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: IoT for water reuse in developing cities

Project Members :

Ir. Dr. Leo Choe Peng

Universiti Sains Malaysia

Ir. Dr. Yen Kin Sam

Universiti Sains Malaysia

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Dr. Senanayake Mudiyanselage Namal Arosha Senanayake

Universiti Brunei Darussalam

Dr. Ho Ngo Anh Dao

Ton Duc Thang University

Mr. Phuoc Loc Nguyen

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

Project Activities:

Scientific/Technological Development/Experiments

- The project team members conducted weekly meeting until 28/10/2021 to report the following activities.

1. Study the effects of $CaCO_3$ filler on membrane properties for water reuse purposes.
2. Electrochemical cleaning of membrane to sustain water reuse system.
3. Design and develop machine vision for automated colonies counting using an appropriate light source and lighting configuration for enhancing the images of *E. coli* colonies on petrifilms captured prior to image processing and analysis.
4. Develop IoT water quality monitoring system with real-time data and cloud storage.
5. Develop D2D wireless system and prepare for installation.

Biweekly meeting will be conducted starting 10/11/2021 to monitor the subsequent progress.

Other activities

- 2 undergraduate students participated this project as their industrial training (10 weeks). The students are:
  1. Tay Ying Keat (Universiti Sains Malaysia)
  2. Teoh Mynn Wei (Universiti Sains Malaysia)

They have submitted their training outcomes to ASEAN IVO Forum 2021. The submission was accepted.

Project Activities:

Other activities

- IoT workshop by Dr. Yu Kok Hwa and Mr. Tay Ying Keat on 29/9/2021.

Budget plan in details

Budget	Details	USD $	Expenditure/ Remarks
Equipment	USM: Custom-made membrane filtration module and modification of greywater system (4 units, Year 1)	2,500	USD 510 (Partial purchase)
	USM: Multiparameter water quality meter, online (4 units, Year 1)	2,000	Pending
	USM: High performance server (multithread, 8 core, 32 GB) (1 unit, Year 1)	3,000	Application submitted
	USM: Smartphone (2 units, Year 1)	1,000	Getting quotation
	USM: Wireless module with camera and sensors (4 units, Year 1)	2,000	USD602.66 (Partial purchase)
	USM: Computer (2 units, Year 1)	3000	Application submitted
	TDTU: Custom-made membrane filtration module and modification of greywater system (2 units, Year 1)	1,250	USD 690 (Partial purchase)
	TDTU: Handheld meter for water quality analysis (2 units, Year 1)	1,000	USD 413.58 (Partial purchase)
	TDTU: Smartphone (1 unit, Year 1)	500	Pending
	Fee: Fee to set up the D2D wireless system and server in Malaysia	12,000	Since the fee will be covered by NICT, the team would like to apply for changing it into publication fees of 4 ISI-indexed journal papers.
	UBD: Smart Tab with AWS cloud resources (1 unit, Year 2)	500	Getting quotation
	UBD: PC with i9 CPU, NVIDIA real time graphics & SSD (1 unit, Year 2)	1,500	Getting quotation

Meeting/Workshop (including travelling cost)	Knowledge transfer workshop I (December 2021): 3 days 2 night TDTU (host): 2,000 (food, local hospitality etc.) USM: 2,000 (flights, hotel, local transport for 2 pax) UBD: 2,000 (flights, hotel, local transport for 2 pax)	6,000	If travelling to Vietnam is still not allowed under pandemics, the team would like to converted the budget into registration fees of conference or publication fees.
	Training on NICT technology (April 2022) 2 weeks USM: 10,000 (flights, accommodation, meals, local transport for 2 pax)	10,000	
	Knowledge transfer workshop II (August 2022) 3 days 2 night UBD (host): 2,000 (food, local hospitality etc.) USM: 2,000 (flights, hotel, local transport for 2 pax) TDTU: 2,000 (flights, hotel, local transport for 2 pax)	6,000	
	Final Meeting and System Validation (April 2023) 3 days 2 night USM (host): 2,000 (food, local hospitality etc.) UBD: 2,000 (flights, hotel, local transport for 2 pax) TDTU: 2,000 (flights, hotel, local transport for 2 pax)	6,000	
Operating cost	USM: Consumables (chemicals etc., 2 years)	3,000	USD 379.90 (Partial purchase)
	TDTU: Consumables (chemicals etc., 2 years)	2,500	
	USM: Cloud virtual machine and storage subscription (2 years)	2,000	
	USM, UBD and TDTU: Mobile plan (4 units, 2 years)	2,000	
	USM: Mobile plan for wireless modules (6 prepaid plans, 2 years)	1,250	
Subtotal Year 1	Equipment (30,250); Meeting/Workshop (6,000); Operation cost (5,625)	39,875	
Subtotal Year 2	Equipment (2,000); Meeting/Workshop (22,000); Operation cost (5,625)	29,625	
Total (Year 1 + 2)	Equipment (25,200) +Meeting/Workshop (28,000) + Operation cost (11,250)	69,500	

R&D results:

1. **Study the effects of $CaCO_3$ filler on membrane properties for water reuse purposes.**

PVDF membrane coated with lignin can be used to remove oil emulsion in greywater up to 99.325% as shown in our previous study. Although $CaCO_3$ nanoparticles could improve the water permeation, the removal efficiency was affected due to the formation of large pores during phase inversion. The amount of $CaCO_3$ nanoparticles should be reduced.

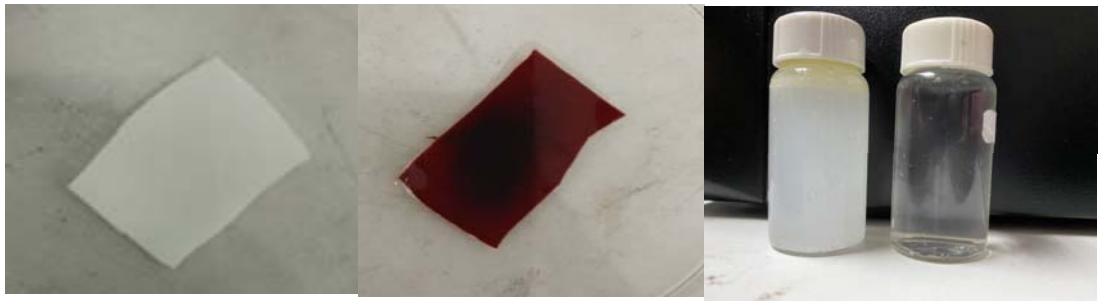

Fig. 1 PVDF membrane before and after lignin coating for removing oil emulsion (from left to right).

Table 1 The modification of membrane for oil emulsion removal from greywater.

Membrane	Lignin content (wt.%)	$CaCO_3$ content (wt.%)	Water Permeability (L/m^2h)	Rejection oil emulsion (%)
PVDF	0	0	426.04	87.500
PVDF-Lig	0.75	0	422.56	99.375
PVDF-CC-Lig	0.75	3	1582.1	71.875
PVDF-CCR-Lig	0.75	3 (removed)	1624.6	78.125

R&D results:

3. Machine vision for automated colonies counting using an appropriate light source and lighting configuration for enhancing the images of *E. coli* colonies on petrifilms captured prior to image processing and analysis.

The red-light illumination gave the best visualization of the stained E. coli colonies when compared to other colored lights. The white light illumination served as a benchmark image. It can be observed that E. coli colonies can be visualized clearly and sharply under the red-light illumination, Figure 2(b). At the same time, other information, such as texts and grids, which are not of our interest, was not seen. While under the blue-light illumination, Figure 2(c), the colonies were unseen but the texts and grids remained clearly in the image.

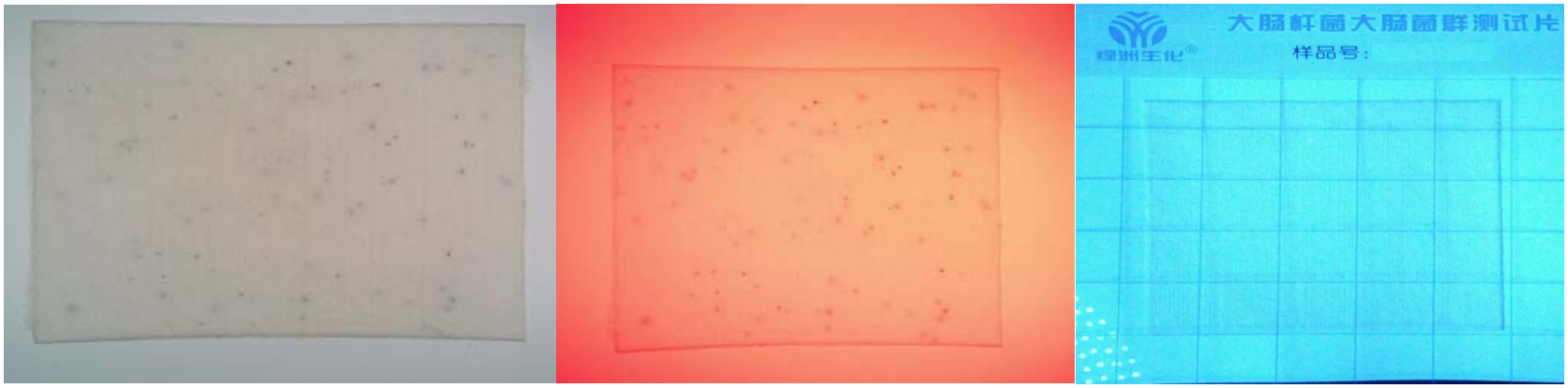

Figure 2: Petrifilm under (a) white (normal) light illumination, (b) red-light illumination (c) blue-light illumination

4. The IoT water quality monitoring system with real time sensors and data logging using cloud server.

The system contains water level and turbidity sensors paired with Arduino UNO Wi-Fi Rev.2 board, that served as the microcontrollerUsing the IoT system, the data obtained from the water quality measurement are uploaded to cloud server ThingSpeak using the Wi-Fi module on Arduino UNO Wi-Fi Rev.2 board. ThingSpeak has a lot of built-in apps such as MATLAB Analysis, React, ThingHTTP, and other functions, which allows different post processing analyses. In the preliminary development, as can be seen from Figure 3, the IoT water quality monitoring system incorporates water level and water turbidity sensors.

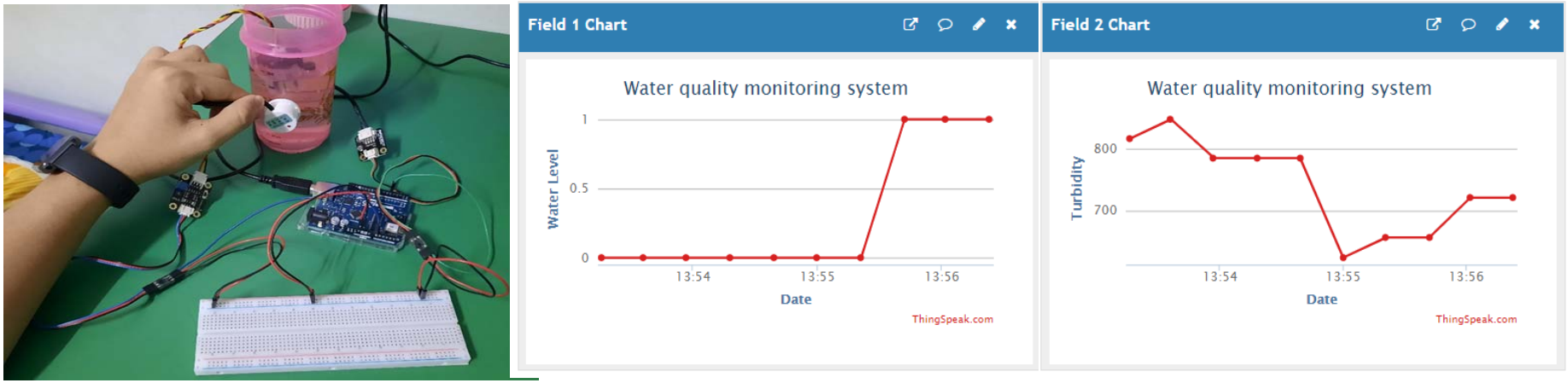

Figure 3: Demonstration of the IoT water quality monitoring system and data logged to ThingSpeak.

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

Societal Impact:

SDG 6 (Clean Water and Sanitation): Our team is in the progress to elevate the sustainability of water reuse projects and moves using IoT. Besides improving the membrane properties and cleaning procedures for water reuse, we are developing optical segmentation on E. coli colonies formed on petrifilms for monitoring the quality of treated water.

SDG 4 (Quality Education): We ensures inclusive and equitable quality education besides promoting lifelong learning opportunities for all. We organized workshop for our team members to learn on IoT devices. We will share our findings in ASEAN IVO Forum 2021 as well.

SDG 13 (Climate Action): We took action to combat climate change and its impacts. We are working on the design of wireless data collection system. We will collect water reuse data to improve water management under climate change.

Conclusion:

1. The amount of $CaCO_3$ filler in membrane should be optimized to remove emulsion effectively. Study will be completed by February 2022.
2. The membrane fouled by surfactant could be electrochemically cleaned. In-situ cleaning will be studied under a PhD student starting December 2022.
3. Machine vision for automated colonies counting will be continued by fabricating the enclosure for cultivation and imaging.
4. Water quality monitoring system with real-time data and cloud storage will be continued with more sensors and real water samples.

Future works:

- Complete design and implementation of ultrafiltration system for greywater treatment (USM and TDTU) by December 2021.
- Complete 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.
- Complete development and implementation cloud-based application software for water quality analysis and monitoring (USM, UBD, NICT) by April 2023.

Gantt Chart