ANNEX 2: List of Products

- References (COSMOS Project Publications (22/10/2021)

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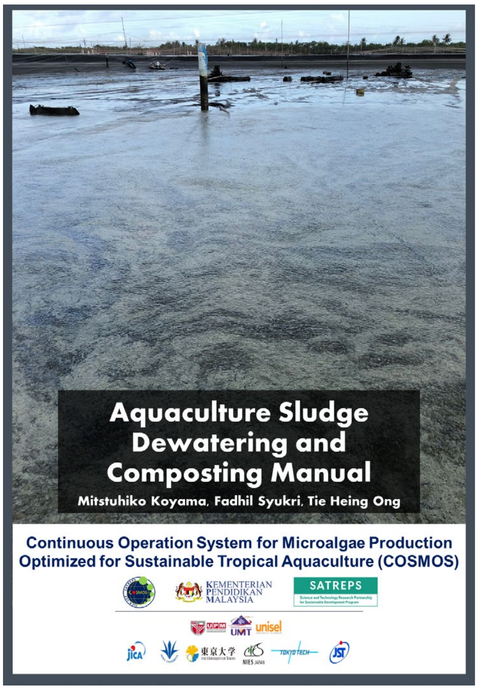
- **Manuals**

- Aquaculture sludge dewatering and Composting Manual

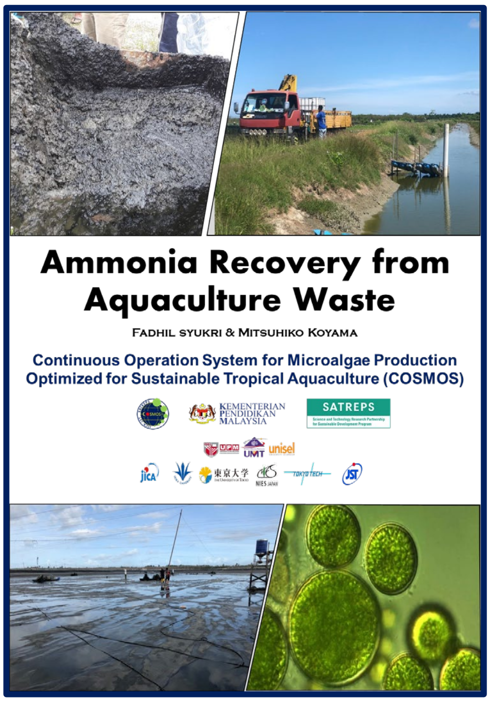


Aquaculture Sludge Dewatering and Composting Manual

Mitstuhiko Koyama, Fadhil Syukri, Tie Heing Ong

Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

- Ammonia recovery from Aquaculture Waste



Ammonia Recovery from Aquaculture Waste

FADHIL SYUKRI & MITSUHIKO KOYAMA

Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

- Production of Microalgae-Bacterial Consortium for Bioencapsulated Live-Feeds

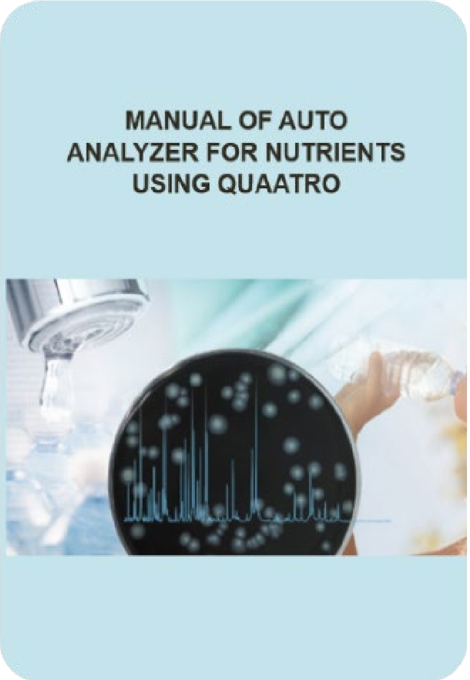
Continuous Operation System for Microalgae Production
Optimized for Sustainable Tropical Aquaculture
(COSMOS)

A Manual

Production of Microalgae-Bacterial Consortium for
Bioencapsulated Live-Feeds

By:
Nur Amirah Izyan Noor Mazli, Fatimah Md. Yusoff &
Murni Marlina Abd Karim

- Manual of Auto Analyzer for Nutrients using Quaatro

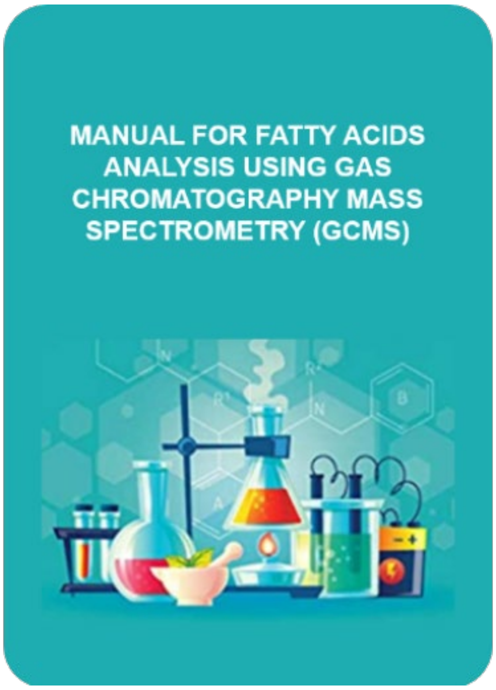


MANUAL OF AUTO
ANALYZER FOR NUTRIENTS
USING QUAATRO

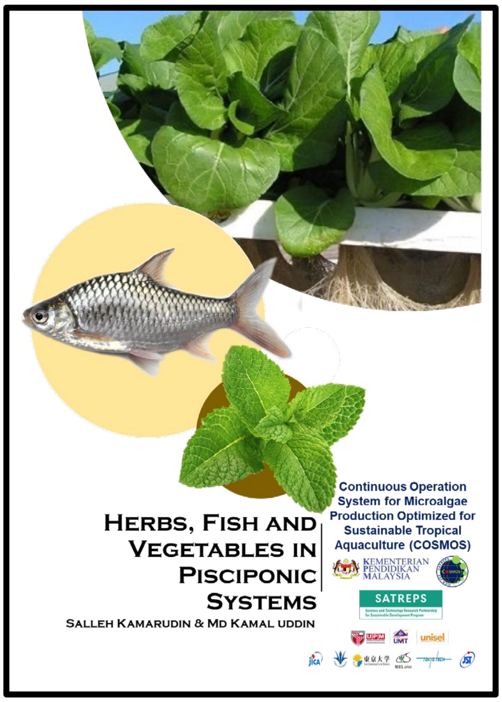
- Manual of Pigments Analysis using High Performance Liquid Chromatography (HPLC)


MANUAL ON PIGMENTS ANALYSIS USING HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC)

- Manual for Fatty Acids Analysis using Gas Chromatography Mass Spectrometry (GCMS)


MANUAL FOR FATTY ACIDS ANALYSIS USING GAS CHROMATOGRAPHY MASS SPECTROMETRY (GCMS)

- Herbs, Fish and Vegetables in Pisciponic Systems



Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

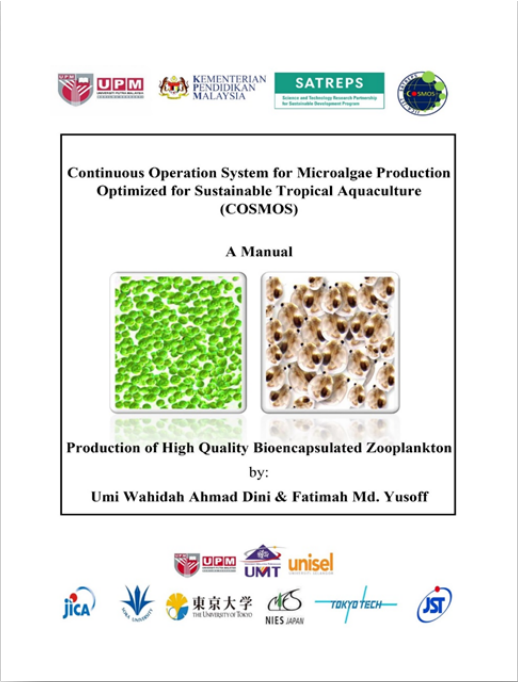
KEMENTERIAN PENDIDIKAN MALAYSIA

SATREPS

HERBS, FISH AND VEGETABLES IN PISCIPONIC SYSTEMS

SALLEH KAMARUDIN & MD KAMAL UDDIN

- Production of High Quality Bioencapsulated Zooplankton



KEMENTERIAN PENDIDIKAN MALAYSIA

SATREPS

Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

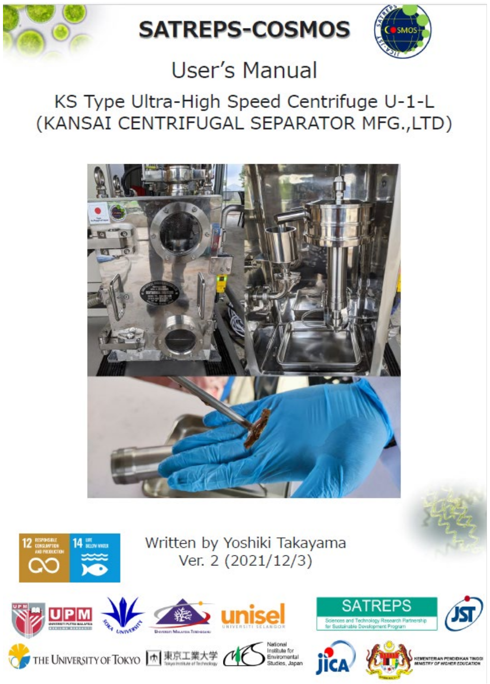
A Manual

Production of High Quality Bioencapsulated Zooplankton

by:

Umi Wahidah Ahmad Dini & Fatimah Md. Yusoff

- User’s Manual for KS Type Ultra-High Speed Centrifuge U-1-L

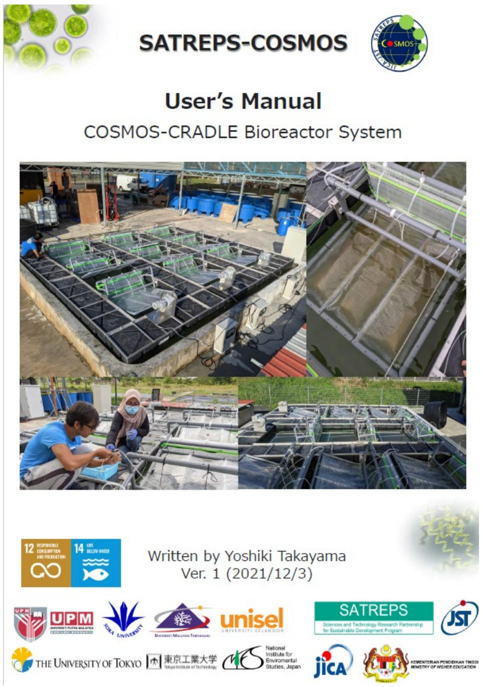

SATREPS-COSMOS

User’s Manual

KS Type Ultra-High Speed Centrifuge U-1-L
(KANSAI CENTRIFUGAL SEPARATOR MFG.,LTD)

Written by Yoshiki Takayama
Ver. 2 (2021/12/3)

- User’s Manual for COSMOS-CRADLE Bioreactor System


SATREPS-COSMOS

User’s Manual

COSMOS-CRADLE Bioreactor System

Written by Yoshiki Takayama
Ver. 1 (2021/12/3)

Project Monitoring Sheet I （Revision of Project Design Matrix）

Version 0

Dated September 30, 2016

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.		UMT has conducted preliminary sampling at Kenyir Lake and Setiu Wetland.
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication			

3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication			NIES is designing the fractionation system of dissolved organic matter for soil and sludge extracts.
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication			UPM and SU student have been conducted continuous test operation system of microalgae production using a pilot scale photobioreactor for 3 months.
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication			TIT started preliminary experiments for nutrient recovery.
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures> None
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Project Monitoring Sheet I （Revision of Project Design Matrix）

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Version 2

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Dated: March 31, 2017

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.		Utokyo has conducted sampling in Selangor and Kuala Terengganu.
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication			

3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication			NIES has installed the fractionation system of dissolved organic matter for soil and sludge extracts. UNISEL has conducted sampling in several locations.
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication			SU has been prospecting materials for functional bag bioreactor.
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication			TIT has been conducted preliminary experiments for nutrient recovery.
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions. 2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1. 3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae. 4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors. 5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production. 6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions <Issues and countermesures> None

Project Monitoring Sheet I （Revision of Project Design Matrix）

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Version 3

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Dated: September 30, 2017

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	Sampling, isolation, and screening of samples have conducted	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication		Modification of growth conditions for two species was completed. Two species were evaluated with fatty acids.	

3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication		Growth promoting effects were observed.	
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication		Patent application for the bag reactor system was prepared.	
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication		Characterization of ammonia production from aquaculture sludge was conducted.	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			⬇
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures> N/A
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Project Monitoring Sheet I （Revision of Project Design Matrix）

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Version 3

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Dated: March 31, 2018

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia

Model Site: N/A

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.		
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication			

3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication			
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication			
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication			
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Project Monitoring Sheet I （Revision of Project Design Matrix）

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Dated: September 30, 2018

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Overall Goal Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		

Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	Collecting microalgae and isolating of the collected microalgae were completed. Screening of isolated microalgae for high contents of useful compounds was conducted to all isolates (209 strains). 9 papers of international journals have been published so far.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication			
3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication		Appropriate methods for soil extraction and fractionation have been established Growth promoting effects of soil extracts have been determined on selected microalgae in NIES culture collection. Molecular weight distribution and fluorescence property of dissolved organic matter in soil extracts have been analyzed.	
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication			
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication		The optimum fermentation temperature, prospective sludge-degrading microorganism, and liming effect for enhancing NH3 recovery from the sludge was elucidated	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO$_2$ emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			⬇
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Project Monitoring Sheet I （Revision of Project Design Matrix）

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Dated: March 31, 2019

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Overall Goal Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		

Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	Collecting microalgae and isolating of the collected microalgae were completed. Screening of isolated microalgae for high contents of useful compounds was conducted to all isolates (209 strains). 9 papers of international journals have been published so far.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication			
3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication		Appropriate methods for soil extraction and fractionation have been established Growth promoting effects of soil extracts have been determined on selected microalgae in NIES culture collection. Molecular weight distribution and fluorescence property of dissolved organic matter in soil extracts have been analyzed. A paper of international journal has been published so far.	
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication		CRADLE system showed the biomass yield of 2050kg/GJ and areal production rate of >10g-ds m-2 day-1 in the semi continuous culture of Chlorella vulgaris and Spirulina platensis. These results indicate that the "An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed" in objectively verifiable ndicators of 4-1 was acheived. 9 papers of international journals have been published so far.	
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication		The optimum fermentation temperature, prospective sludge-degrading microorganism, and liming effect for enhancing NH3 recovery from the sludge was elucidated. 2 papers of international journals have been published so far.	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			⬇
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures> N/A
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Project Monitoring Sheet I　（Revision of Project Design Matrix）

Dated: SEPT 30, 2019

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia　**Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained		
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology		

Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	A total of 201 isolates were collected from both seawater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states.All isolates have been purified, screened for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA. Two microalgae species, Thalassiosira weissflogii and Isochrysis galbanawere chosen as "high value microalgae" based on results from second screening. High oil production culture conditions established for C. vulgaris and M. gracile microalgae model. These conditions will be used for Thalassiosira weissflogii and Isochrysis galbana. Transcriptome profilling of the high-oil and nitrate-inducible genes completed. Further bioinformatic analysis is currently conducted at MGI.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	2. Project report and publication			
3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication		Objectively verifiable indicator (OVI) 3.1 has been achieved, and the preparation of the soil extracts have been completed. The incubation experiments have been in rapid progress, and a fully automatic fractionation system has been developed and installed at UNISEL. The OVI 3.2 has been achieved for soil samples from 6 sites (from a total of 9 sites) tested on 7 species (from a total of 11 species). Characterization of the soil extracts by fluorescence analysis and size distribution is OVI 3.3 is still in progress. Preparation of manuscripts is in progress.	
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication		Culture experiments on Spirulina and Chlorella were carried out by using the small-scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per GJ, which is around 20 times high energy efficiency compared to the value in a current raceway pond.Thus, the “Objectively verifiable indicators of 4.1” in PDM has been completed. A scale-up bag photobioreactor system was installed in a UPM laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, was operated continuously for more than 2 months.Thus, the “Objectively verifiable indicators of 4.2” in PDM has been completed. The two species identified by UMT, Thalassiosira weissflogii and Isochrysis galbana will b used in the outdoor PBR.	

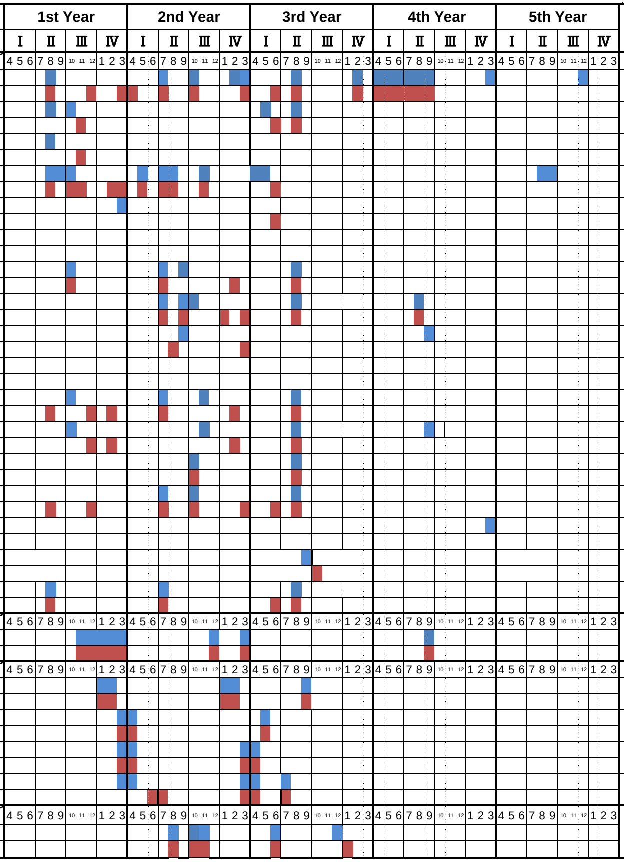
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication		TiTech, Soka University and UPM started to optimize NH3 trapping/storage/supply method in a viewpoint of efficient utilization of nutrient (i.e. NH3) and CO2 emitted from sludge composting, for culturing high-value microalgal biomass. The demonstration site (pilot-scale sludge composting system with NH3 recovery unit, connected with a bag-reactor microalgae cultivation system) has been constructed on UPM.	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Project Monitoring Sheet II (Revision of Plan of Operation)

As of October 31, 2019

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)



Inputs	Year	Remarks	Monitoring: Issue	Monitoring: Solution
Expert				
Planktonologist/ Project Leader (T. Toda)	Plan Actual	SU		
Phycologyist 1 (K. Takahashi)	Plan Actual	UTokyo		
Phycologyist 2 (M. Sato)	Plan Actual	UTokyo		
Phycologyist 3 (T. Katayama)	Plan Actual	UTokyo		
Natural organic chemist/Soil chemist, GC-MAS	Plan Actual	SU		
Analytical chemist 2 LC-MAS	Plan Actual			
Waste treatment scientist 1 (K. Nakasaki)	Plan Actual	Tokyo Tech		
Waste treatment scientist 2 (M. Koyama)	Plan Actual	Tokyo Tech		
Chemical engineer/Bioreactor engineer 3 (T. Matsuyama)	Plan Actual	SU		
Chemical engineer/Bioreactor engineer 4 (J. Ida)	Plan Actual	SU		
Water chemist 1 (A. Imai)	Plan Actual	NIES		
Water chemist 2 (K. Komatsu)	Plan Actual	NIES		
Microbiologist (N. Kurosawa)	Plan Actual	SU		
Photobiologist (V. Kuwahara)	Plan Actual	SU		
Natural product chemist (M. Watanabe or Tominaga)	Plan Actual	WOL		
Electron Microscopist (M. Kuwata)	Plan Actual	SU		
Advisor/ Phycologist 4 (K. Furuya)	Plan Actual	SU		
Equipment				
Transport, installation and commissioning of equipment purchased in Japan	Plan Actual			
Training in Japan				
Training at NIES	Plan Actual	NIES		
Training at Utokyo	Plan Actual	Tokyo Tech		
Training at Tokyo Tech	Plan Actual	UTokyo		
Training at SU	Plan Actual	SU		
In-country/Third country Training				
Workshop in Malaysia, held by Japanese Researchers	Plan Actual			

Activities				Year	1st Year				2nd Year				3rd Year				4th Year				5th Year				Responsible Organization		Achievements	Issue & Countermeasures
					Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Japan	GOM		
Output 1: High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.																												
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia.				**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦												UTokyo	UMT	This has been completed and a total of 201 isolates were collected from both seawater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states.	
				Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥															
1-2. Screen, isolate and purify the collected microalgae.				**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦												UTokyo	UMT	All isolates have been purified, screened for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA.	
				Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥															
1-3. Characterize microalgae for high contents of valuable compounds.				**Plan**					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							UTokyo	UMT	Two microalgae species, *Thalassiosira weissflogii and Isochrysis galbana* were chosen as "high value microalgae" based on results from second screening.	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥														
1-4. Conduct incubation experiments using variable growth conditions.				**Plan**									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	UTokyo	UMT	Two microalgae species, *Chlorella vulgaris* and *Tetraselmis chuii* were chosen to check their variable growth conditions. The established methods for variable growth conditions will be applied to *Thalssiosira weissflogii* and *Isochrysis galbana.*	
				Actual									🟥	🟥														
Output 2: Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).																												
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds.				**Plan**								🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					UTokyo	UMT	High oil production culture conditions established for *C. vulgaris* and *M. gracile* microalgae model. These conditions will be used for *Thalassiosira weissflogii* and *Isochrysis galbana.* Transcriptome profilling of the high-oil and nitrate-inducible genes completed. Further bioinformatic analysis is currently conducted at MGI.	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥														
2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.				**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	UTokyo	UMT	The methods for quantification is now established and will be used for *Thalassiosira weissflogii* and *Isochrysis galbana.*	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥														

Output 3: Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.																												
3-1. Collect soil and sludge from various locations in Peninsular Malaysia.				**Plan**	🟦	🟦	🟦	🟦	🟦	🟦															NIES	UNISEL	All samples have been collected (completed)	
				Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥															
3-2. Study soil and sludge extraction methods.				**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦											NIES	UNISEL	This has been completed where the methods have been identified and established.	
				Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
3-3. Examine and optimize the fractionation method of soil and sludge extracts.				**Plan**						🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							NIES	UNISEL	The right method has been identified and established (completed)	
				Actual						🟥	🟥	🟥	🟥	🟥														
3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction.				**Plan**			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦									NIES	UNISEL	Out of 9 sites, 6 has been completed and remaining 3 sites is ongoing for investigation where 4 species left to investigate out of 11 species.	
				Actual			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.				**Plan**												🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	NIES	UNISEL	Chemical characteristics of the growth-promoting fractions were continued to be carried using samples from all other areas where the soil samples were collected.	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥														
Output 4: Closed photobioreactor is scaled-up for outdoor culture.																												
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor.				**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦													SU	UPM	Culture experiments on *Spirulina* and *Chlorella* were carried out by using the small-scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per GJ, which is around 20 times high energy efficiency compared to the value in a current raceway pond.Thus, the “Objectively verifiable indicators of 4.1” in PDM has been completed.	
				Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																
4-2. Develop scaled-up novel photobioreactor for outdoor mass culture.				**Plan**			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							SU	UPM	A scale-up bag photobioreactor system was installed in a UPM laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, was operated continuously for more than 2 months.Thus, the “Objectively verifiable indicators of 4.2” in PDM has been completed.	
				Actual			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										
4-3. Develop a multi-sequence system of operational photobioreactors.				**Plan**											🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	The construction of demonstration site in UPM was completed to install “Multi-sequence outdoor system”. A part of the system has been installed in the demonstration site in UPM. The test operation of the system will be conducted in term 8, 2020 to complete the “Objectively verifiable indicators of 4.3” in PDM.	
				Actual											🟥	🟥	🟥	🟥										

Output 5: Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.																									
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge.	**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦									Tokyo Tech	UPM	TiTech has been investigating the NH3 recovery potential of shrimp aquaculture sludge using laboratory scale aerobic fermentation system. TiTech examined the effect of alkaline agent (Ca(OH)2) dosing on NH3 recovery from the sludge in a bench-scale composting process. UPM has been investigating the self-heating capacity of the shrimp aquaculture sludge during aerobic fermentation and found that the sludge collected directly from the plastic-lined pond exhibits high temperature (approx. 55℃) during fermentation. Also, TiTech have been investigating the phosphate recovery and salinity removal from the fermentation solid residue (i.e. compost) of shrimp pond sludge for culturing microalgal biomass and desalinating the compost for agricultural application. UPM started to examine the plant growth effect of the shrimp sludge compost, investigating the growth of some local and/or halo-tolerant crops.	
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
5-2. Establish a technology utilizing nutrients for microalgae production.	**Plan**									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	Tokyo Tech	UPM	TiTech, Soka University and UPM started to optimize NH3 trapping/storage/supply method in a viewpoint of efficient utilization of nutrient (i.e. NH3) and CO2 emitted from sludge composting, for culturing high-value microalgal biomass. The demonstration site (pilot-scale sludge composting system with NH3 recovery unit, connected with a bag-reactor microalgae cultivation system) has been constructed on UPM.	
	Actual									🟥	🟥														
Output 6: Economic profitability and environmental compatibility of the system are verified.																									
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC.	**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM		
	Actual																								
6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.	**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM		
	Actual																								

Duration / Phasing	**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														

Monitoring Plan	Year	1st Year				2nd Year				3rd Year				4th Year				5th Year				Remarks	Issue	Solution
		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ			
Monitoring		4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3			
Joint Coordinating Committee	**Plan**		🟦				🟦	No. 4			🟦			No.7	🟦				🟦			No. of participants: 50 (4th JCC)		
	Actual		🟥				🟥				🟥				🟥									
Submission of Monitoring Sheet	**Plan**		🟦		🟦		🟦		🟦		🟦			🟦		🟦		🟦		🟦		Submission deadline: Oct 31st, 2019 (Term 7)		
	Actual		🟥		🟥			🟥	🟥			🟥		🟥		🟥								
Monitoring Mission from Japan	**Plan**										🟦													
	Actual										🟥													
Joint Monitoring	**Plan**																							
	Actual																							
Post Monitoring	**Plan**																							
	Actual																							
Reports/Documents		4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3			
	Plan																							
	Actual																							
Project Completion Report	**Plan**																				🟦			
	Actual																							
Public Relations		4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3	4 5 6	7 8 9	10 11 12	1 2 3			
Opening project's website	**Plan**		🟦																			www.cosmos-satreps.org		
	Actual		🟥																					
Press release	**Plan**						🟦				🟦													
	Actual						🟥				🟥													

Draft Semi-final - Project Monitoring Sheet I （Revision of Project Design Matrix）

Dated: March 31, 2020

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 5 years (2016-2021)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. Three (3) or more aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained	1. High value microalgae species have been shown to produce useful compunds under laboratory conditions. These are 1. Anti-oxidants (UMT Group 2) and 3) Fatty acids (UMT Group 3). Detail chemical properties of the compunds are being analysed. 2. The mass-culture of high values microalgae will be established at the SATREPS-COSMOS Demonstration site in UPM as a model for farmers to adopt. Upon establishment of the outdoor bioreactor at the demo site, technologies will be disseminated to farmers. .	Delay in Theme 3 and Theme 4 due to unfavorable climatic conditions affecting the consruction of the SATREPS-COSMOS Demonstration site. In mid-March the site was ready, but the outbreak of Covid 19 caused further delay as all Universities and offices in Malaysia were closed. The project is preparing countermeasures including an extension of the project duration. It is expected that the project requires at **least a six month-extension.**
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	"1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per gigajoule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology	1. Production of one tonne per ha has been achieved based on in-door photobioreactor production. However, the oudoor proudction has to be calculated after the outdoor production system has completed 2. Not yet because of the delay in the installation of the outdoor bioreactor due to climatic problem and COVID19 pandemic 3. The ammonia from the pond sludge has been shown to be sutable for the microalgae culture (Two papers on the issue have been published in Q1 journals). The whole process is being established at the demonstration site to integrate the nutrient production process from the aquaculture pond sludge (Theme 4) for the culture in the outdoor photobioreactor (Theme 3).	If we can go back to work at the demonstration site, the ourdoor bioreactor should be able to be established by October 2020. From then, we should have another year to complete the project and achive all objectives.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified. 1-2.Three indigenous microalgae species: *Chlorella vulgaris, Isochrysis galban* a and *Tetraselmis chuii* with high content of antioxidants at the best growth phase are identified. 1-3. Optimum growth conditions are determined for selected microalgae species.	1. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	A total of 212 isolates were collected from both seawater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states. All isolates have been purified, screened for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA. Three indigenous microalgae species: *Chlorella vulgaris, Isochrysis galbana* and *Tetraselmis chuii* with high content of antioxidants are identified at different growth phases. Based on the early stationary phase, these three microalgae were cultured under different medium compositions. *Isochrysis galbana* shows increased of α-Tocopherol and ascorbic acid under 10 times and 100 times of both phosphate and nitrate treatment. **Two micro*algae* species, *Thalassiosira weissflogii* and *Isochrysis galban* a were chosen as "high value microalgae" based on results from second screening. High oil production culture conditions established for *C. vulgaris* and *M. graci* le microalgae model. These conditions will be used for *Thalassiosira weissflogii* and *Isochrysis galbana* .** Transcriptome profilling of the high-oil and nitrate-inducible genes completed. Further bioinformatic analysis is currently conducted at MGI.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species. 2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition. 2-3. Productivity of antioxidants is increased by 10 times and 100 times of nitrate and phosphate treatments in *Chlorella vulgaris, Isochrysis galbana* and *Tetraselmis chuii* .	2. Project report and publication			
3. Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.	3-1. Appropriate methods for soil extraction and fractionation are developed. 3-2. Growth promoting effects of soil-extracted fractions on selected microalgae are determined. 3-3. Chemical characteristics of the soil-extracted fractions with growth promoting effects are evaluated.	3. Project report and publication		Objectively verifiable indicator (OVI) 3.1 has been achieved, and the preparation of the soil extracts have been completed. The incubation experiments have been in rapid progress, and a fully automatic fractionation system has been developed and installed at UNISEL. The OVI 3.2 has been achieved for soil samples from 6 sites (from a total of 9 sites) tested on 11 species. Undiluted fraction samples will be given to UPM for further testing in small and large scale bioreactors.Characterization of the soil extracts with growth promoting effects are still in progress in OVI 3.3. The samples were send to Japan for further analyses. Pristine soils dissolved organic matters and bacterial community profiling via shotgun metagenomics approach was successfully carried out. The preparation of manuscripts is in progress.	

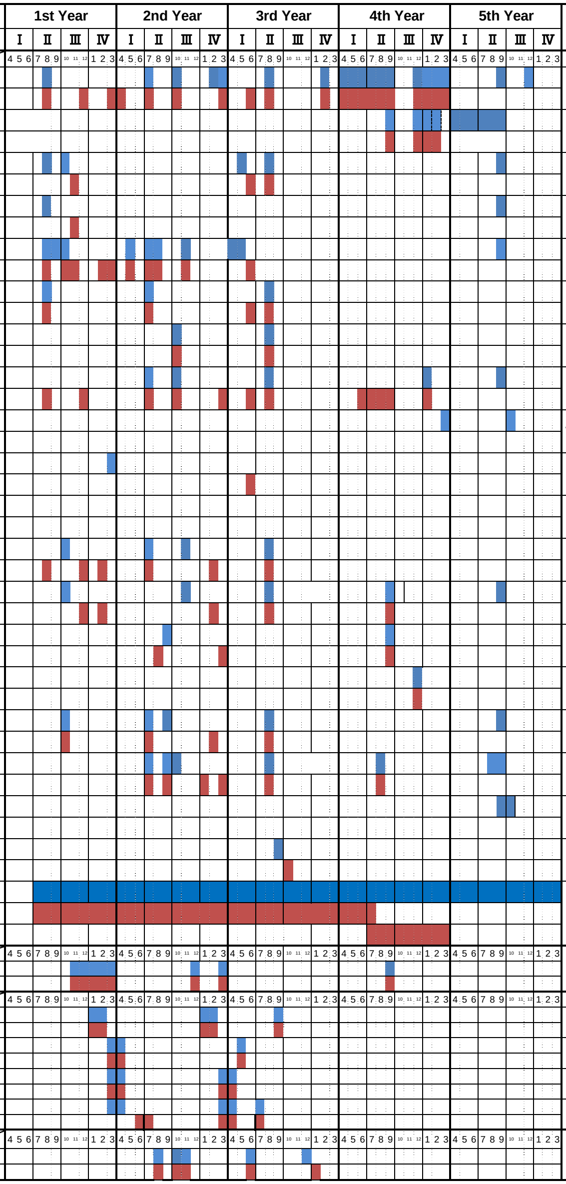
Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
4. Closed photobioreactor is scaled-up for outdoor culture.	4-1. An experimental small-scale novel photobioreactor whose biomass yield is two (2) ton per gigajoule, which is twenty (20) times higher than conventional reactors, is developed. 4-2. Scaled-up novel photobioreactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed. 4-3. More than two (2) species of selected microalgae are cultured outdoors in sequenced photobioreactors.	4. Project report and publication		Culture experiments on Spirulina and Chlorella were carried out by using the small-scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per GJ, which is around 20 times high energy efficiency compared to the value in a current raceway pond.Thus, the "Objectively verifiable indicators of 4.1" in PDM has been completed. A scale-up bag photobioreactor system was installed in a UPM laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, was operated continuously for more than 2 months.Thus, the "Objectively verifiable indicators of 4.2" in PDM has been completed. The two species identified by UMT, Thalassiosira weissflogii and Isochrysis galbana are being tested to be used in the outdoor photobioreactor system which is being finalised. Further improvements at the COSMOS demonstration site was done (additional pool to install the PBR driver system) for the installation of the multi-sequence outdoor system to achieve OVI 4.3.	
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is established. 5-2. Technology to utilize ammonia and phosphorus as a low-cost alternative nutrient source is established.	5. Project report and publication		lab-scale investigation of phosphate recovery and desalination from the sludge compost under anaerobic condition (Terms 6-8) revealed that the leaching of phosphate is faster at higher temperature condition, although the phosphate recovery at 55°C and 37°C condition became similar within three days. Increase of NH4+ concentration by 33-64% was observed during anaerobic phosphate recovery, indicating the NH4+ production from the aerobically-degraded residual sludge. From these results, it was suggested that the phosphate recovery and desalination operation could be feasible for utilizing the treated liquid fraction for culturing middle-to-low value microalgal biomass, and for decreasing the salinity level of the solid fraction to be used for compost in the agricultural field. On the other hand, the decrease in the nutrient content of the solid fraction by this operation could negatively influence the plant growth. This suggested the trade-off relationship between the promotion of desalination and loss of nutrient. With regards to publications, the findings of NH3 recovery and microbial community succession of the different shrimp pond sludges during thermophilic composting was accepted and published in Journal of Cleaner Production in Term 8.	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle revenue generated from a production unit exceeds life cycle cost. 6-2. The system does not negatively affect the current aquaculture production. 6-3. Total CO_2 emission by life cycle assessment is reduced as compared to conventional sludge treatment methods.	6. Project report and publication			

Activities	Inputs		Pre-Conditions
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be ellaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.			⬇
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.			<Issues and countermesures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.			
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.			
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.			

Draft Semi-final - Project Monitoring Sheet II (Revision of Plan of Operation)

As of March 31, 2020

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)



Inputs	AFF	No.	Year	Remarks	Monitoring: Issue	Monitoring: Solution
Expert	**AFF**	**No.**				
Planktonologist 1/ Project Leader (T. Toda)	SU	1	Plan Actual	SU		
Planktonologist 2 (M. Hirahara)	SU	2	Plan Actual	SU		
Phycologyist 1 (K. Takahashi)	UT	3	Plan Actual	UTokyo		
Phycologyist 2 (M. Sato)	UT	4	Plan Actual	UTokyo		
Phycologyist 3 (T. Katayama)	UT	5	Plan Actual	UTokyo		
Advisor/ Phycologist 4 (K. Furuya)	SU	6	Plan Actual	SU		
Microbiologist (N. Kurosawa)	SU	7	Plan Actual	SU		
Photobiologist (V. Kuwahara)	SU	8	Plan Actual	SU		
Natural product chemist (M. Watanabe or Tominaga), Watanabe Oyster Laboratory	WOL	9	Plan Actual	Watanabe Oyster Laboratory (WOL)		
Natural organic chemist/Soil chemist, GC-MAS	SU	10	Plan Actual	SU		
Analytical chemist 2 LC-MAS		11	Plan Actual			
Water chemist 1 (A. Imai)	NIES	12	Plan Actual	NIES		
Water chemist 2 (K. Komatsu)	NIES	13	Plan Actual	NIES		
Chemical engineer/Bioreactor engineer 3 (T. Matsuyama)	SU	14	Plan Actual	SU		
Chemical engineer/Bioreactor engineer 4 (J. Ida)	SU	15	Plan Actual	SU		
Waste treatment scientist 1 (K. Nakasaki)	TT	16	Plan Actual	Tokyo Tech		
Waste treatment scientist 2 (M. Koyama)	TT	17	Plan Actual	Tokyo Tech		
Waste Treatment Scientist 3 (T.N.M. Quyen)	TT	18	Plan Actual	Tokyo Tech		
Electron Microscopist (M. Kuwata)	SU	19	Plan Actual	SU		
JICA Project Coordinator Ms. Mari Miller Mr. Masaru Yamada	N.A.	20	Plan Actual Actual	Not available		
Equipment						
Transport, installation and commissioning of equipment purchased in Japan			Plan Actual			
Training in Japan						
Training at NIES			Plan Actual	NIES		
Training at Utokyo			Plan Actual	Tokyo Tech		
Training at Tokyo Tech			Plan Actual	UTokyo		
Training at SU			Plan Actual	SU		
In-country/Third country Training						
Workshop in Malaysia, held by Japanese Researchers			Plan Actual			

Yamada:
I sorted this Expert list **by Experties** for easy reference.

Short-term Expert: (Listed on the R/D)
1 Planktonology
2Phycology
3 Molecular biology/ Microbiology
4 Photobiology and optics of natural environments
5 Natural product chemistry/ Natural organic chemistry/ Soil chemistry
6 Analytical chemistry
7 Water chemistry
8 Chemical engineering/ Bioreactor engineering
9 Waste treatment science

Activities				Year	1st Year				2nd Year				3rd Year				4th Year				5th Year				Responsible Organization		Achievements	Issue & Countermeasures
					Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Japan	GOM		
Output 1: High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.																												
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia.				**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦												UTokyo	UMT	This has been completed and a total of 212 isolates were collected from both seawater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states.	
				Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥															
1-2. Screen, isolate and purify the collected microalgae.				**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦												UTokyo	UMT	All isolates have been purified, screened for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA.	
				Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥															
1-3. Characterize microalgae for high contents of valuable compounds.				**Plan**					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							UTokyo	UMT	Two microalgae species, *Thalassiosira weissflogii and Isochrysis galbana* were chosen as "high value microalgae" based on results from second screening.	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										
1-4. Conduct incubation experiments using variable growth conditions.				**Plan**									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	UTokyo	UMT	Two microalgae species, *Chlorella vulgaris* and *Tetraselmis chuii* were chosen to check their variable growth conditions. The established methods for variable growth conditions will be applied to *Thalssiosira weissflogii* and *Isochrysis galbana.* Experiments with select isolates, T. weissflogii and I. galbana, have proceeded for determination of the optimal growth in culture conditions manipulating temperature, light intensity, salinity, and starvation of nitrate and phosphate.	
				Actual									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
Output 2: Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).																												
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds.				**Plan**								🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦					UTokyo	UMT	High oil production culture conditions established for *C. vulgaris* and *M. gracile* microalgae model. These conditions will be used for *Thalassiosira weissflogii* and *Isochrysis galbana.* Transcriptome profiling of the high-oil and nitrate-inducible genes completed. Further bioinformatic analysis is currently conducted at MGI. Establishment of high-lipid/carotenoid production culture conditions is proceeding for the selected isolates under variable conditions.	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.				**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	UTokyo	UMT	The methods for quantification is now established and will be used for *Thalassiosira weissflogii* and *Isochrysis galbana.*	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
Output 3: Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are determined.																												
3-1. Collect soil and sludge from various locations in Peninsular Malaysia.				**Plan**	🟦	🟦	🟦	🟦	🟦	🟦															NIES	UNISEL	All samples have been collected (completed)	
				Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥															
3-2. Study soil and sludge extraction methods.				**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦											NIES	UNISEL	This has been completed where the methods have been identified and established.	
				Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
3-3. Examine and optimize the fractionation method of soil and sludge extracts.				**Plan**						🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							NIES	UNISEL	The right method has been identified and established (completed). In addition to the resin fractionation technique, the molecular size fractionation method using the UF membrane installed in the centrifuging tube has been established.	
				Actual						🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										
3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction.				**Plan**			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦									NIES	UNISEL	Plate incubation experiments using 13 microalgal strains isolated from Peninsula Malaysia have been conducted. In addition to 9 strains selected by Theme 1,4 strains that was not selected as the high-value microalgae candidates due to slow growth rate were incubated using growth promoting substances. Results suggest growth-promoting effects are different among microalgal strains.	
				Actual			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.				**Plan**												🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	NIES	UNISEL	Characterization of dissolved organic matter from all soil extracts (S.E.) imported from UNISEL has been completed by fluorescence analysis (EEM-PARAFAC). Through the combined plate incubation and fractionation experiments, it was determined that the hydrophobic fraction, or low-molecular size fraction of S.E. effectively enhance algal growth.	
				Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
Output 4: Closed photobioreactor is scaled-up for outdoor culture.																												
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor.				**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦													SU	UPM	Culture experiments on *Spirulina* and *Chlorella* were carried out by using the small-scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per GJ, which is around 20 times high energy efficiency compared to the value in a current raceway pond.Thus, the "Objectively verifiable indicators of 4.1" in PDM has been completed.	
				Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																
4-2. Develop scaled-up novel photobioreactor for outdoor mass culture.				**Plan**			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							SU	UPM	A scale-up bag photobioreactor system was installed in a UPM laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, was operated continuously for more than 2 months.Thus, the "Objectively verifiable indicators of 4.2" in PDM has been completed.	
				Actual			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										
4-3. Develop a multi-sequence system of operational photobioreactors.				**Plan**											🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	The construction of demonstration site in UPM was completed to install "Multi-sequence outdoor system". A part of the system has been installed in the demonstration site in UPM. The test operation of the system will be conducted in term 8, 2020 to complete the "Objectively verifiable indicators of 4.3" in PDM. However, we have to reconstruct the outdoor photobioreactor due to some damage related to flood at the demonstration site. Corrective measures at the demonstration sites have been completed. More experiments are being carried out on the selected high microalgae species (from UMT) to predict their responses in the outdoor bioreactors. However, experimental work has to be stopped in Mid-March due to the COVID19 and UPM had to close until 14th April 2020.	
				Actual											🟥	🟥	🟥	🟥	🟥	🟥								

Output 5: Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.																												
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge.				**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			Tokyo Tech	UPM	The NH3 recovery potential of shrimp aquaculture sludge using laboratory scale aerobic fermentation system has been completed. The assessment of the effect of alkaline agent (Ca(OH)2) dosing on NH3 recovery from the sludge in a bench-scale composting process has also been completed. UPM has been investigating the self-heating capacity of the shrimp aquaculture sludge during aerobic fermentation and found that the sludge collected directly from the plastic-lined pond exhibits high temperature (approx. 55℃) during fermentation. Also, TiTech have been investigating the phosphate recovery and salinity removal from the fermentation solid residue (i.e. compost) of shrimp pond sludge for culturing microalgal biomass and desalinating the compost for agricultural application. UPM started to examine the plant growth effect of the shrimp sludge compost, investigating the growth of some local and/or halo-tolerant crops.	
				Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
5-2. Establish a technology utilizing nutrients for microalgae production.				**Plan**									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	Tokyo Tech	UPM	TiTech, SU and UPM started to optimize a NH3 trapping/storage/supply method towards the efficient utilization of nutrients and CO2 emitted from sludge composting, for culturing high-value microalgal biomass. A two-stage gas absorption system, which (1) directly absorbs the majority of the emitted NH3 and CO2 from the composting reactor into the algal medium and (2) a trap to recover excessive NH3 in a phosphoric acid solution, was proposed for the complete NH3 recovery and efficient nutrient storage/supply. Feasibility of this system has been investigated. The construction of the composting system was completed, and preliminary operation without using compost was started. TiTech and UPM have also started designing and constructing the sludge de-watering facility to pretreat large amounts of sludge, in order to operate the pilot-scale composting system.	
				Actual									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥								
Output 6: Economic profitability and environmental compatibility of the system are verified.																												
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC.				**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM		
				Actual																								
6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.				**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM		
				Actual																								

Duration / Phasing	**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥													

Monitoring Plan	**Year**	**1st Year**												**2nd Year**												**3rd Year**												**4th Year**												**5th Year**												Remarks	Issue	Solution
		Ⅰ			**Ⅱ**			**Ⅲ**			**Ⅳ**			**Ⅰ**			**Ⅱ**			**Ⅲ**			**Ⅳ**			**Ⅰ**			**Ⅱ**			**Ⅲ**			**Ⅳ**			**Ⅰ**			**Ⅱ**			**Ⅲ**			**Ⅳ**			**Ⅰ**			**Ⅱ**			**Ⅲ**			**Ⅳ**					
Monitoring		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3			
Joint Coordinating Committee	**Plan**					🟦											🟦													🟦													🟦											🟦								No. of participants: 50 (4th JCC)		
	Actual					🟥											🟥													🟥													🟥																					
Submission of Monitoring Sheet	**Plan**						🟦						🟦						🟦						🟦						🟦							🟦						🟦						🟦						🟦								
	Actual						🟥						🟥							🟥					🟥							🟥						🟥						🟥						🟥														
Monitoring Mission from Japan	**Plan**																													🟦																																		
	Actual																													🟥																																		
Joint Monitoring	**Plan**																																																															
	Actual																																																															
Post Monitoring	**Plan**																																																															
	Actual																																																															
Reports/Documents		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3			
	Plan																																																															
	Actual																																																															
Project Completion Report	**Plan**																																																											🟦				
	Actual																																																															
Public Relations		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3			
Opening project's website	**Plan**						🟦																																																								www.cosmos-satreps.org		
	Actual						🟥																																																											
Press release	**Plan**															🟦														🟦																																		
	Actual															🟥														🟥																																		

Project Monitoring Sheet I (Project Design Matrix, PDM)

PDM Version 1 (Revised as of JCC5, 28 August 2020)
Reporting date: September 30, 2020

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 6 years (2016.04 - 2022.03)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. More than three (3) aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained	1. High value microalgae species have been shown to produce useful compounds under laboratory conditions. These are **Anti-oxidants (UMT Group 2)** and **Fatty acids (UMT Group 3)**. Detail chemical properties of the compounds are being analysed. 2. The mass-culture of high values microalgae will be established at the ***demo site*** in UPM as a model for farms to adopt. Upon establishment of **the multi-sequence system of operational photobioreactor** (outdoor bioreactor), technologies will be disseminated to farms. In Malaysia, some Aquaculture Companies showed their interest: (1) Blue Archipelago Sdn Bhd, (2) Hannan Sdn Bhd, (3) RE Millenium Sdn Bhd (Term 4). In Japan, Shin Kami town in Goto island, Nagasaki, large-scale implementation is operational.	The construction of the SATREPS-COSMOS Demonstration site was delayed unfavorable climatic conditions in June 2019. The outbreak of Covid19 delayed the project progress further. The extension of the project duration was agreed on the fifth JCC meeting in August 2020.
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per giga joule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology	*The construction of the* ***demonstration site (demo site)*** *was proposed and initiated by UPM in order to integrate and disseminate those technologies developed by the project, particularly at the outdoor (bench) scale. This* ***construction*** *was* ***completed as of October 2020.*** 1. Production of **one tonne per ha (1t/ha)** has been **achieved based on the scale-up novel photobioreactor** (in-door photobioreactor). However, **the production by the multi-sequence system of operational photobioreactors has to be calculated after** the installation (scheduled in June 2021). 2. **Fabrication phase** because of the delay in the installation of **the multi-sequence system of operational photobioreactors** (outdoor bioreactor) due to climatic problem and COVID19 pandemic. 3. **Fabrication phase.** The ammonia from the pond sludge has been shown to be suitable for the microalgae culture (Two papers published in Q1 journals). The whole process is to be established at the demo site in July 2021.	The **multi-sequence system of operational photobioreactor** is under preparation in Japan and will be shipped to Malaysia in March 20212. The **pilot-scale nutrient recycling system** is needed to be modified and tested as matter of urgency (the system safety and the gas absorption system) The whole integration at the demo site is scheduled in June 2021.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	1-1: **Two** indigenous microalgae species, ***Thalassiosira weissflogii*** and ***Isochrysis galbana***, have been **chosen** as high value microalgae with high content of lipid and carotenoid.	
	1-2. Optimum growth conditions are determined for selected microalgae species.	Project report and publication		1-2: On-going **Optimum growth conditions are currently determined** for the two selected microalgae species, *Thalassiosira weissflogii* and *Isochrysis galbana.* With regards to publications, the findings of screening and characterization of the indigenous microalgae was accepted and will be published in Frontiers in Term 10.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species.	Project report and publication		2-1: On-going (light, temperature, salinity conditions); **Completed** (nutrients condition). High oil production culture conditions were established for *Chlorella vulgaris* and *Messastrum gracile* microalgae model. Based on these findings, suitable culture conditions for inducing production of useful compounds **are currently determined** for the two selected microalgae species, *Thalassiosira weissflogii* and *Isochrysis galbana*.	
	2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	Project report and publication		2-2. On-going Productivity of useful compounds **is currently determined** for the cultured microalgae as in 2-1.	

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
3. Efficient microalgae culturing technique utilizing growth-enhancing substances extracted from soil and sludge is proposed.	3-1. Optimal methodologies for extraction and fractionation of growth enhancing substances are identified.	3. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	3-1: By the development of a fully automatic fractionation system, **the optimal methodologies for fractionation** has been **established**. Additionally, the methodology of the molecular size fractionation by ultrafiltration with centrifugation has been established. Those two established fractionation techniques were applied to OVI. 3.2.	
	3-2. Using plate culture technique, relationships between enhancing effect on algal growth and chemical characteristics of soil extraction fraction are clarified.	Project report and publication		3-2: Using plate culture techniques, the growth effects on some algal species by the soil extracts have been clarified. **Growth promoting effects of soil extracts have been determined** on selected microalgae provided from the NIES culture collection. In cooperation with Theme 1, the growth promoting effects of soil extracts on high-valued microalgae **have been investigated** and then observed. Furthermore, the effective soil extract fractions were found by the combined experiment of plate incubation and fractionation. **The role of each fraction (hydrophobic/hydrophilic) of soil extract was examined and the synergetic/offset effects of the fractions were determined by the advanced plate incubation experiments.** Out of the 11 sites, 6 sites were completely examined for the 11 species of microalgae. Undiluted fraction M-a samples was provided to UPM for further testing in small and large scale bioreactors. Characterization of the soil extracts with growth promoting effects are still in progress. Pristine soils dissolved organic matters and bacterial community profiling via shotgun metagenomics approach was successfully carried out on Royal Belum samples. The preparation of manuscripts is in progress.	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	**Achievement**	**Remarks**
4. Closed photobioreactor is scaled up for outdoor culture.	4-1. An experimental small-scale CRADLE reactor whose biomass yield is two (2) ton per giga Joule, which is twenty (20) times higher than conventional reactors, is developed.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	4-1: **Achieved** in 2018 Culture experiments on Spirulina and Chlorella were carried out by using **the laboratory-scale photobioreactor** and **achieved** the yield of more than **2 Ton-Dry biomass per GJ** (Term 3), which is around 20 times high energy efficiency compared to the value in a current raceway pond. The **laboratory-scale photobioreactor** has been installed since 2016 (Term 1). Twelve (12) **column reactors** which control temperature and aeration rate were designed and installed in the laboratory (Term 2).	
	4-2. Scaled-up bag CRADLE reactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed.			4-2: **Achieved** in 2019 (Term 7) The **scale-up novel bag photobioreactor system** was installed in a UPM (Term 4) laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, **was operated continuously for more than 2 months** (Term 7).	
	4-3. More than two (2) species of microalgae are cultured outdoors in sequenced bag reactors.			4-3: On-going (to be conducted from **July 2021**). The two species **identified** by Theme 1, *Thalassiosira weissflogii* and *Isochrysis galbana,* are being tested to be used. The **multi-sequence system of operational photobioreactors** is being finalised and to be installed in **May 2021.**	Two designs of **multi-sequence system of operational photobioreactors** reactors were **developed** in consultation with Japanese chemical manufacturers Selected 3 types of **reactor materials** and conducting toxicity tests for evaluating the optimum material using 3 microalgal species (i.e., *Chaetoceros gracilis*、*Isochrysis galbana*、*Thalassiosira weissflogii*) until **November.** Several types of **low-cost drives** using an actuator are under consideration in consultation with two experts and its trial run scheduled in **early 2021.** The **lab-scale reactor** will be installed at Soka University to monitor the operational performance until **January 2021**.

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is **established**.	5. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	5-1: **Achieved** in **lab-scale** experiments (Term 5-6). Bacillus sp. strain R2 was successfully isolated from sludge compost sample. We have found the optimum fermentation temperature, prospective sludge-degrading microorganism, and liming effect for enhancing NH3 recovery (Term5). The ammonia production potential of shrimp sludge was 5.4 kg-N per one ton of sludge. This is sufficient for the project goal "production of 10 kg dry weight of algal biomass (=0.9 kg-N) from one ton of sludge". $Ca(OH)_2$ dosing operation to enhance **ammonia volatilization was established without inhibiting microbial activity, both in lab-scale and bench-scale**. Sludge sampling in Malaysia (Term 2 and 3) Designed a system for recovery of nutrients from aquaculture pond sludge (Term 3). Set up the **outdoor medium-scale nutrient recycling system** (**Bench-scale nutrient recycling system**) (Term 4). Delivered the **outdoor large-scale nutrient recycling system (Pilot-scale nutrient recycling system)** to the demo site (Term 8) but needed to fully installed.	Been modifying the **Pilot-scale nutrient recycling system** (4 m3) at the demo-site for improving the system safety and to install the gas absorption system. Test-run must be conducted as soon as the modification is completed. The system operation needs to be optimized for the safe and sustainable operation for a long time. UPM started to examine plant growth effect of the shrimp sludge compost, expecting the growth of some halo-tolerant and high-value crops (mango and fig) using saline sludge.
	5-2. Technology to utilize ammonia as a low-cost alternative nitrogen source is **established**.			5-2: **To be tested shortly at the demo site** Proposed a two-stage gas absorption system to optimize a NH3 trapping/storage/supply method. Installed the sludge de-watering facility to pretreat large amounts of sludge at the demo site.	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle **revenue** generated from a production unit **exceeds** life cycle **cost**. 6-2. The system is proven not to **negatively affect** the current aquaculture production. 6-3. Total CO2 emission by Life cycle assessment is **reduced** as compared to **conventional** sludge treatment **methods**.	6. Project report and publication		6-1: Data and information are being collected. To be examined and compiled in August 2021. 6-2: Data and information are being collected. To be examined and compiled in June 2021. 6-3: Data and information are being collected. To be examined and compiled in September 2021.	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Activities			**Inputs**		**Pre-Conditions**
			The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.			Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・ Phycology ・ Molecular biology/ Microbiology ・ Photobiology and optics of natural environments ・ Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・ Analytical chemistry ・ Water chemistry ・ Chemical engineering/ Bioreactor engineering ・ Waste treatment science ・ Other specialists as needed Equipment and equipment To be elaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.					⬇
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.					<Issues and countermeasures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.					
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.					
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.					

Appendix 8

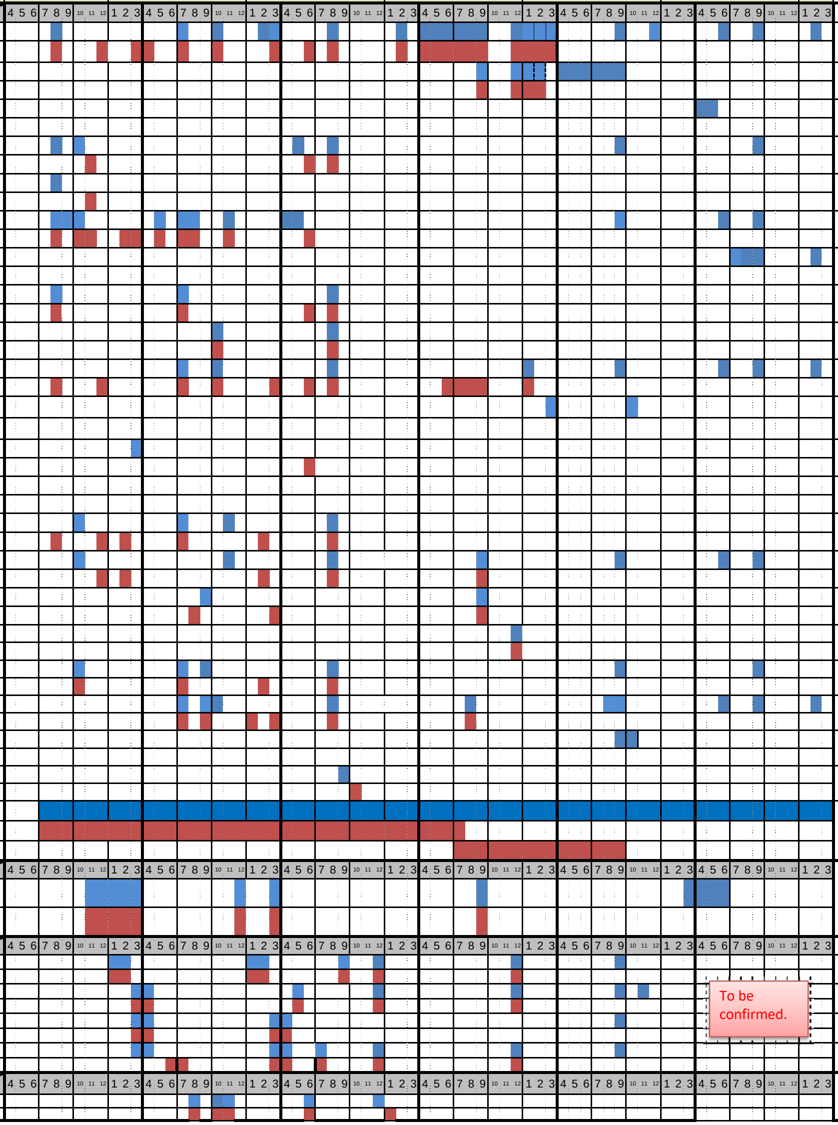
Project Monitoring Sheet II (Plan of Operation)

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

PO version 1 (Approved JCC5, 28 August 2020)

Reported as of September 30, 2020

Inputs	Project Duration	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
	ontract btw JICA and Soka Univ.	Term 1	Term 2	Term 3	Term 3	Term 4	
	Monitoring Sheet (Report)	Term 1, Term 2	Term 3, Term 4	Term 5, Term 6	Term 7, Term 8	Term 9, Term 10	Term 11, Term 12
	Year	2016	2017	2018	2019	2020	2021, 2022



Expert	AFF	No.		Remarks
Planktonologist 1/ Project Leader (T. Toda)	SU	1	Plan Actual	SU
Planktonologist 2 (M. Hirahara)	SU	2	Plan Actual	SU
Planktonologist 3 (Y. Takayama)	UT	3	Plan Actual	SU
Phycologist 1 (K. Takahashi)	UT	4	Plan Actual	UTokyo
Phycologist 2 (M. Sato)	UT	5	Plan Actual	UTokyo
Phycologist 3 (T. Katayama)	UT	6	Plan Actual	UTokyo
Phycologist 4 (M. Ohtake)	UT	7	Plan Actual	SU
Advisor/ Phycologist 4 (K. Furuya)	SU	8	Plan Actual	SU
Microbiologist (N. Kurosawa)	SU	9	Plan Actual	SU
Photobiologist (V. Kuwahara)	SU	10	Plan Actual	SU
Natural product chemist (M. Watanabe or Tominaga), Watanabe Oyster Laboratory	WOL	11	Plan Actual	Watanabe Oyster Laboratory (WOL)
Natural organic chemist/Soil chemist, GC-MAS	SU	12	Plan Actual	SU
Analytical chemist 2 LC-MAS		13	Plan Actual	
Water chemist 1 (A. Imai)	NIES	14	Plan Actual	NIES
Water chemist 2 (K. Komatsu)	NIES	15	Plan Actual	NIES
Chemical engineer/Bioreactor engineer 3 (T. Matsuyama)	SU	16	Plan Actual	SU
Chemical engineer/Bioreactor engineer 4 (J. Ida)	SU	17	Plan Actual	SU
Waste treatment scientist 1 (K. Nakasaki)	TT	18	Plan Actual	Tokyo Tech
Waste treatment scientist 2 (M. Koyama)	TT	19	Plan Actual	Tokyo Tech
Waste Treatment Scientist 3 (T.N.M. Ouyen)	TT	20	Plan Actual	Tokyo Tech
Electron Microscopist (M. Kuwata)	SU	21	Plan Actual	SU
JICA Project Coordinator Ms. Mari Miller Mr. Masaru Yamada	N.A.	22	Plan Actual Actual	Not available
Equipment				
Transport, installation and commissioning of equipment purchased in Japan			Plan Actual	
Training in Japan				
Training at NIES			Plan Actual	NIES
Training at Utokyo			Plan Actual	Tokyo Tech
Training at Tokyo Tech			Plan Actual	UTokyo
Training at SU			Plan Actual	SU
In-country/Third country Training				
Workshop in Malaysia, held by Japanese Researchers			Plan Actual	

Issue/ Remarks	Solution
Since May 2020, planned dispatchment from Japan was suspended due to Covid-19 pandemic to up-to-date. In order to contain the COVID–19 pandemic, the government of Malaysia initiated the Movement Control Order (MCO), effective on 18 March 2020. The MCO order was extended three times, each for additonal two week period, until 12 May 2020. On 13 May, the Conditional Movement Control Order (CMCO) was issued. On 8 June, the Recovery Movement Control Order (RMCO) was issued. On 25 March, the MCO was extended until 14 April. On 10 April, the MCO was extended until 28 April. On 23 April, the MCO was extended until 12 May. On 11 May, the CMCO was initiated as per 13 May until 9 June. On 7 June, the RMCO was initiated as per 10 June until 31 August. On 28 August,the RMCO was extended until 31 December. source:https://www.mdbc.com.my/mco-updates/ On 14 October, the CMCO was implemented until 27 October. On 27 October, the CMCO was extended until 9 November.	To follow the instruction and regulation from the government
The reactor (Theme 3) is to be delivered to the demo site in Malaysia in March 2021. The composting reactor (Theme 4) is needed to be assembled and tested before functioning.	
Planned training in 2020 was cancelled due to the Covid-19 pandemic. Training in 2021 to be confirmed later once the pademic is contained.	

Appendix 8

Inputs	Project Duration	1st Year				2nd Year				3rd Year				4th Year				5th Year				6th Year				Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.		Term 1				Term 2				Term 3						Term 4												
	Monitoring Sheet (Report)	Term 1		Term 2		Term 3		Term 4		Term 5		Term 6		Term 7		Term 8		Term 9		Term 10		Term 11		Term 12					
	Year	2016			2017				2018				2019				2020				2021				2022				
Output 1: High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.																													
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia.	Plan		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																UTokyo	UMT	This has been **completed** and **a total of 212 isolates** were collected from both seawater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states. Developed a protocol for bio-prospecting of high-value native microalgae (Term2). Completed all samplings of native microalgae in 26 sites as planned in the proposal: 16 sites from seawater and 10 sites from freshwater (Term 5).	
	Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																			
1-2. Screen, isolate and purify the collected microalgae.	Plan		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																UTokyo	UMT	All isolates have been **purified, screened** for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA. Two hundred and twelve (212) strains of microalgae have been successfully isolated and purified (Term 5). A total of 212 isolates were screened for high lipids/carotenoids using Nile red fluorescence dye and seven (7) candidates were selected as high-value microalgae candidates: (1) *Chlorella sorokiniana* , (2) *Cymatosiraceae* sp., (3) *Oocystis heteromucosa* , (4) *Oocystis marssonii* , (5) *Nitzschia capitellata* , (6) *Thalassiosira weissflogii* 1, (7) *Isochrysis galbana* 2 (Term 8) .	
	Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																			
1-3. Characterize microalgae for high contents of valuable compounds.	Plan					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦											UTokyo	UMT	Two microalgae species, Thalassiosira weissflogii and Isochrysis galbanawere chosen as "high value microalgae" based on results from second screening. The seven candidates have been characterized for contents of useful compounds (Term 8). Six (6) isolates from UMT and UPM identified earlier [Chaetoceros gracilis (UPM), Chlorella sp. (UMT), Chlorella vulgaris 1 (UMT), Chlorella vulgaris 2 (UPM), Isochrysis galbana (UPM), Tetraselmis suecica (UMT)] have been also characterized for the useful compounds (Term 8).	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
1-4. Conduct incubation experiments using variable growth conditions.	Plan									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		UTokyo	UMT	Optimum growth conditions are **currently being determined for the two selected microalgae** species, Thalassiosira weissflogii and Isochrysis galbana. Experiments by manipulating starvation of nitrate and phosphate have been completed for determination of the optimal growth in culture conditions, while other culture conditions such as temperature, salinity, and light intensity are now currently tested for the two strains. Incubation experiments under variable growth conditions (light, temperature, salinity, nutrients, etc.) has been conducted using some candidates (Term 5).	
	Actual									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										
Output 2: Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).																													
2-1. Conduct incubation experiments under manipulated culture conditions to enhance productivity of useful compounds.	Plan								🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦									UTokyo	UMT	**Not yet** because of COVID19 pandemic. Establishment of high-lipid/carotenoid production culture conditions is now currently proceeding for the selected isolates under variable conditions. Carotenoids extraction method was established for the screening of the native microalgae species (Term 5). Establishment of high-oil production culture conditions had been completed using Chlorella vulgaris UMT-M1. Nitrate starvation and inducible conditions for Ankistrodesmus gracilis was successfully established (Term 8).	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										
2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.	Plan													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		UTokyo	UMT	Productivity of useful compounds is currently determined for the cultured microalgae as in 2-1. The established methods for quantification are now used for *Thalassiosira weissflogii* and *Isochrysis galbana.*	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥										

Inputs	Project Duration	1st Year		2nd Year		3rd Year		4th Year		5th Year		6th Year		Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.		Term 1		Term 2		Term 3			Term 4							
	Monitoring Sheet (Report)	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10	Term 11	Term 12				
	Year	**2016**		**2017**		**2018**		**2019**		**2020**		**2021**	2022				
Output 3: Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the fractions are																	
3-1. Collect soil and sludge from various locations in Peninsula Malaysia.	**Plan**	🟦🟦	🟦🟦	🟦🟦										NIES	UNISEL	All samples have been collected/ completed (Term 7). For the application at the demonstration site, ~~the~~ soil samples at Singa Island and Timun Island in Pulau Lngkawi Forest Reserve will be additionally obtained. The following is the completed works in the previous years: Obtained permission for soil sampling (Perak, Johore, Pahang, Terengganu and Kelantan) from the HQ of Forestry Department of Peninsular Malaysia, Ministry of Natural Resources & Environment (18 January 2017). Soil samplings at three different sites in Selangor were completed: Rentas Saga Shrimp Ponds (RSSP), Raja Musa Peat-Swamp Forest Reserve (RMFR), and Ayer Hitam Forest Reserve (AHFR), Selangor (Term 3). **Completed for all 9 sites (Raja Musa Peat Swamp Forest, Air Hitam, Royal Belum, Tasik Kenyir, Tasik Bera, Tasik Chini, Pulau Langkawi, Prawn Farm Tanjung Karang, and Fish Pond Sludge Kuala Selangor, Term 7)**	
	Actual	🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥											
3-2. Study soil and sludge extraction methods.	**Plan**	🟦	🟦🟦	🟦🟦	🟦🟦	🟦🟦								NIES	UNISEL	This has been completed where the methods have been identified and established. The following is the completed works in the previous years. Nine (9) different soil extraction conditions were designed and tested for yield recovery, chemical and plate incubation analyses (Term 3). **Completed where seven (7) extraction methods were tested namely 1H, 4H, 24H natural extraction, 105˚C, 105˚C two hours extraction, 121˚C and 121˚C two hours extraction (Term 7).**	
	Actual	🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥											
3-3. Examine and optimize the fractionation method of soil and sludge extracts.	**Plan**			🟦	🟦🟦	🟦🟦	🟦🟦	🟦🟦						NIES	UNISEL	This activity has been completed. In addition to the resin fractionation technique, the molecular size fractionation method by using UF membranes has been established. The following is the completed works in the previous years. The fractionation system, multi-plate reader and related equipment were installed and related training was conducted in February 2017. The various techniques of soil identification, soil collections and the use of various equipment were carried out at RISDA-ESPEK Academy in Keratong, Rompin Pahang in March 2017. (Term 2). The custom-made automatic fractionation system is being modified based on the results of preliminary experiments (Term2). The custom-made automatic fractionation system was confirmed to be comparable to the conventional fractionation system. Several conditions of using soil extracts collected from sampling sites were examined (Term 3). A fully automatic fractionation system has been certified as an employee invention by NIES and the patent procedures has been completed (Term 5). **Completed successfully where automated fractionation system invented by NIES Japan scientists have been setup and optimized to be used by Malaysian scientists in Unisel Bestari Jaya campus. During the optimization period 9 samples were successfully fractionated into humic and non-humic substances (Term 7).**	
	Actual			🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥									
3-4. Conduct plate culture technique and identify the growth-enhancing fractions from soil and sludge extraction.	**Plan**		🟦🟦	🟦🟦	🟦🟦	🟦🟦	🟦🟦							NIES	UNISEL	Plate incubation experiments using microalgal strains selected by Theme 1 have been continued. It was found that L-b (soil extract of Singa Island in Pulau Langkawi Forest Reserve) and L-a (soil extract of Timun Island in Pulau Langkawi Forest Reserve) were the most effective for growth-promoting of Thalassiosira weissflogii and Isochrysis galbana (selected high-value microalgae in SATREPS-COSMOS program), respectively. 1 new high-value strain *Chaetoceros* will be tested again using 9 soils extract.	
	Actual		🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥							
3-5. Examine the chemical characteristics of the growth-enhancing fractions and their effects on the physiological responses of microalgae.	**Plan**						🟦	🟦🟦	🟦🟦	🟦🟦	🟦🟦	🟦🟦	🟦	NIES	UNISEL	The growth-promoting effects of DOM fractions were examined by the advanced plate incubation experiments. In the case of Thalassiosira weissflogii, the hydrophobic fraction showed better growth effects than the hydrophilic fraction or non-fractionated soil extracts. Through EEM-PARAFAC, it was suggested that all the S.E. should commonly include 4 kinds of fluorophore components (C-P: protein-like, C-M: marine-humic like, C-F: fulvic-acid like and C-H: humic-acid like). The percentages of the C-H and C-M were significantly correlated with the standardized specific growth rates of Thalassiosira weissflogii and Isochrysis galbana, respectively. Pristine soils dissolved organic matters and bacterial community profiling via shotgun metagenomics approach was successfully carried out on Royal Belum samples.	
	Actual			🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥	🟥🟥							

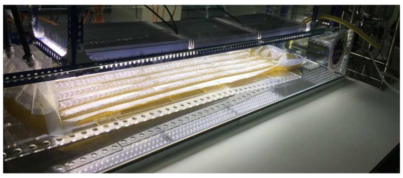
Inputs	Project Duration		1st Year		2nd Year		3rd Year		4th Year		5th Year		6th Year		Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.			Term 1		Term 2		Term 3			Term 4							
	Monitoring Sheet (Report)		Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10	Term 11	Term 12				
	Year		2016		2017		2018		2019		2020		2021	2022				
Output 4: Closed photobioreactor is scaled-up for outdoor culture.																		
4-1. Develop culture methods of indigenous microalgae in a small scale reactor. Note: A laboratory-scale photobioreactor		**Plan**	🟦	🟦	🟦	🟦									SU	UPM	Culture experiments on *Spirulina* and *Chlorella* were carried out by using the small-scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per GJ, which is around 20 times high energy efficiency compared to the value in a current raceway pond.Thus, the “Objectively verifiable indicators of 4.1” in PDM has been completed.	
		Actual	🟥	🟥	🟥	🟥												
4-2. Develop scaled-up CRADLE photo-bioreactor for outdoor mass culture. Note: A scale-up novel photobioreactor		**Plan**		🟦	🟦	🟦	🟦	🟦	🟦						SU	UPM	A scale-up novel photobioreactor system was installed in a UPM laboratory in March 2018 (Term 5), and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, was operated continuously for more than 2 months (Term 7).	
		Actual		🟥	🟥	🟥	🟥	🟥	🟥									
4-3. Develop a multi-sequence of operational bag reactors. Note: The multi-sequence system of operational photobioreactors		**Plan**						🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	The construction of demonstration site in UPM was completed as of October 2020 (Term 9). More experiments are being carried out on the selected high microalgae species (from UMT) to predict their responses in the outdoor bioreactors using soil extract obtained from UniSel. Unfortunately, some experiments were delayed due to CMCO.	The outdoor photobioreactor is being developed and to be delivered to the demo site in April 2021.
		Actual				🟥		🟥	🟥	🟥	🟥							
Output 5: Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.																		
5-1. Establish technology for recycling nutrients from aquaculture waste for use in microalgae production.		**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	Tokyo Tech	UPM	Not yet established. Several research works and trials are being conducted: lab-scale (100 mL) optimization has been completed (clarifying the bottle-neck step of sludge fermentation, optimum temperature, effectiveness of NH3 volatilization operation by alkaline agent dosing). The effect of alkaline agent was also clarified in bench-scale (200 L). The self-heating capacity of the shrimp sludge was in bench-scale. The phosphate recovery and salinity removal from the fermentation solid residue of shrimp sludge was clarified in lab-scale. The plant growth using the shrimp sludge compost is ongoing.	
		Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥							
5-2 Establish technology and method for recycling waste from the whole system.		**Plan**					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	Tokyo Tech	UPM	Not yet established. Several research works and trials are being conducted: a a two-stage gas absorption system was proposed for the complete NH3 recovery and efficient nutrient storage/supply. TiTech and UPM completed constructing the sludge de-watering unit to pretreat large amounts of sludge, in order to operate the pilot-scale nutrient recycling system at demo-site.	
		Actual					🟥	🟥	🟥	🟥	🟥							

Appendix 8

Inputs	Project Duration	1st Year												2nd Year												3rd Year											
	ontract btw JICA and Soka Univ.				Term 1												Term 2												Term 3								
	Monitoring Sheet (Report)	Term 1						Term 2						Term 3						Term 4						Term 5						Term 6					
	Year	2016									2017												2018												2019		
Output 6: Economic profitability and environmental compatibility of the system are verified.																																					
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC.	Plan																																				
	Actual																																				
6-2. Monitor biological production and environmental properties in aquaculture pond installed with algae production system.	Plan																																				
	Actual																																				
Duration / Phasing	Plan	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Monitoring Plan		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Joint Coordinating Committee	Plan					🟦											🟦													🟦							
	Actual					🟥											🟥													🟥							
Submission of Monitoring Sheet	Plan						🟦						🟦						🟦						🟦						🟦						
	Actual						🟥						🟥							🟥					🟥							🟥					
Monitoring Mission from Japan	Plan																													🟦							
	Actual																													🟥							
Joint Monitoring	Plan																																				
	Actual																																				
Post Monitoring	Plan																																				
	Actual																																				
Reports/Documents		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
	Plan																																				
	Actual																																				
Project Completion Report	Plan																																				
	Actual																																				
Public Relations		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Opening project's website	Plan						🟦																														
	Actual						🟥																														
Press release	Plan																🟦													🟦							
	Actual																🟥													🟥							

Inputs	Project Duration	4th Year												5th Year												6th Year												Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.									Term 4																															
	Monitoring Sheet (Report)	Term 7						Term 8						Term 9						Term 10						Term 11						Term 12									
	Year										2020										2021										2022										
Output 6: Economic profitability and environmental compatibility of the system are verified.																																									
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC.	Plan	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	To be condcuted in June 2021.	
	Actual													🟥	🟥	🟥	🟥	🟥	🟥																						
6-2. Monitor biological production and environmental properties in aquaculture pond installed with algae production system.	Plan	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	To be condcuted in June 2021.	
	Actual																																								
Duration / Phasing	Plan	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																						
Monitoring Plan		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3				
Joint Coordinating Committee	Plan						🟦											🟦													🟦										
	Actual						🟥											🟥																							
Submission of Monitoring Sheet	Plan	🟦						🟦						🟦						🟦						🟦						🟦									
	Actual	🟥						🟥						🟥							🟥																				
Monitoring Mission from Japan	Plan																																								
	Actual																																								
Joint Monitoring	Plan																														🟦										
	Actual																																								
Post Monitoring	Plan																																								
	Actual																																								
Reports/Documents		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3				
	Plan																																								
	Actual																																								
Project Completion Report	Plan																																			🟦					
	Actual																																								
Public Relations		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3				
Opening project's website	Plan																																								
	Actual																																								
Press release	Plan																																								
	Actual																																								

ANNEX - Terminology (The name of the rectors)

Theme	Photo	Terminology Official and Alternatives	Name and number in Form A4
3	 	**Official**: The laboratory-scale photobioreactor Alt1: Column reactor Alt2: Bubble column reactor	Indoor experimental small-scale reactor 45
3		**Official**: The scale-up novel photobioreactor Alt1: Laboratory bag reactor	Outdoor scaled-up bag reactor unit system 50
3	 To be replaced	**Official**: The multi-sequence system of operational photobioreactors Alt1: The outdoor-scaled-up photobioreactors	Outdoor scaled-up multiple bag reactor system 51
4		**Official**: The pilot-scale nutrient recycling system Alt1: Pilot-scale composting system	Outdoor large-scale nutrient recycle system 52
4		**Official**: The bench-scale nutrient recycling system Alt1: Bench-scale composting system	Outdoor medium-scale nutrient recycle system 53
4		**Official**: The lab-scale nutrient recycling system (installed at TiTech)	This is Not handover equipment.

Project Monitoring Sheet I (Project Design Matrix, PDM)

PDM Version 1 (Revised as of JCC5, 28 August 2020)

Reporting date: March 31 2021 (TERM 10)

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 6 years (2016.04 - 2022.03)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. More than three (3) aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained	1. High value microalgae species have been shown to produce useful compounds under laboratory conditions. These are **Anti-oxidants (UMT Group 2)** and **Fatty acids (UMT Group 3)**. Detail chemical properties of the compounds are being analysed. 2. The mass-culture of high values microalgae will be established at the ***demo site*** in UPM as a model for farms to adopt. Upon establishment of **the multi-sequence system of operational photobioreactor** (outdoor bioreactor), technologies will be disseminated to farms. In Malaysia, some Aquaculture Companies showed their interest: (1) Blue Archipelago Sdn Bhd, (2) Hannan Sdn Bhd, (3) RE Millenium Sdn Bhd (Term 4). In Japan, Shin Kami town in Goto island, Nagasaki, large-scale implementation is operational.	The construction of the SATREPS-COSMOS Demonstration site was delayed unfavorable climatic conditions in June 2019. The outbreak of Covid19 delayed the project progress further. The extension of the project duration was agreed on the fifth JCC meeting in August 2020.
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per giga joule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) .	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology	*The construction of the* ***demonstration site (demo site)*** *was proposed and initiated by UPM in order to integrate and disseminate those technologies developed by the project, particularly at the outdoor (bench) scale. This* ***construction*** *was* ***completed as of October 2020.*** 1. Production of **one tonne per ha (1t/ha)** has been **achieved based on the scale-up novel photobioreactor** (in-door photobioreactor). However, **the production by the multi-sequence system of operational photobioreactors has to be calculated after** the installation (scheduled in June 2021). 2. **Fabrication phase** because of the delay in the installation of **the multi-sequence system of operational photobioreactors** (outdoor bioreactor) due to climatic problem and COVID19 pandemic. 3. **Fabrication phase**. The ammonia from the pond sludge has been shown to be suitable for the microalgae culture (Two papers published in Q1 journals). The whole process is to be established at the demo site in July 2021.	The **multi-sequence system of operational photobioreactor** is under preparation in Japan and will be shipped to Malaysia in March 20212. The **pilot-scale nutrient recycling system** is needed to be modified and tested as matter of urgency (the system safety and the gas absorption system) The whole integration at the demo site is scheduled in June 2021.

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	1-1: **Two** indigenous microalgae species, ***Thalassiosira weissflogii*** and ***Isochrysis galbana***, have been **chosen** as high value microalgae with high content of lipid and carotenoid.	
	1-2. Optimum growth conditions are determined for selected microalgae species.	Project report and publication		1-2: On-going **Optimum growth conditions are currently determined** for the two selected microalgae species, *Thalassiosira weissflogii* and *Isochrysis galbana.* With regards to publications, the findings of screening and characterization of the indigenous microalgae has already been published as five papers.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species.	Project report and publication		2-1: On-going (light, temperature condition); **Completed** (nutrients, salinity conditions). High oil production culture conditions were established for *Chlorella vulgaris* and *Messastrum gracile* microalgae model. Based on these findings, suitable culture conditions for inducing production of useful compounds **are currently determined** for the two selected microalgae species, *Thalassiosira weissflogii* and *Isochrysis galbana*.	REMARKS (210411): Sampling trip to retrieve more soil samples for large-scale outdoor reactor is required, but currently postponed. We hope to retrive more samples in Malaysia in June-July 2021. Processing soil samples for experimental use requires approximately 2-months to prepare.
	2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	Project report and publication		2-2. On-going Productivity of useful compounds (fatty acids, carotenoids) **is currently determined** for the cultured microalgae as in 2-1. Five related papers have already been published.	

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
3. Efficient microalgae culturing technique utilizing growth-enhancing substances extracted from soil and sludge is proposed.	3-1. Optimal methodologies for extraction and fractionation of growth enhancing substances are identified.	3. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	3-1: By the development of a fully automatic fractionation system, **the optimal methodologies for fractionation** has been **established**. Additionally, the methodology of the molecular size fractionation by ultrafiltration with centrifugation has been established. Those two established fractionation techniques were applied to OVI. 3.2.	
	3-2. Using plate culture technique, relationships between enhancing effect on algal growth and chemical characteristics of soil extraction fraction are clarified.	Project report and publication		3-2: Using plate culture techniques, the growth effects on some algal species by the soil extracts have been clarified. **Growth promoting effects of soil extracts have been determined** on selected microalgae provided from the NIES culture collection. In cooperation with Theme 1, the growth promoting effects of soil extracts on high-valued microalgae **have been investigated** and then observed. Furthermore, the effective soil extract fractions were found by the combined experiment of plate incubation and fractionation. **The role of each fraction (hydrophobic/hydrophilic) of soil extract was examined and the synergetic/offset effects of the fractions were determined by the advanced plate incubation experiments.** Out of the 11 sites, 6 sites were completely examined for the 11 species of microalgae. Undiluted fraction M-a samples was provided to UPM for further testing in small and large scale bioreactors. Characterization of the soil extracts with growth promoting effects are still in progress. Pristine soils dissolved organic matters and bacterial community profiling via shotgun metagenomics approach was successfully carried out on Royal Belum samples. Three related papers have already been published, and two other related manuscripts are in preparation.	

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
4. Closed photobioreactor is scaled up for outdoor culture.	4-1. An experimental small-scale CRADLE reactor whose biomass yield is two (2) ton per giga Joule, which is twenty (20) times higher than conventional reactors, is developed.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	4-1: **Achieved** in 2018 Culture experiments on Spirulina and Chlorella were carried out by using **the laboratory-scale photobioreactor** and **achieved** the yield of more than **2 Ton-Dry biomass per GJ** (Term 3), which is around 20 times high energy efficiency compared to the value in a current raceway pond. The **laboratory-scale photobioreactor** has been installed since 2016 (Term 1). Twelve (12) **column reactors** which control temperature and aeration rate were designed and installed in the laboratory (Term 2).	
	4-2. Scaled-up bag CRADLE reactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed.			4-2: **Achieved** in 2019 (Term 7) The **scale-up novel bag photobioreactor system** was installed in a UPM (Term 4) laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, **was operated continuously for more than 2 months** (Term 7).	
	4-3. More than two (2) species of microalgae are cultured outdoors in sequenced bag reactors.			4-3: On-going (to be conducted from **July 2021**). The two species **identified** by Theme 1, *Thalassiosira weissflogii* and *Isochrysis galbana,* are being tested to be used. The **multi-sequence system of operational photobioreactors** is being finalised and to be installed in **June/July 2021.**	The **multi-sequence system of operational photobioreactors** has been **developed** in consultation with Japanese chemical manufacturers Three types of **reactor materials** were used for toxicity tests in November 2020 to evaluate the optimum material using 3 microalgal species (i.e., *Chaetoceros gracilis*、*Isochrysis galbana*、*Thalassiosira weissflogii*)**.** The **low-cost drive** using an actuator is under consideration in consultation with two experts and its trial run scheduled in **early 2021.** The **prototype** was installed at Soka University to monitor the operational performance in **March 2021.**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is **established**.	5. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	5-1: **Achieved** in **lab-scale** experiments (Term 5-6). Bacillus sp. strain R2 was successfully isolated from sludge compost sample. We have found the optimum fermentation temperature, prospective sludge-degrading microorganism, and liming effect for enhancing NH3 recovery (Term5). The ammonia production potential of shrimp sludge was 5.4 kg-N per one ton of sludge. This is sufficient for the project goal "production of 10 kg dry weight of algal biomass (=0.9 kg-N) from one ton of sludge". $Ca(OH)_2$ dosing operation to enhance **ammonia volatilization was established without inhibiting microbial activity, both in lab-scale and bench-scale**. Sludge sampling in Malaysia (Term 2 and 3) Designed a system for recovery of nutrients from aquaculture pond sludge (Term 3). Set up the **outdoor medium-scale nutrient recycling system** (**Bench-scale nutrient recycling system**) (Term 4). Delivered the **outdoor large-scale nutrient recycling system (Pilot-scale nutrient recycling system)** to the demo site (Term 8) but needed to fully installed. The modification of the Outdoor large-scale nutrient recycle system was completed (Term 9-10).	Been modifying the **Pilot-scale nutrient recycling system** (4 m3) at the demo-site for improving the system safety and to install the gas absorption system. Test-run must be conducted as soon as the modification is completed. The system operation needs to be optimized for the safe and sustainable operation for a long time. UPM started to examine plant growth effect of the shrimp sludge compost, expecting the growth of some halo-tolerant and high-value crops (mango and fig) using saline sludge.
	5-2. Technology to utilize ammonia as a low-cost alternative nitrogen source is **established**.			5-2: **To be tested shortly at the demo site** Proposed a two-stage gas absorption system to optimize a NH3 trapping/storage/supply method. Installed the sludge de-watering facility to pretreat large amounts of sludge at the demo site.	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle **revenue** generated from a production unit **exceeds** life cycle **cost**. 6-2. The system is proven not to **negatively affect** the current aquaculture production. 6-3. Total CO2 emission by Life cycle assessment is **reduced** as compared to **conventional** sludge treatment **methods**.	6. Project report and publication		6-1: Data and information are being collected. To be examined and compiled in August 2021. Working on setting up scenario and evaluation system boundaries. In addition, collecting each value (carbon intensity, construction cost, revenue amount, and operation cost) necessary for the evaluation. 6-2: Data and information are being collected. To be examined and compiled in September 2021. The photobioreactor part of the multi-sequence system does not adopt the use of toxic chemicals such as heavy metals for aquatic organisms. Additionally, trial run by using the prototype of photobioreactor installed at Soka University is under way for confirming that there is no leakage of culture in the reactor. 6-3: Data and information are being collected. To be examined and compiled in September 2021. Working on setting up scenario and evaluation system boundaries. In addition, collecting each value (carbon intensity, construction cost, revenue amount, and operation cost) necessary for the evaluation.	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Activities			Inputs		Pre-Conditions
			The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.			Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・Phycology ・Molecular biology/ Microbiology ・Photobiology and optics of natural environments ・Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・Analytical chemistry ・Water chemistry ・Chemical engineering/ Bioreactor engineering ・Waste treatment science ・Other specialists as needed Equipment and equipment To be elaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.					
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.					<Issues and countermeasures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.					
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.					
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.					

Project Monitoring Sheet I (Project Design Matrix, PDM) **PDM Version 1 (Revised as of JCC5, 28 August 2020)**
Reporting date: September 30 2021 (TERM 11)

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS)

Implementing Institutions (Malaysian side): Universiti Putra Malaysia (UPM), Universiti Malaysia Terengganu (UMT), Universiti Selangor (UNISEL)

Implementing Institutions (Japanese side): Soka University (SU), The University of Tokyo (UT), Tokyo Institute of Technology (TITech), National Institute for Environmental Studies (NIES)

Target Group: Researchers, Technicians and Graduate students of implementing institutions

Period of Project: 6 years (2016.04 - 2022.03)

Project Site: Peninsular Malaysia **Model Site: N/A**

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Overall Goal					
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	1. More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 2. More than three (3) aquaculture farms have introduced mass culture of algae in Malaysia and/or other tropical countries.	Report from aquaculture farms Memorandum of Understanding on the use of mass-culture technology between the private farms and implementing institutions	Market demand for useful compounds is maintained	1. High value microalgae species have been shown to produce useful compounds under laboratory conditions. These are **Anti-oxidants (UMT Group 2)** and **Fatty acids (UMT Group 3)**. Detail chemical properties of the compounds are being analysed. 2. The mass-culture of high values microalgae will be established at the ***demo site*** in UPM as a model for farms to adopt. Upon establishment of **the multi-sequence system of operational photobioreactor** (outdoor bioreactor), technologies will be disseminated to farms. In Malaysia, some Aquaculture Companies showed their interest: (1) Blue Archipelago Sdn Bhd, (2) Hannan Sdn Bhd, (3) RE Millenium Sdn Bhd (Term 4). In Japan, Shin Kami town in Goto island, Nagasaki, large-scale implementation is operational.	The construction of the SATREPS-COSMOS Demonstration site was delayed unfavorable climatic conditions in June 2019. The outbreak of Covid19 delayed the project progress further. The extension of the project duration was agreed on the fifth JCC meeting in August 2020.
Project Purpose					
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	1. Annual algal biomass production of one (1) tonne or more per hectare is achieved. 2. Biomass yield per giga joule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass	Project report and publication	Private aquaculture farms are willing to cooperate in adopting the sustainable technology	1. Production of **one tonne per ha (1t/ha)** has been **achieved based on the scale-up novel photobioreactor** (in-door photobioreactor). 2. The biomass yield per giga joule of two (2) times or more than the conventional raceway system for two (2) indigenous microalgae species production by the multi-sequence system of operational photobioreactors will be calculated upon completion of the ongoing experiment (scheduled in February 2022). 3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10) kilograms algal biomass production (dry weight basis) will be calculated upon completion of experiment (scheduled in February 2022).	The pilot-scale nutrient recycling system is needed to be modified and tested as matter of urgency (the system safety and the gas absorption system). The ammonia from the pond sludge has been shown to be suitable for the microalgae culture (Two papers published in Q1 journals). The whole integration at the demo site and continued experiments are scheduled in February 2022.

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
Outputs					
1. High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are determined.	1-1. More than two (2) indigenous microalgae species with high contents of fatty-acid, antioxidant and other useful compounds are identified.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	1-1: **Two** indigenous microalgae species, ***Thalassiosira weissflogii*** and ***Isochrysis galbana***, have been **chosen** as high value microalgae with high content of lipid and carotenoid.	
	1-2. Optimum growth conditions are determined for selected microalgae species.	Project report and publication		1-2: On-going (light, temperature condition); **Completed** (nutrients, salinity conditions). **Optimum growth conditions are currently determined** for the two selected microalgae species*, Thalassiosira weissflogii* and *Isochrysis galbana.* For both microalgae species, 20 ppt has been shown to have the most profound effect on their growth.	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species.	Project report and publication		2-1: On-going (light, temperature condition); **Completed** (nutrients, salinity conditions). High oil production culture conditions were established for *Chlorella vulgaris* and *Messastrum gracile* microalgae model. Based on these findings, suitable culture conditions for inducing production of useful compounds **are currently determined** for the two selected microalgae species, *Thalassiosira weissflogii* and *Isochrysis galbana*. For T. weissflogii, the best culture conditions are full strength phosphate and nitrate in 20 ppt salinity to induce EPA content. Meanwhile for I. galbana, 1/4 strength of phosphate is the best to induce high DHA production.	
	2-2. Productivity of useful compounds is increased by twenty (20) percent as compared with the standard growth condition.	Project report and publication		2-2. On-going Productivity of carotenoids **is currently determined** for the cultured microalgae as in 2-1. For I. galbana, DHA production has been increased more than 20% by reducing phosphate (1/4 from the Control).	

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
3. Efficient microalgae culturing technique utilizing growth-enhancing substances extracted from soil and sludge is proposed.	3-1. Optimal methodologies for extraction and fractionation of growth enhancing substances are identified.	3. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	3-1: By the development of a fully automatic fractionation system, **the optimal methodologies for fractionation** have been **established**. Additionally, the methodology of the molecular size fractionation by ultrafiltration with centrifugation has been established. Those two established fractionation techniques were applied to OVI. 3.2.	REMARKS (210930): Sampling trip to retrieve more soil samples for large-scale outdoor reactor is required, but currently postponed. We hope to retrive more samples in Malaysia in Term 11. Processing soil samples for experimental use requires approximately 2-months to prepare.
	3-2. Using plate culture technique, relationships between enhancing effect on algal growth and chemical characteristics of soil extraction fraction are clarified.	Project report and publication		3-2: Using plate culture techniques, the growth effects on some algal species by the soil extracts have been clarified. **Growth promoting effects of soil extracts have been determined** on selected microalgae provided from the NIES culture collection. In cooperation with Theme 1, the growth promoting effects of soil extracts on high-valued microalgae **have been investigated** and then observed. Furthermore, the effective soil extract fractions were found by the combined experiment of plate incubation and fractionation. **The role of each fraction (hydrophobic/hydrophilic) of soil extract was examined and the synergetic/offset effects of the fractions were determined by the advanced plate incubation experiments.** Through the EEM-PARAFAC (Excitation Emission Matrix combined with Parallel Factor Analysis), it was suggested that either humic-acid like or marine-humic like fluorophores had the significantly correlated with the specific growth rate. Furthermore, it was suggested that iron is one of the most conceivable factors for the algal growth enhancement. Out of the 11 sites, 6 sites were completely examined for the 11 species of microalgae. The undiluted fraction of M-a samples was provided to UPM for further testing in small- and large-scale bioreactors. Characterization of the soil extracts with growth promoting effects are still in progress. Pristine soils dissolved organic matters and bacterial community profiling via shotgun metagenomics approach was successfully carried out on Royal Belum samples.	

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
4. Closed photobioreactor is scaled up for outdoor culture.	4-1. An experimental small-scale CRADLE reactor whose biomass yield is two (2) ton per giga Joule, which is twenty (20) times higher than conventional reactors, is developed.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	4-1: **Achieved** in 2018 Culture experiments on Spirulina and Chlorella were carried out by using **the laboratory-scale photobioreactor** and **achieved** the yield of more than **2 Ton-Dry biomass per GJ** (Term 3), which is around 20 times high energy efficiency compared to the value in a current raceway pond. The **laboratory-scale photobioreactor** has been installed since 2016 (Term 1). Twelve (12) **column reactors** which control temperature and aeration rate were designed and installed in the laboratory (Term 2).	
	4-2. Scaled-up bag CRADLE reactor of more than one (1) square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed.			4-2: **Achieved** in 2019 (Term 7) The **scale-up novel bag photobioreactor system** was installed in a UPM (Term 4) laboratory, and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, **was operated continuously for more than 2 months** (Term 7).	
	4-3. More than two (2) species of microalgae are cultured outdoors in sequenced bag reactors.			4-3: On-going (to be conducted from **October 2021**). The two species **identified** by Theme 1, *Thalassiosira weissflogii* and *Isochrysis galbana,* are being tested to be used. The **multi-sequence system of operational photobioreactors** is being finalised and to be installed in **October 2021.**	The **multi-sequence system of operational photobioreactors** has been **developed** in consultation with Japanese chemical manufacturers. Three types of **reactor materials** were used for toxicity tests in November 2020 to evaluate the optimum material using 3 microalgal species (i.e., *Chaetoceros gracilis* , *Isochrysis galbana* , *Thalassiosira weissflogii*)**.** The trial run of the **low-cost drive** using an actuator was completed in **early 2021.** The **prototype** was installed at Soka University to monitor the operational performance in **March 2021.**

Narrative Summary	**Objectively Verifiable Indicators**	Means of Verification	Important Assumption	**Achievement**	**Remarks**
5. Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are developed.	5-1. Technology for ammonia and phosphorus recovery from aquaculture pond sludge is **established**.	5. Project report and publication	Biological and other related samples can be brought to Japan for analyses.	5-1: **Achieved** in **lab-scale** experiments (Term 5-6). Bacillus sp. strain R2 was successfully isolated from sludge compost sample. We have found the optimum fermentation temperature, prospective sludge-degrading microorganism, and liming effect for enhancing NH3 recovery (Term5). The ammonia production potential of shrimp sludge was 5.4 kg-N per one ton of sludge. This is sufficient for the project goal "production of 10 kg dry weight of algal biomass (=0.9 kg-N) from one ton of sludge". $Ca(OH)_2$ dosing operation to enhance **ammonia volatilization was established without inhibiting microbial activity, both in lab-scale and bench-scale**. Sludge sampling in Malaysia (Term 2 and 3) Designed a system for recovery of nutrients from aquaculture pond sludge (Term 3). Set up the **outdoor medium-scale nutrient recycling system** (**Bench-scale nutrient recycling system**) (Term 4). Delivered the **outdoor large-scale nutrient recycling system (Pilot-scale nutrient recycling system)** to the demo site (Term 8). The modification of the Outdoor large-scale nutrient recycle system was completed (Term 9-10).	Been modifying the **Pilot-scale nutrient recycling system** (4 m3) at the demo-site for improving the system safety and to install the gas absorption system. UPM started to examine plant growth effect of the shrimp sludge compost, expecting the growth of some halo-tolerant and high-value crops (mango and fig) using saline sludge.
	5-2. Technology to utilize ammonia as a low-cost alternative nitrogen source is **established**.			5-2: **Trial run completed, full operation planned at the demo site** Proposed a two-stage gas absorption system to optimize a NH3 trapping/storage/supply method. Installed the sludge de-watering facility to pretreat large amounts of sludge at the demo site. The trial run of the two-stage gas absorption system and sludge de-watering facility were conducted and progress of thermophilic composting was confirmed (Term 11).	
6. Economic profitability and environmental compatibility of the system are verified.	6-1. Calculated life cycle **revenue** generated from a production unit **exceeds** life cycle **cost**. 6-2. The system is proven not to **negatively affect** the current aquaculture production. 6-3. Total CO2 emission by Life cycle assessment is **reduced** as compared to **conventional** sludge treatment **methods**.	6. Project report and publication		6-1: The calculation of life cycle revenue generated from a production unit exceeds life cycle cost was achieved (Term 11). Collecting the algal biomass production will be necessary for the final evaluation in February 2022. 6-2: The evaluation of negative affects of no leakage of culture and toxic chemicals of the integrated system to current aquaculture production will be completed in February 2022. 6-3: The calculation of total CO2 emission was achieved (Term 11). Scenario simulations and evaluation system boundaries are being conducted until February 2022.	A detailed Life Cycle Cost (LCC) assessment suggests that application of the integrated project technologies (utilized at the demo-site) for 40 ha scale shrimp farm (1 ha plastic-lined shrimp pond x 40, which is a common scale in Malaysia) with plastic lining in Malaysia will recover the initial cost within 1-year of operation. However, the LCC estimation is based on preliminary (lab-scale) micro-algae culture information, and it is necessary to reassess specific calculations upon obtaining micro-algae growth from the demo-site operation planned in February 2022.

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Activities			**Inputs**		**Pre-Conditions**
			The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia. 1-2. Screen, isolate and purify the collected microalgae. 1-3. Characterize microalgae for high contents of valuable compounds. 1-4. Conduct incubation experiments using variable growth conditions.			Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: ・ Planktonology ・Phycology ・Molecular biology/ Microbiology ・Photobiology and optics of natural environments ・Natural product chemistry/ Natural organic chemistry/ Soil chemistry ・Analytical chemistry ・Water chemistry ・Chemical engineering/ Bioreactor engineering ・Waste treatment science ・Other specialists as needed Equipment and equipment To be elaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment Supply or replacement of machinery, equipment, instruments, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than the Equipment provided by JICA Running expenses necessary for the implementation of the Project (in the form of matching fund).	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds. 2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.					⬇
3-1. Collect soil and sludge from various locations in Peninsular Malaysia. 3-2. Study soil and sludge extraction methods. 3-3. Examine and optimize the fractionation method of soil and sludge extracts. 3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction. 3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.					<Issues and countermeasures>
4-1. Develop culture methods of selected microalgae in a small scale photobioreactor. 4-2. Develop scaled-up novel photobioreactor for outdoor mass culture. 4-3. Develop a multi-sequence system of operational photobioreactors.					
5-1. Establish a technology for recovery of nutrients from aquaculture pond sludge. 5-2. Establish a technology utilizing nutrients for microalgae production.					
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC. 6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.					

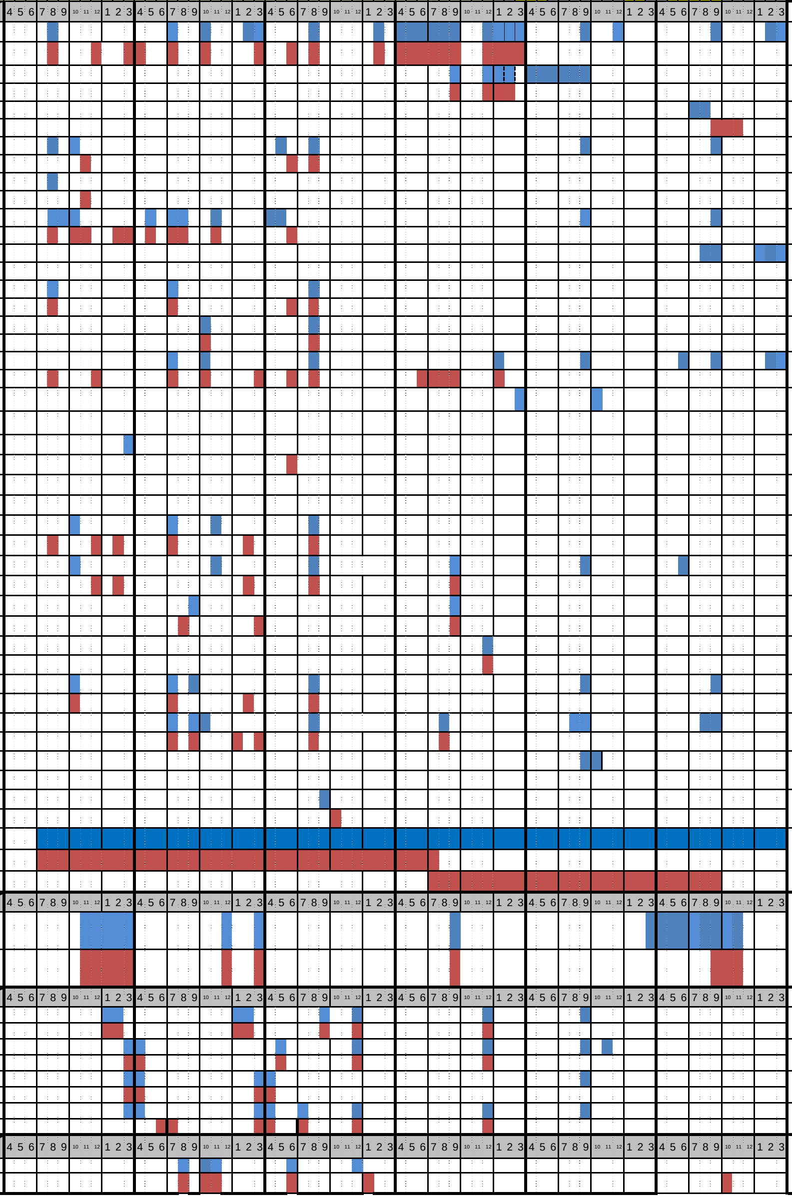
Project Monitoring Sheet II (Plan of Operation)

PO version 1 (Approved JCC5, 28 August 2020)

Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (CC

Reported as of September 30, 2021

Project Duration	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
Contract btw JICA and Soka Univ.	Term 1	Term 2	Term 3	Term 4		
Monitoring Sheet (Report)	Term 1 Term 2	Term 3 Term 4	Term 5 Term 6	Term 7 Term 8	Term 9 Term 10	Term 11 Term 12
Year	2016	2017	2018	2019	2020	2021 2022
MCO(Movement Control Order)					1 2 3 4 5 6 7 8 9 10 11 12	1 2 3 4 5 6 7 8 9 10 11 12 1 2 3



Inputs	AFF	No.		Remarks
Expert				
Planktonologist 1/ Project Leader (T. Toda)	SU	1	Plan Actual	SU
Planktonologist 2 (M. Hirahara)	SU	2	Plan Actual	SU
Planktonologist 3 (Y. Takayama)	UT	3	Plan Actual	SU
Phycologist 1 (K. Takahashi)	UT	4	Plan Actual	UTokyo
Phycologist 2 (M. Sato)	UT	5	Plan Actual	UTokyo
Phycologist 3 (T. Katayama)	UT	6	Plan Actual	UTokyo
Phycologist 4 (M. Ohtake)	UT	7	Plan Actual	SU
Advisor/ Phycologist 4 (K. Furuya)	SU	8	Plan Actual	SU
Microbiologist (N. Kurosawa)	SU	9	Plan Actual	SU
Photobiologist (V. Kuwahara)	SU	10	Plan Actual	SU
Natural product chemist (M. Watanabe or Tominaga), Watanabe Oyster Laboratory	WOL	11	Plan Actual	Watanabe Oyster Laboratory (WOL)
Natural organic chemist/Soil chemist, GC-MAS	SU	12	Plan Actual	SU
Analytical chemist 2 LC-MAS		13	Plan Actual	
Water chemist 1 (A. Imai)	NIES	14	Plan Actual	NIES
Water chemist 2 (K. Komatsu)	NIES	15	Plan Actual	NIES
Chemical engineer/Bioreactor engineer 3 (T. Matsuyama)	SU	16	Plan Actual	SU
Chemical engineer/Bioreactor engineer 4 (J. Ida)	SU	17	Plan Actual	SU
Waste treatment scientist 1 (K. Nakasaki)	TT	18	Plan Actual	Tokyo Tech
Waste treatment scientist 2 (M. Koyama)	TT	19	Plan Actual	Tokyo Tech
Waste Treatment Scientist 3 (T.N.M. Quyen)	TT	20	Plan Actual	Tokyo Tech
Electron Microscopist (M. Kuwata)	SU	21	Plan Actual	SU
JICA Project Coordinator Ms. Mari Miller Mr. Masaru Yamada	N.A.	22	Plan Actual Actual	Not available
Equipment				
Transport, installation and commissioning of equipment purchased in Japan			Plan Actual	
Training in Japan				
Training at NIES			Plan Actual	NIES
Training at Utokyo			Plan Actual	Tokyo Tech
Training at Tokyo Tech			Plan Actual	UTokyo
Training at SU			Plan Actual	SU
In-country/Third country Training				
Workshop in Malaysia, held by Japanese Researchers			Plan Actual	

Issue/ Remarks

Listed below is the Movement Control Orders (MCOs) to contain the Covid-19 outbreaks

Since May 2020, planned dispatchment from Japan was suspended due to Covid-19 pandemic to up-to-date.
In order to contain the COVID–19 pandemic, the government of Malaysia initiated the Movement Control Order (MCO), effective on 18 March 2020. The MCO order was extended three times, each for additional two week period, until 12 May 2020.
On 13 May, the Conditional Movement Control Order (CMCO) was issued.
On 8 June, the Recovery Movement Control Order (RMCO) was issued.
On 25 March, the MCO was extended until 14 April.
On 10 April, the MCO was extended until 28 April.
On 23 April, the MCO was extended until 12 May.
On 11 May, the CMCO was initiated as per 13 May until 9 June.
On 7 June, the RMCO was initiated as per 10 June until 31 August.
On 28 August, the RMCO was extended until 31 December.
source:https://www.mdbc.com.my/mco-updates/
On 14 October, the CMCO was implemented until 27 October.
On 27 October, the CMCO was extended until 9 November.
On 8 November, the CMCO was extended until 6 December.
On 7 December, the CMCO was extended until 20 December.
On 28 December, the CMCO was extended until 14 January.
On 1 January 2021, the RMCO was extended until 31 March 2021.
On 11 January, the MCO was issued until 26 January. A state of emergency in the federation until early August, more than half a year from January.
On 21 January, the MCO was extended until 4 February.
On 2 February, the MCO was extended until 18 February.
On 16 February, the MCO was extended until 4 March (for KL and Selangor).
On 2 March, the MCO was replaced by the CMCO from 5 to 18 March.(for KL and Selangor).
On 16 March, the CMCO was extended until 31 March (for KL and Selangor).
On 30 March, the CMCO was extended until 14 April.

On 12 April, the CMCO was extended until 28 April.
On 27 April, the CMCO was extended until 17 May.
On 6 May, the MCO was declared once again until 6 June.
From 1 to 14 June, Full MCO (FMCO) was implemented across the country.
On 11 June, the FMCO was extended until 28 June.
On 28 June, the FMCO was extended until clear the target of 4,000 new cases/ day.
On 1 July, Enhanced MCO (EMCO) was implemented in the targeted district in KL and Selangor from 3 to 16 July.
From 10 September, Selangor joined Putrajaya and Kuala Lumpur in transitioning to Phase Two of the National Recovery Plan (NRP)..
Langkawi island reopened public access from 16 September 2021.
From 1 October, Selangor, Putrajaya and Kuala Lumpur entered Phase Three of the National Recovery Plan (NRP).

The reactor (Theme 3) was delivered to the demo site in Malaysia on 14th October 2021. The composting reactor (Theme 4) was assembled as of March 2021 and is needed to be tested before functioning.

Planned training in 2020 was cancelled due to the Covid-19 pandemic.

Workshop on centrifuge and photo bio-reactor was conducted at the demo site (2021.10).

Solution

To follow the instruction and regulation from the government

Appendix 8

Inputs	Project Duration	1st Year				2nd Year				3rd Year				4th Year				5th Year				6th Year				Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.		Term 1				Term 2				Term 3					Term 4													
	Monitoring Sheet (Report)	Term 1		Term 2		Term 3		Term 4		Term 5		Term 6		Term 7		Term 8		Term 9		Term 10		Term 11		Term 12					
	Year	2016			2017				2018				2019				2020				2021				2022				
Output 1: High value microalgae are isolated and suitable growth conditions in their life cycle and physiological attributes are																													
1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia.	**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																UTokyo	UMT	This has been **completed** and **a total of 212 isolates** were collected from both seawater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states. Developed a protocol for bio-prospecting of high-value native microalgae (Term2). Completed all samplings of native microalgae in 26 sites as planned in the proposal: 16 sites from seawater and 10 sites from freshwater (Term 5).	
	Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																			
1-2. Screen, isolate and purify the collected microalgae.	**Plan**		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																UTokyo	UMT	All isolates have been **purified, screened** for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA. Two hundred and twelve (212) strains of microalgae have been successfully isolated and purified (Term 5). A total of 212 isolates were screened for high lipids/carotenoids using Nile red fluorescence dye and seven (7) candidates were selected as high-value microalgae candidates: (1) *Chlorella sorokiniana* , (2) *Cymatosiraceae* sp., (3) *Oocystis heteromucosa* , (4) *Oocystis marssonii* , (5) *Nitzschia capitellata* , (6) *Thalassiosira weissflogii* 1, (7) *Thalassiosira weissflogii* 2 (Term 8) .	
	Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																			
1-3. Characterize microalgae for high contents of valuable compounds.	**Plan**					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦											UTokyo	UMT	This has been completed and two microalgae species, *Thalassiosira weissflogii* and *Isochrysis galbana* were chosen as "high value microalgae" based on results from second screening. The seven candidates have been characterized for contents of useful compounds (Term 8). Six (6) isolates from UMT and UPM identified earlier [*Chaetoceros gracilis* (UPM), *Chlorella* sp. (UMT), *Chlorella vulgaris* 1 (UMT), *Chlorella vulgaris* 2 (UPM), *Isochrysis galbana* (UPM), *Tetraselmis suecica* (UMT)] have been also characterized for the useful compounds (Term 8).	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
1-4. Conduct incubation experiments using variable growth conditions.	**Plan**									🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		UTokyo	UMT	Optimum growth conditions are **currently being determined for the two selected microalgae** species, *Thalassiosira weissflogii* and *Isochrysis galbana* . Experiments by manipulating starvation of nitrate and phosphate and different salinity have been completed for determination of the optimal growth in culture conditions, while other culture conditions such as temperature and light intensity are now currently tested for the two strains. The COVID19 pandemic has caused delay in several experiments. For the two selected microalgae species, 20 ppt has been shown to have the most profound effect on their growth.	
	Actual									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						
Output 2: Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-																													
2-1. Conduct incubation experiments under manipulated culture conditions to enhance productivity of useful compounds.	**Plan**								🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦									UTokyo	UMT	**Not yet** because of COVID19 pandemic. Establishment of high-lipid/carotenoid production culture conditions is now currently proceeding for the selected isolates under variable conditions. Experiments by manipulating starvation of nitrate and phosphate and different salinity have been completed. For *T. weissflogii,* the best culture conditions are full strength phosphate and nitrate in 20 ppt salinity to induce EPA content. Meanwhile for I. galbana, 1/4 strength of phosphate is the best to induce high DHA production. Carotenoids extraction method was established for the screening of the native microalgae species (Term 5). Establishment of high-oil production culture conditions had been completed using *Chlorella vulgaris* UMT-M1. Nitrate starvation and inducible conditions for *Ankistrodesmus gracilis* was successfully established (Term 8).	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						
2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.	**Plan**													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		UTokyo	UMT	Productivity of useful compounds is currently determined for the cultured microalgae as in 2-1. The established methods for quantification are now used for *Thalassiosira weissflogii* and *Isochrysis galbana.* For I. galbana, DHA production has been increased more than 20% by reducing phosphate (1/4 from the Control).	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						

Inputs		Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10	Term 11	Term 12	Remarks		Issue/ Remarks	Solution
	Project Duration	1st Year		2nd Year		3rd Year		4th Year		5th Year		6th Year					
	ontract btw JICA and Soka Univ.		Term 1		Term 2		Term 3			Term 4							
	Monitoring Sheet (Report)	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10	Term 11	Term 12				
	Year	2016		2017		2018		2019		2020		2021	2022				
Output 3: Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical properties of the																	
3-1. Collect soil and sludge from various locations in Peninsula Malaysia.	**Plan**	🟦	🟦	🟦										NIES	UNISEL	All samples have been collected/ completed (Term 7). For the application at the demonstration site, soil samples at Singa Island and Timun Island in Pulau Lngkawi Forest Reserve will be additionally obtained. The following is the completed works in the previous years: Obtained permission for soil sampling (Perak, Johore, Pahang, Terengganu and Kelantan) from the HQ of Forestry Department of Peninsular Malaysia, Ministry of Natural Resources & Environment (18 January 2017). Soil samplings at three different sites in Selangor were completed: Rentas Saga Shrimp Ponds (RSSP), Raja Musa Peat-Swamp Forest Reserve (RMFR), and Ayer Hitam Forest Reserve (AHFR), Selangor (Term 3). **Completed for all 9 sites (Raja Musa Peat Swamp Forest, Air Hitam, Royal Belum, Tasik Kenyir, Tasik Bera, Tasik Chini, Pulau Langkawi, Prawn Farm Tanjung Karang, and Fish Pond Sludge Kuala Selangor, Term 7).**	REMARKS (210930): Sampling trip to retrieve more soil samples for large-scale outdoor reactor is required, but currently postponed. We hope to retrive more samples in Malaysia in Term 11.
	Actual	🟥	🟥	🟥	🟥	🟥						🟥					
3-2. Study soil and sludge extraction methods.	**Plan**	🟦	🟦	🟦	🟦	🟦								NIES	UNISEL	This has been completed where the methods have been identified and established. The following is the completed works in the previous years. Nine (9) different soil extraction conditions were designed and tested for yield recovery, chemical and plate incubation analyses (Term 3). **Completed where seven (7) extraction methods were tested namely 1H, 4H, 24H natural extraction, 105˚C, 105˚C two hours extraction, 121˚C and 121˚C two hours extraction (Term 7).**	
	Actual	🟥	🟥	🟥	🟥	🟥											
3-3. Examine and optimize the fractionation method of soil and sludge extracts.	**Plan**			🟦	🟦	🟦	🟦	🟦						NIES	UNISEL	This activity has been completed. In addition to the resin fractionation technique, the molecular size fractionation method by using UF membranes has been established. The following is the completed works in the previous years. The fractionation system, multi-plate reader and related equipment were installed and related training was conducted in February 2017. The various techniques of soil identification, soil collections and the use of various equipment were carried out at RISDA-ESPEK Academy in Keratong, Rompin Pahang in March 2017. (Term 2). The custom-made automatic fractionation system is being modified based on the results of preliminary experiments (Term2). The custom-made automatic fractionation system was confirmed to be comparable to the conventional fractionation system. Several conditions of using soil extracts collected from sampling sites were examined (Term 3). A fully automatic fractionation system has been certified as an employee invention by NIES and the patent procedures has been completed (Term 5). **Completed successfully where automated fractionation system invented by NIES Japan scientists have been setup and optimized to be used by Malaysian scientists in Unisel Bestari Jaya campus. During the optimization period 9 samples were successfully fractionated into humic and non-humic substances (Term 7).**	
	Actual			🟥	🟥	🟥	🟥	🟥									
3-4. Conduct plate culture technique and identify the growth-enhancing fractions from soil and sludge extraction.	**Plan**		🟦	🟦	🟦	🟦	🟦							NIES	UNISEL	Plate incubation experiments using microalgal strains selected by Theme 1 have been continued. It was found that L-b (soil extract of Singa Island in Pulau Langkawi Forest Reserve) and L-a (soil extract of Timun Island in Pulau Langkawi Forest Reserve) were the most effective for growth-promoting of Thalassiosira weissflogii and Isochrysis galbana (selected high-value microalgae in SATREPS-COSMOS program), respectively. 1 new high-value strain *Chaetoceros* will be tested again using 9 soils extract.	
	Actual		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥					

Inputs	Project Duration	1st Year				2nd Year				3rd Year				4th Year				5th Year				6th Year				Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.		Term 1				Term 2				Term 3					Term 4													
	Monitoring Sheet (Report)	Term 1		Term 2		Term 3		Term 4		Term 5		Term 6		Term 7		Term 8		Term 9		Term 10		Term 11		Term 12					
	Year	2016			2017				2018				2019				2020				2021				2022				
3-5. Examine the chemical characteristics of the growth-enhancing fractions and their effects on the physiological responses of microalgae.	**Plan**												🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		NIES	UNISEL	The growth-promoting effects of DOM fractions were examined by the advanced plate incubation experiments. In the case of Thalassiosira weissflogii, the hydrophobic fraction showed better growth effects than the hydrophilic fraction or non-fractionated soil extracts. Through EEM-PARAFAC, it was suggested that all the S.E. should commonly include 4 kinds of fluorophore components (C-P: protein-like, C-M: marine-humic like, C-F: fulvic-acid like and C-H: humic-acid like). The percentages of the C-H and C-M were significantly correlated with the standardized specific growth rates of Thalassiosira weissflogii and Isochrysis galbana, respectively.In addition, since the highest iron concentration in L-b which was one of the most effective soil extracts was observed, it may suggest that iron supply is also one of the most conceivable factors for the algal growth enhancement.	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						
Output 4: Closed photobioreactor is scaled-up for outdoor culture.																													
4-1. Develop culture methods of indigenous microalgae in a small scale reactor. Note: A laboratory-scale photobioreactor	**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦																	SU	UPM	Culture experiments on *Spirulina* and *Chlorella* were carried out by using the small-scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per GJ, which is around 20 times high energy efficiency compared to the value in a current raceway pond.Thus, the "Objectively verifiable indicators of 4.1" in PDM has been completed.	
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥																				
4-2. Develop scaled-up CRADLE photo-bioreactor for outdoor mass culture. Note: A scale-up novel photobioreactor	**Plan**			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦											SU	UPM	A scale-up novel photobioreactor system was installed in a UPM laboratory in March 2018 (Term 5), and the culture experiment on indigenous Chaetoceros strain, which produces high value compounds, was operated continuously for more than 2 months (Term 7).	
	Actual			🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥														
4-3. Develop a multi-sequence of operational bag reactors. Note: The multi-sequence system of operational photobioreactors	**Plan**											🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	The construction of demonstration site in UPM was completed as of October 2020 (Term 9). More experiments are being carried out on the selected high microalgae species (from UMT) to predict their responses in the outdoor bioreactors using soil extract obtained from UniSel. Unfortunately, some experiments were delayed due to CMCO.	A multi-sequence of operational bag reactor is being developed and to be delivered to the demo site in October
	Actual							🟥				🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						

Inputs	Project Duration	1st Year		2nd Year		3rd Year		4th Year		5th Year		6th Year		Remarks		Issue/ Remarks	Solution
	ontract btw JICA and Soka Univ.		Term 1		Term 2		Term 3			Term 4							
	Monitoring Sheet (Report)	Term 1	Term 2	Term 3	Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10	Term 11	Term 12				
	Year	2016		2017		2018		2019		2020		2021	2022				
Output 5: Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrients for microalgae production are																	
5-1. Establish technology for recycling nutrients from aquaculture waste for use in microalgae production.	**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	Tokyo Tech	UPM	Several research works and trials are being conducted: lab-scale (100 mL) optimization has been completed (clarifying the bottle-neck step of sludge fermentation, optimum temperature, effectiveness of NH3 volatilization operation by alkaline agent dosing). The effect of alkaline agent was also clarified in bench-scale (200 L). The self-heating capacity of the shrimp sludge was in bench-scale. The phosphate recovery and salinity removal from the fermentation solid residue of shrimp sludge was clarified in lab-scale. The plant growth using the shrimp sludge compost is ongoing. Works on the use of equipment at the demo site to produce ammonia have been slow due to COVID19 pandemic. The modification of the Outdoor large-scale nutrient recycle system was completed (Term 9-10). The trial run of the Outdoor large-scale nutrient recycle system was conducted and progress of thermophilic composting was confirmed (Term 11).	
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥					
5-2 Establish technology and method for recycling waste from the whole system.	**Plan**					🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	Tokyo Tech	UPM	Not yet established. Several research works and trials are being conducted: a a two-stage gas absorption system was proposed for the complete NH3 recovery and efficient nutrient storage/supply. TiTech and UPM completed constructing the sludge de-watering unit to pretreat large amounts of sludge, in order to operate the pilot-scale nutrient recycling system at demo-site.	
	Actual					🟥	🟥	🟥	🟥	🟥	🟥	🟥					
Output 6: Economic profitability and environmental compatibility of the system are verified.																	
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC.	**Plan**							🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	The system scale was determined as "40 shrimp ponds (common scale for small-scale shrimp farm)" to economically treat the sludge. Three scenarios were constructed in which 100%, 50%, and 25% of the recovered ammonia were used in PBR, respectively (Term 11).	
	Actual									🟥	🟥	🟥					
6-2. Monitor biological production and environmental properties in aquaculture pond installed with algae production system.	**Plan**							🟦	🟦	🟦	🟦	🟦	🟦	SU	UPM	To be condcuted in February 2022.	
	Actual																
Duration / Phasing	**Plan**	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦				
	Actual	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥					

Monitoring Plan		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Joint Coordinating Committee	**Plan**					🟦											🟦													🟦													🟦											🟦														🟦				
	Actual					🟥											🟥													🟥													🟥											🟥																		
Submission of Monitoring Sheet	**Plan**						🟦						🟦						🟦						🟦						🟦							🟦						🟦						🟦						🟦						🟦						🟦					
	Actual						🟥						🟥							🟥					🟥							🟥						🟥						🟥						🟥							🟥					🟥						🟥					
Monitoring Mission from Japan	**Plan**																													🟦																																											
	Actual																													🟥																																											
Joint Monitoring	**Plan**																																																																		🟦						
	Actual																																																																								
Post Monitoring	**Plan**																																																																								
	Actual																																																																								
Reports/Documents		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
	Plan																																																																										
	Actual																																																																								
Project Completion Report	**Plan**																																																																						🟦	
	Actual																																																																								
Public Relations		4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Opening project's website	**Plan**						🟦																																																																		
	Actual						🟥																																																																	
Press release	**Plan**																🟦													🟦																																											
	Actual																🟥													🟥																																											

3. Tentative Plan after COSMOS Project

Post COSMOS Exit Strategy: BLUE-SEED Project (2022-2026)

B **Business & Commercialization**

- ✓ Business model and industrial linkage development – **LCA / LCC**
- ✓ Early private sector engagement; technology transfer engagement
- ✓ Commercialization of products, *i.e.* patents, PBR system, high-value microalgae biomass, nutrient recycle system, *etc.*
- ✓ Certification & Accreditation; Environmental Impact Assessment (EIA)

R **Research & Development**

- ✓ Product and technology improvement; low-cost, high-performance
- ✓ ABS & MTA Agreements and MOU/MOA
- ✓ Active researcher exchange and collaboration including private sector
- ✓ Research grant and funding application
- ✓ Continuation of field and laboratory experiments for optimization

S **Social Engagement & Education**

- ✓ Stakeholder engagement, *i.e.*, shrimp farmers, Malaysia Fisheries Society, SPLAM (Malaysia Aquaculture Farm Certification Scheme), Best Aquaculture Practice (BAP), government agencies, *etc.*
- ✓ Education outreach, SDGs & STEM programs; K-12 and higher learning
- ✓ Community outreach: development for B40 communities

D **Demonstration Site & Donated Equipment**

- ✓ On-going research and maintenance
- ✓ Collaboration development with industry and research access
- ✓ Algal biorefinery plant development
- ✓ Microalgae & aquaculture hub
- ✓ Fish culturing and horticulture expansion; blue-culturing

Activity	2022												2023												2024												2025												2026											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Business & Commercialization																																																												
Business model and industrial linkage development - LCA/LCC	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																													
Early private sector engagement; technology transfer engagement	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																				
Commercialization of products, i.e. patents, PBR system, high-value microalgae biomass, nutrient recycle system, etc.								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																								
Certification & Accreditation; Environmental Impact Assessment (EIA)													■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■												
Research & Development																																																												
Product and technology improvement; low-cost, high-performance				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																				
ABS & MTA Agreements and MOU/MOA				■	■	■	■	■	■	■	■	■																																																
Active researcher exchange and collaboration including private sector		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																								
Research grant and funding application	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																				
Continuation of field and laboratory experiments for optimization				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																							
Social Engagement & Education																																																												
Stakeholder engagement, i.e., shrimp farmers, Malaysia Fisheries Society, SPLAM (Malaysia Aquaculture Farm Certification Scheme), Best Aquaculture Practice (BAP), government agencies, etc.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																				
Education outreach, SDGs & STEM programs; K-12 and higher learning				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Community outreach: development for B40 communities				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Demonstration Site & Donated Equipment																																																												
On-going research and maintenance	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Collaboration development with industry and research access	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■											
Algal biorefinery plant development				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																			
Microalgae & aquaculture hub				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																			
Fish culturing and horticulture expansion; blue-culturing				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																							