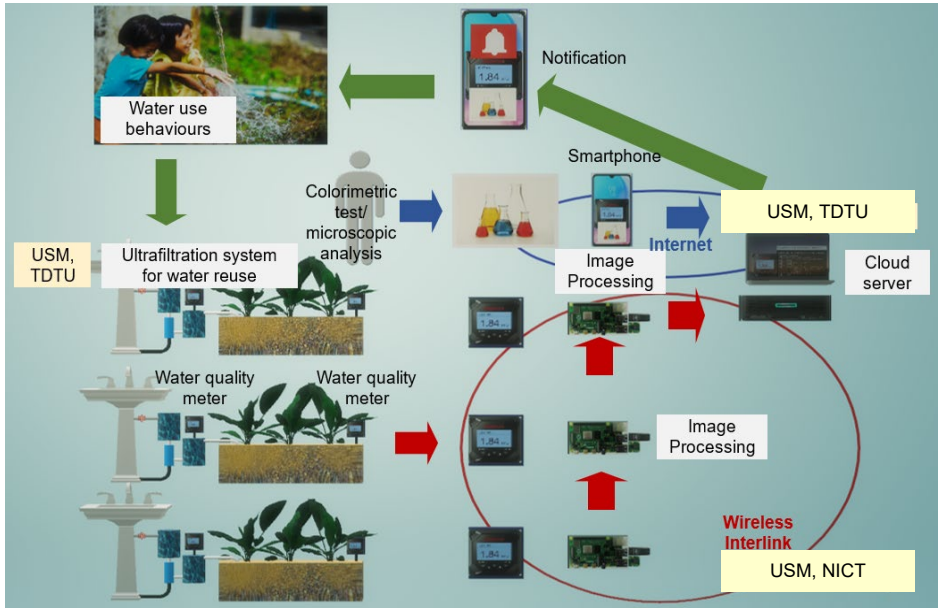
Project Title: IoT for water reuse in developing cities

Background :

Due to the limited water resources, the increasing urban water demand and the climate change, many urban water systems are facing the ever- increasing pressure to supply potable water. Water reuse technologies has been extensively developed over the years under the promotion of city sustainability. Many water reuse projects failed in the past due to the insufficient monitoring and maintenance. Hence, it should be paired up with ICT technologies which allow the real-time analysis and monitoring of water quality to preserve the water reuse system and the safety of vulnerable citizen. Moreover, big data should be collected through IoT to improve water management in cities.

Targets:

- To develop low cost and sustainable membrane filter for water reuse.
- To develop image processing for the analysis and recording of water quality.
- To gain insights from water quality, reusability and use behaviors in ASEAN countries.



Speaker: Assoc. Prof. Ir. Dr. Leo Choe Peng

Project Title:

Project Members :

Ir. Dr. Leo Choe Peng

Universiti Sains Malaysia

Ir. Dr. Yen Kin Sam

Universiti Sains Malaysia

Dr. Yu Kok Hwa

Universiti Sains Malaysia

Dr. Ho Ngo Anh Dao

Ton Duc Thang University

Mr. Nguyen Thanh Quang
Ton Duc Thang University

Dr. Huan-Bang Li

National Institute of Information and Communications Technology

Dr. Takeshi Matsumura

National Institute of Information and Communications Technology

Project Duration :

2 Years

Project Budget:

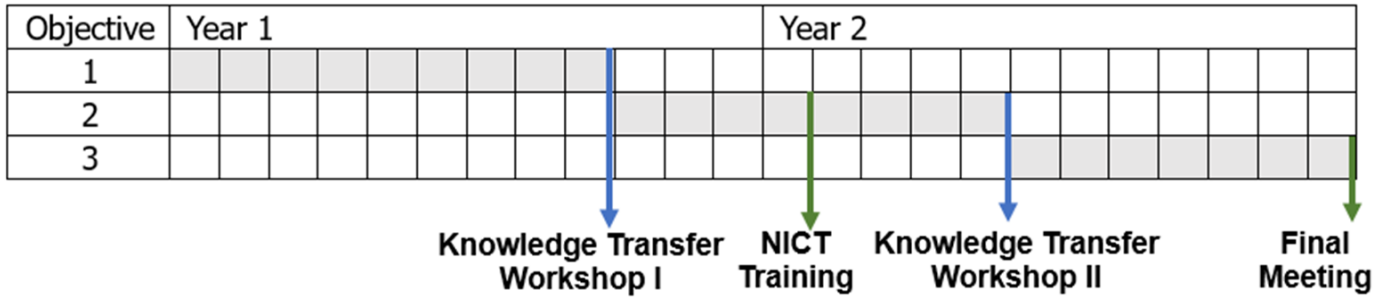
USD 69,500.00
current budget balance : 45,477.60 USD;
Budget to be spent by end of Nov 2022: 15,85260 USD
maximum budget that can be carried over 2022: 29,625.00 USD

Project Activities:

Milestones

- Completed: design and implementation of ultrafiltration system for greywater treatment (USM and TDTU) by December 2021.
- In progress: development of water quality analysis and monitoring procedures using image processing (USM, TDTU, UBD) as well as the D2D wireless system (NICT) by August 2022.
- In progress: development and implementation cloud-based application software for water quality analysis and monitoring (USM, UBD, NICT) by April 2023.

Gantt Chart



Knowledge Transfer Workshop I Completed

NICT Training Postponed (2023)

Knowledge Transfer Workshop II Planned (February 2023)

Final Meeting (April 2023)

Project Meeting by USM

- Virtual meetings were conducted biweekly except public holidays or the absence of project leader.
- Physical meeting was organized once the control of borders under pandemics were lifted.

29/8/2022 (USM)	Activities	Participant
8.30-10.30am	Report and discussion on progress Part I	Huan-Bang Li; Matsumura Takeshi; Leo Choe Peng; Yu Kok Hwa; Ho Ngo Anh Dao
10.30-11.00am	Tea Break	
11.00-1.00pm	Report and discussion on progress Part II	Huan-Bang Li; Matsumura Takeshi; Leo Choe Peng; Yu Kok Hwa; Ho Ngo Anh Dao
1.00-2.00pm	Lunch	
2.00 – 4.00pm	Visit to the D2D system and water reuse system	Huan-Bang Li; Matsumura Takeshi; Leo Choe Peng; Yu Kok Hwa; Ho Ngo Anh Dao
4.00-4.30 pm	Tea Break	
4.30 – 5.30pm	Visit to School of Mechanical Engineering	Huan-Bang Li; Matsumura Takeshi; Leo Choe Peng; Yu Kok Hwa; Ho Ngo Anh Dao

Knowledge Transfer Workshop by USM

- Knowledge transfer workshop include 36 participants from NICT, TDTU, USM (Engineering Campus and Main Campus), Universiti Malaysia Perlis, Monash University, Universiti Kebangsaan Malaysia, local industry, and representative from the Institution of Engineers, Malaysia.

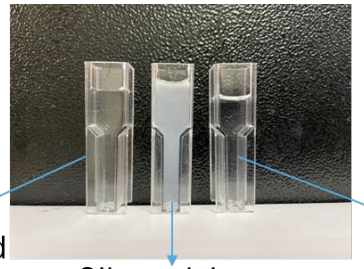
30/8/2022 (Iconic Hotel)	Activities	Speaker
8.30-9.00 am	Welcome remarks	Project Leader
9.00-9.30 am	Opening remarks	The Dean of the School of Chemical Engineering
9.30-10.00 am	Introduction to NICT	NICT
10.00 -10.30 am	Tea Break	
10.30 -11.30 am	Membranes for water reuse	Assoc. Prof. Dr. Poh Phaik Eong (Monash University)
11.30 am -12.30 pm	D2D Technology	Prof. Dr. Huan-Bang Li (NICT)
12.30 pm – 1.00 pm	Networking Session	Participants to exchange name cards and network.
1.00 -2.00 pm	Lunch	
2.00-3.00 pm	The transformative powers of Big Data and the Internet of Things (IoT).	Mr. Chan Zhen Yu, WyseTime Technologies Sdn. Bhd.
3.00-4.00 pm	IR4.0 for water recovery	Assoc. Prof. Dr. Mohamad Hanif Md Saad (Institute of IR4.0, UKM)
4.00-5.00 pm	Dielectrophoresis for water quality monitoring (Virtual)	Dr. Muhamad Ramdzan Buyong (Institute of Microengineering and Nanoelectronics)
5.00-5.10 pm	Closing remarks	Project Leader
5.10 – 5.30 pm	Networking and tea break	Participants to exchange name cards and network.

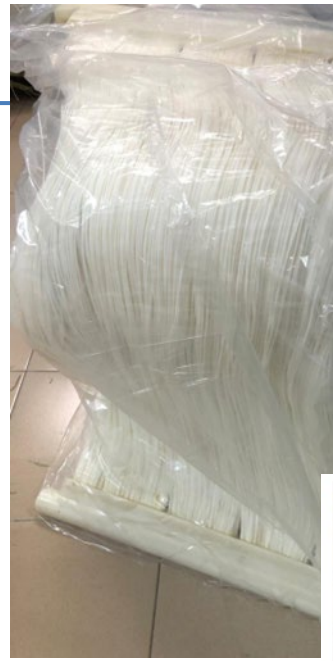
Photos of workshop:

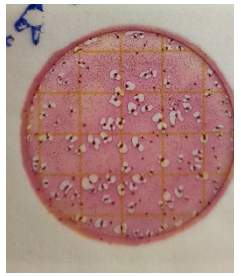
R&D results:

Membrane modification for water reuse
by Assoc. Prof. Ir. Dr. Leo Choe Peng

- The commercial hollow fiber membranes with oil rejection of 34.2% were chemically modified and rearranged into a membrane module.
- The removal of oil in the feed was improved from 77.3% to 83.2% by changing the coating material from ethanol to lignin.
- However, the water permeation was reduced (> 40%) and $CaCO_3$ was added as the pore template for lignin coating.
- Oil rejection was improved to 90% and permeate flux was enhanced (permeation reduction <20%).
- In addition, electrically conductive membrane and electrochemical cleaning were developed.

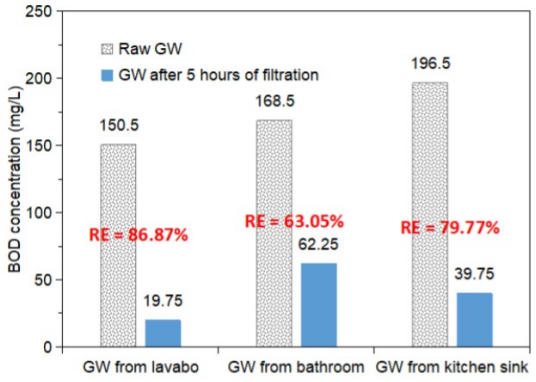


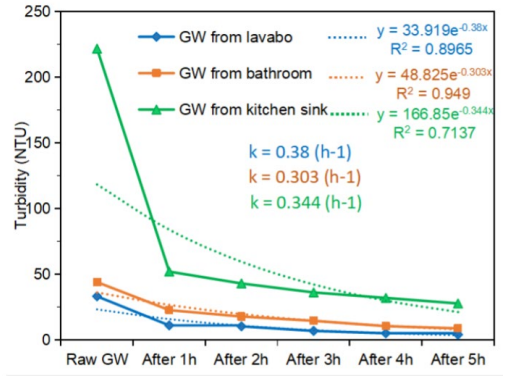


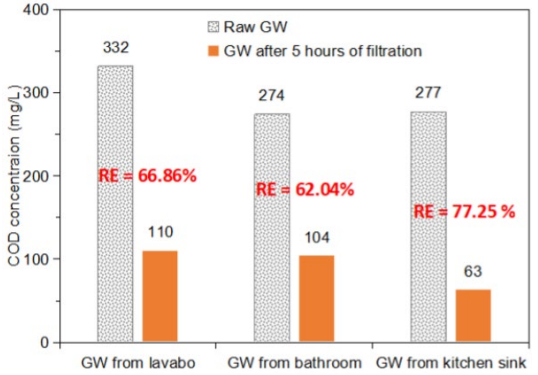


Greywater treatment for irrigation at TDTU
by Dr. Ho Ngo Anh Dao

- The membrane modification methods were transferred from USM to TDTU and the modified membrane was installed into a greywater treatment system in TDTU.
- The treated greywater from lavabo fulfilled standard C stated in TCVN 12180-2:2017, ISO 16075-2:2015 for irrigation purposes.







Coliform MPN/1ml with dilution of 1000 times

Type of GW	Raw GW	After 5h	RE (%)
GW from lavabo	$350x10^5$	$166x10^5$	52.57
GW from bathroom	$63x10^5$	$43x10^5$	31.74
GW from kitchen sink	$10080x10^5$	$5580x10^5$	44.64

Evaluation of turbidity measurement using IOT

by Dr Yu Kok Hwa and Mr. Nguyen Thanh Quang

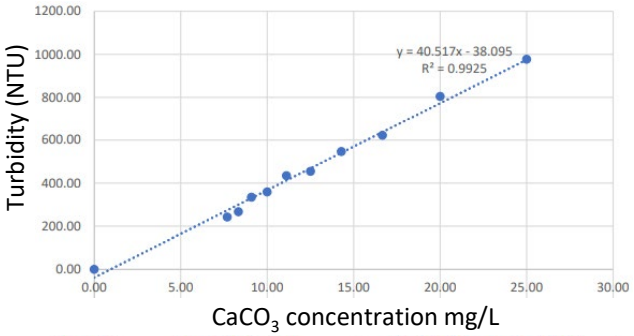
The turbidity measurement using IoT water quality monitoring system was studied to identify the difference from the standard method.

The gravity arduino turbidity sensor measures turbidity or opaqueness using light transmittance and scattering rate, which changes with the amount of total suspended solids (TSS) in water.

A new voltage-turbidity conversion equation was derived for the turbidity sensor and then applied in the measurement of turbidity caused by $CaCO_3$ nanoparticles, oil emulsion, and dye.

The turbidity measurement on calcium carbonate solution was strongly affected by the sensor selection, ranging between 1.10 and 15.99%. As for the time-based turbidity measurement, the liquid solutions used are calcium carbonate solution, oil emulsion, dye solution, and protein emulsion. The dynamic measure of solution turbidity was affected by the settlement of $CaCO_3$ and the separation of oil emulsion.

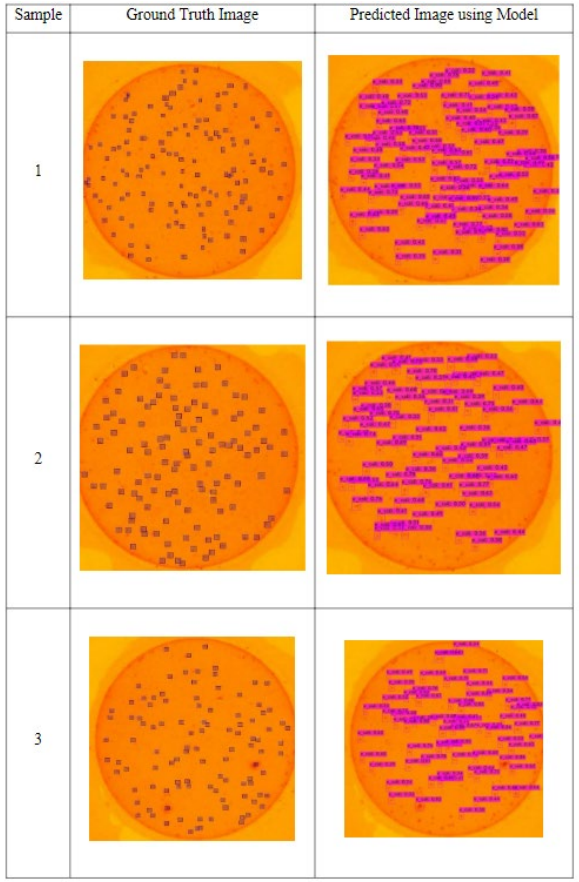
In conclusions, the limitation of sensor should be studied before implementing.



Detection and counting of E. coli on petri film using YOLO v4

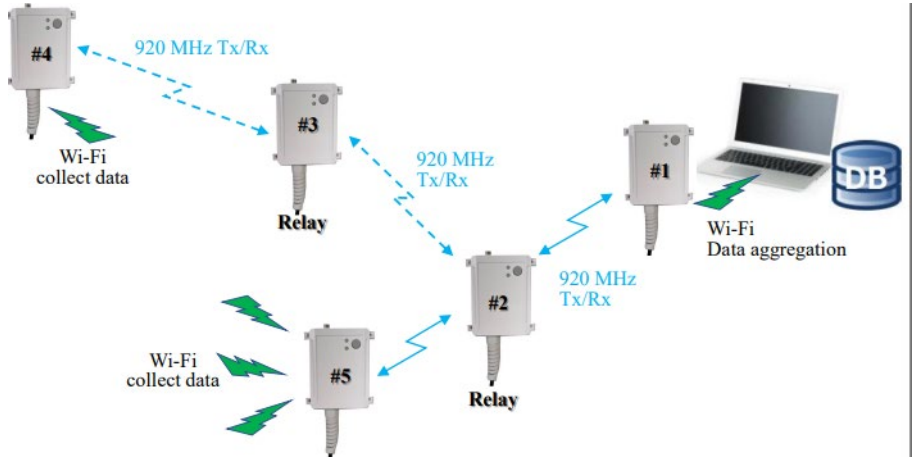
by Ir. Dr. Yen Kim Sam

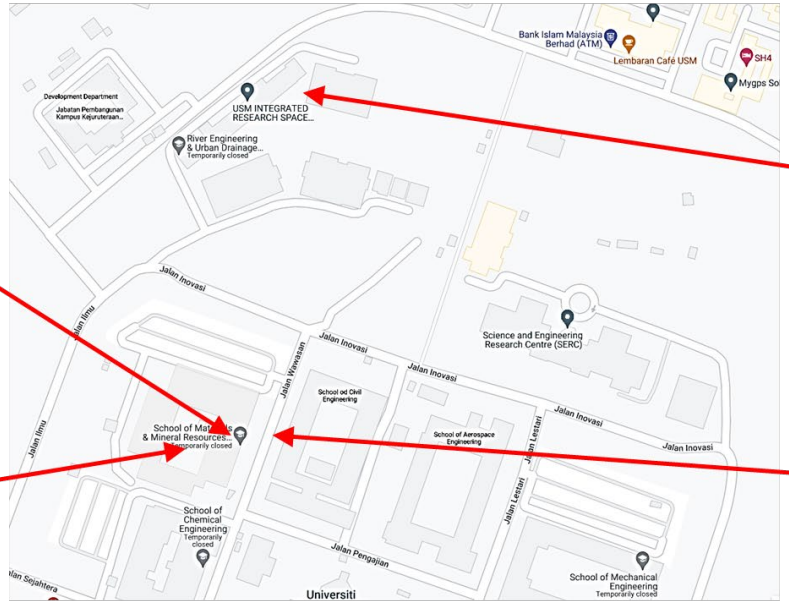
- The presence of Escherichia coli limits the water reuse purposes and the safety of water is measured by colony forming unit per 100mL (CFUs/100mL).
- Since the manual counting by a laboratory personnel is time-consuming, there is a dire need for vision automation in the count of E. Coli bacteria.
- The study includes the usage of machine learning capabilities to detect and count the colony present on the commercial petri film.
- The sample images obtained from the analysis of lake, drainage and river samples was captured under the selected lighting condition before augmentation.
- The processed images are then annotated using Label Studio and later trained using YOLO v4, an object classifier network that employs Convolutional Neural Network (CNN).
- The network is being trained to pick up presence of E. Coli on petri film in the unit of CFU.
- The results showed that with only 50 test piece sample images, the model achieve amAP accuracy of approximately 75%, IOU score of 0.82 and an average loss of 3.6555.
- During the test phase, this work recorded a precision of 0.9087±0.00737, recall of 0.0.9468±0.00573 and F-score of 0.9273±0.00577.



D2D Wireless System for Water Reuse System by Dr Huang-Bang Li and Dr. Takeshi Matsumura

For data transfer, 4 units of antennas were successfully installed in USM for the development of D2D wireless system.
It encloses 920 MHz radio module and CPU with build-in Wi-Fi as interface for senser data and image/picture transmission and aggregation.
Manual of operation was developed and pass down to USM team.
USM team will study the transfer of data from IoT sensor into the D2D wireless system.





Scientific Contribution:

Presentations at International Conferences:

No:	Paper title:	Author names	Affiliation	Conference name	The date of the conference	The venue of the conference
1.	Optical Segmentation on E. coli colonies formed on E. coli test piece (Petrifilm) - for the development of IoT devices for water quality monitoring	Teoh Mynn Wei, Yen Kin Sam, Yap Jia Xin, Leo Choe Peng, Namal Arosha S. Senanayake Mudiyanselage	Universiti Sains Malaysia, Universiti Brunei Darussalam	ASEAN IVO Forum 2021	18/11/2021	Virtual
2.	Development of IoT Water Quality Monitoring System	Tay Ying Keat; Yu Kok Hwa; Yen Kin Sam; Leo Choe Peng; Hong Chia Huey	Universiti Sains Malaysia	ASEAN IVO Forum 2021	18/11/2021	Virtual

Scientific Contribution:

Published Journal Papers:

No:	Paper title:	Author names	Affiliation	Journal name:	The publisher of the Journal	The volume number and Pages
1.	Porous cellulose beads intercalated with calcium carbonate nanoparticles for dye adsorption	Jia Xin Yap, Wei Chee Gan, C.P. Leo	Universiti Sains Malaysia,	Desalination and Water Treatment	Taylor & Francis Online	doi: 10.5004/dwt.2022.28938
2.	Electrochemical cleaning of superhydrophobic polyvinylidene fluoride/polymethyl methacrylate/carbon black membrane after membrane distillation,	N.A. Zakaria, S.Q. Zaliman, C.P. Leo A.L. Ahmad, B.S. Ooi, Phaik Eong Poh,	Universiti Sains Malaysia, Monash University	Journal of the Taiwan Institute of Chemical Engineers	Elsevier B.V.	2022, 38, 104448
3.	3D imprinted superhydrophobic polyvinylidene fluoride/carbon black membrane for membrane distillation with electrochemical cleaning evaluation	NA Zakaria, SQ Zaliman, CP Leo, AL Ahmad, BS Ooi, PE Poh	Universiti Sains Malaysia, Monash University	Journal of Environmental Chemical Engineering	Elsevier B.V.	2022, 10 (2), 107346

Societal Impact:

- 2 chemical engineers, 2 mechanical engineers, and 3 electrical and electronic engineers improved their engineering competence through the interdisciplinary collaboration.

- USM (2 final year students, 1 MSc. student) and TDTU students (2 undergraduate students) learned on IoT and water reuse technologies in the experimental works.

- 36 participants, including representative from local universities, industry and professional society enhanced their knowledge on ASEAN IVO Project, NICT, IoT and water reuse technologies in Knowledge Transfer Workshop.

Conclusion:

- Water reuse requires improved treatment technology, and sensors to meet the local standards.
- Image analysis enhanced the analysis of water quality for reuse.
- Data collection is essential to gain
  in insights from water quality, reusability and use behaviors in ASEAN countries.

Future works:

USM:

- Purchase sufficient items to sustain the water reuse system.
- Study the data transfer between IoT sensor and D2D wireless system.
- Arrange training at NICT.

TDTU:

- Conduct Knowledge Transfer Workshop
- Prepare manuscript for submission to indexed journal.

NICT:

- Study the stability of D2D wireless system.
- Arrange training at NICT.