ANNEX 2: List of Products

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• Manuals

- Aquaculture sludge dewatering and Composting Manual



- Ammonia recovery from Aquaculture Waste



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



- 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)





- Herbs, Fish and Vegetables in Pisciponic Systems

- Production of High Quality Bioencapsulated Zooplankton



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



User's Manual for COSMOS-CRADLE Bioreactor System



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)

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Project Site Pan	incular Mal	aveia

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.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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			

Version 0 **Dated September 30, 2016**

3. Effects of fractions of growth-promoting	3-1. Appropriate methods for soil extraction	3. Project report and publication
soil extracts on selected microalgae and	and fractionation are developed.	
chemical properties of the fractions are	3-2. Growth promoting effects of soil-extracted	
determined.	fractions on selected microalgae are	
	determined.	
	3-3. Chemical characteristics of the soil-	
	extracted fractions with growth promoting	
	effects are evaluated.	
4. Closed photobioreactor is scaled-up for	4-1. An experimental small-scale novel	4. Project report and publication
outdoor culture.	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.	
5. Technologies for recovery of nutrients	5-1. Technology for ammonia and phosphorus	5. Project report and publication
from aquaculture pond sludge and	recovery from aquaculture pond sludge is	
utilization of the nutrients for microalgae	established.	
production are developed.	5-2. Technology to utilize ammonia and	
	phosphorus as a low-cost alternative nutrient	
	source is established.	
6. Economic profitability and environmental	6-1. Calculated life cycle revenue generated	6. Project report and publication
compatibility of the system are verified.	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.	

NIES is designing the fractionation system of dissolved organic matter for soil and sludge extracts. UPM and SU student have been conducted continuous test operation system of microalgae production using a pilot scale photobioreacto r for 3 months. TIT started preliminary experiments for nutrient recovery.

Activities	Inputs		Pre-Co
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland	Dispatch of Experts	Services of the Malaysian Counterpart	Terms and condit
and coastal water bodies in Peninsular	Long-term Expert: Project Coordinator	personnel and administrative personnel	collaborative rese
Malaysia.	Short-term Expert:		are agreed betwe
1-2. Screen, isolate and purify the collected	Planktonology	Suitable office space with necessary	implementing ins
microalgae.	Phycology	equipment	Malaysian impler
1-3. Characterize microalgae for high	Molecular biology/ Microbiology		institutions
contents of valuable compounds.	Photobiology and optics of natural	Supply or replacement of machinery,	
1-4. Conduct incubation experiments using	environments	equipment, instruments, vehicles, tools, spare	
variable growth conditions	Natural product chemistry/ Natural organic	parts and any other materials necessary for	
2-1. Conduct incubation experiments under	chemistry/ Soil chemistry	the implementation of the Project other than	
controlled culture conditions to enhance	Analytical chemistry	the Equipment provided by JICA	
productivity of useful compounds.	Water chemistry		
2-2. Characterize and quantify the useful	Chemical engineering/ Bioreactor	Running expenses necessary for the	
compounds in cultured microalgae as in 2-	lengineering	implementation of the Project (in the form of	
1.	Waste treatment science	matching fund)	
3-1. Collect soil and sludge from various	Other specialists as needed		Issues and co
locations in Peninsular Malaysia.			
3-2. Study soil and sludge extraction	Equipment and equipment		None
methods.	To be ellaborated later		
3-3. Examine and optimize the fractionation			
method of soil and sludge extracts.	Training in Japan		
3-4. Conduct plate culture technique and			
examine the growth-promoting fractions	Necessary expenses except for the running		
from soil and sludge extraction.	cost for the collaborative research activities		
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	1		
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	1		
nutrients from aquaculture pond sludge.			
5-2 Establish a technology utilizing			
nutrients for microalgae production			
6-1. Analyze environmental impact and	1		
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			
		1	



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)

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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.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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			

Version 2 Dated: March 31, 2017

3. Effects of fractions of growth-promoting	3-1. Appropriate methods for soil extraction	3. Project report and publication
soil extracts on selected microalgae and	and fractionation are developed.	
chemical properties of the fractions are	3-2. Growth promoting effects of soil-extracted	
determined.	fractions on selected microalgae are	
	determined.	
	3-3. Chemical characteristics of the soil-	
	extracted fractions with growth promoting	
	effects are evaluated.	
4. Closed photobioreactor is scaled-up for	4-1. An experimental small-scale novel	4. Project report and publication
outdoor culture.	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.	
5. Technologies for recovery of nutrients	5-1. Technology for ammonia and phosphorus	5. Project report and publication
from aquaculture pond sludge and	recovery from aquaculture pond sludge is	
utilization of the nutrients for microalgae	established.	
production are developed.	5-2. Technology to utilize ammonia and	
	phosphorus as a low-cost alternative nutrient	
	source is established.	
6. Economic profitability and environmental	6-1. Calculated life cycle revenue generated	6. Project report and publication
compatibility of the system are verified.	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.	

NIES has installed the fractionation system of dissolved organic matter for soil and sludge extracts. UNISEL has conducted sampling in several locations.
SU has been prospecting materials for functional bag bioreactor.
TIT has been conducted preliminary experiments for nutrient recovery.

Activities	Inputs		Pre-Co
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland	Dispatch of Experts	Services of the Malaysian Counterpart	Terms and condit
and coastal water bodies in Peninsular	Long-term Expert: Project Coordinator	personnel and administrative personnel	collaborative rese
Malaysia.	Short-term Expert:		are agreed betwe
1-2. Screen, isolate and purify the collected	Planktonology	Suitable office space with necessary	implementing ins
microalgae.	Phycology	equipment	Malaysian impler
1-3. Characterize microalgae for high	Molecular biology/ Microbiology		institutions
contents of valuable compounds.	Photobiology and optics of natural	Supply or replacement of machinery,	
1-4. Conduct incubation experiments using	environments	equipment, instruments, vehicles, tools, spare	
variable growth conditions	Natural product chemistry/ Natural organic	parts and any other materials necessary for	
2-1. Conduct incubation experiments under	chemistry/ Soil chemistry	the implementation of the Project other than	
controlled culture conditions to enhance	Analytical chemistry	the Equipment provided by JICA	
productivity of useful compounds.	Water chemistry		
2-2. Characterize and quantify the useful	Chemical engineering/ Bioreactor	Running expenses necessary for the	
compounds in cultured microalgae as in 2-	lengineering	implementation of the Project (in the form of	
1.	Waste treatment science	matching fund)	
3-1. Collect soil and sludge from various	Other specialists as needed		Issues and co
locations in Peninsular Malaysia.			
3-2. Study soil and sludge extraction	Equipment and equipment		None
methods.	To be ellaborated later		
3-3. Examine and optimize the fractionation			
method of soil and sludge extracts.	Training in Japan		
3-4. Conduct plate culture technique and			
examine the growth-promoting fractions	Necessary expenses except for the running		
from soil and sludge extraction.	cost for the collaborative research activities		
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	1		
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	1		
nutrients from aquaculture pond sludge.			
5-2 Establish a technology utilizing			
nutrients for microalgae production			
6-1. Analyze environmental impact and	1		
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			
		1	



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	• Donineular	Malaveia	

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.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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.	

Version 3 Dated: September 30, 2017

3. Effects of fractions of growth-promoting	3-1. Appropriate methods for soil extraction	3. Project report and publication
soil extracts on selected microalgae and	and fractionation are developed.	
chemical properties of the fractions are	3-2. Growth promoting effects of soil-extracted	
determined.	fractions on selected microalgae are	
	determined.	
	3-3. Chemical characteristics of the soil-	
	extracted fractions with growth promoting	
	effects are evaluated.	
4. Closed photobioreactor is scaled-up for	4-1. An experimental small-scale novel	4. Project report and publication
outdoor culture.	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.	
5. Technologies for recovery of nutrients	5-1. Technology for ammonia and phosphorus	5. Project report and publication
from aquaculture pond sludge and	recovery from aquaculture pond sludge is	
utilization of the nutrients for microalgae	established.	
production are developed.	5-2. Technology to utilize ammonia and	
	phosphorus as a low-cost alternative nutrient	
	source is established.	
6. Economic profitability and environmental	6-1. Calculated life cycle revenue generated	6. Project report and publication
compatibility of the system are verified.	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.	

	Pre-Co
The Japanese Side The Malaysian Side	
1-1. Collect microalgae from various inland Dispatch of Experts Services of the Malaysian Counterpart Term	ns and condit
and coastal water bodies in Peninsular Long-term Expert: Project Coordinator personnel and administrative personnel collar	aborative rese
Malaysia. Short-term Expert: are a	agreed betwe
1-2. Screen, isolate and purify the collected · Planktonology Suitable office space with necessary	lementing ins
microalgae. • Phycology equipment Mala	avsian impler
1-3. Characterize microalgae for high · Molecular biology/ Microbiology	itutions
contents of valuable compounds. • Photobiology and optics of natural Supply or replacement of machinery,	
1-4. Conduct incubation experiments using environments environments equipment, instruments, vehicles, tools, spare	
• Natural product chemistry/ Natural organic parts and any other materials necessary for	
2-1. Conduct incubation experiments under chemistry/ Soil chemistry the implementation of the Project other than	
controlled culture conditions to enhance · Analytical chemistry the Equipment provided by JICA	
Productivity of useful compounds. • Water chemistry	
2-2. Characterize and quantify the useful · Chemical engineering/ Bioreactor Running expenses necessary for the	
compounds in cultured microalgae as in 2- engineering	
1. • Waste treatment science matching fund).	
3-1. Collect soil and sludge from various · Other specialists as needed 	sues and co
locations in Peninsular Malaysia.	
3-2. Study soil and sludge extraction Equipment and equipment	L Contraction of the second seco
To be ellaborated later.	
3-3. Examine and optimize the fractionation	
method of soil and sludge extracts. Training in Japan	
3-4. Conduct plate culture technique and	
examine the growth-promoting fractions Necessary expenses, except for the running	
from soil and sludge extraction.	
3-5. Examine the chemical characteristics	
of the growth-promoting fractions and their	
effects on the physiological responses of	
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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 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	• Donineular	Malaveia	

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.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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			

Version 3 **Dated: March 31, 2018**

3. Effects of fractions of growth-promoting	3-1. Appropriate methods for soil extraction	3. Project report and publication
soil extracts on selected microalgae and	and fractionation are developed.	
chemical properties of the fractions are	3-2. Growth promoting effects of soil-extracted	
determined.	fractions on selected microalgae are	
	determined.	
	3-3. Chemical characteristics of the soil-	
	extracted fractions with growth promoting	
	effects are evaluated.	
4. Closed photobioreactor is scaled-up for	4-1. An experimental small-scale novel	4. Project report and publication
outdoor culture.	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.	
5. Technologies for recovery of nutrients	5-1. Technology for ammonia and phosphorus	5. Project report and publication
from aquaculture pond sludge and	recovery from aquaculture pond sludge is	
utilization of the nutrients for microalgae	established.	
production are developed.	5-2. Technology to utilize ammonia and	
	phosphorus as a low-cost alternative nutrient	
	source is established.	
6. Economic profitability and environmental	6-1. Calculated life cycle revenue generated	6. Project report and publication
compatibility of the system are verified.	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.	

Activities	Inputs		
	The Japanese Side	The Malaysian Side	
1-1. Collect microalgae from various inland	Dispatch of Experts	Services of the Malaysian Counterpart	Terms and condit
and coastal water bodies in Peninsular	Long-term Expert: Project Coordinator	personnel and administrative personnel	collaborative rese
Malaysia.	Short-term Expert:		are agreed betwee
1-2. Screen, isolate and purify the collected	Planktonology	Suitable office space with necessary	implementing ins
microalgae.	Phycology	equipment	Malavsian impler
1-3. Characterize microalgae for high	Molecular biology/ Microbiology		institutions
contents of valuable compounds.	 Photobiology and optics of natural 	Supply or replacement of machinery,	
1-4. Conduct incubation experiments using	environments	equipment, instruments, vehicles, tools, spare	
variable growth conditions	Natural product chemistry/ Natural organic	parts and any other materials necessary for	
2-1. Conduct incubation experiments under	chemistry/ Soil chemistry	the implementation of the Project other than	
controlled culture conditions to enhance	Analytical chemistry	the Equipment provided by JICA	
productivity of useful compounds.	Water chemistry		
2-2. Characterize and quantify the useful	Chemical engineering/ Bioreactor	Running expenses necessary for the	
compounds in cultured microalgae as in 2-	engineering	implementation of the Project (in the form of	
1.	Waste treatment science	matching fund).	
3-1. Collect soil and sludge from various	 Other specialists as needed 		<pre><lssues and="" co<="" pre=""></lssues></pre>
locations in Peninsular Malaysia.			
3-2. Study soil and sludge extraction	Equipment and equipment		
methods.	To be ellaborated later.		
3-3. Examine and optimize the fractionation			
method of soil and sludge extracts.	Training in Japan		
3-4. Conduct plate culture technique and			
examine the growth-promoting fractions	Necessary expenses, except for the running		
from soil and sludge extraction.	cost, for the collaborative research activities.		
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.			



Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS) Dated: September 30, 2018 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)

Proiect Site: Peninsular Malavsia 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	1. More than two (2) types of useful compounds are produced from cultured	Report from aquaculture farms Memorandum of Understanding on the use of	Market demand for useful compounds is maintained		
Malaysia and/or other aquaculture	aquaculture pond sludge	farms and implementing institutions			
producing countries	2 Three (3) or more aquaculture farms have				
	introduced mass culture of algae in Malavsia				
	and/or other tropical countries.				
Project Purpose					
An energy-efficient mass-culture system of	"1. Annual algal biomass production of one (1)	Project report and publication	Private aquaculture farms are		
high value microalgae using recycled	tonne or more per hectare is achieved.		willing to cooperate in adopting		
nutrients from aquaculture pond sludge is	2. Biomass yield per gigajoule of two (2)		the sustainable technology		
established.	times or more than the conventional raceway				
	system is achieved for two (2) indigenous				
	3 More than one (1) tonne of aquaculture				
	pond sludge is reduced for every ten (10)				
	kilograms algal biomass production (dry				
	weight basis).				

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 samples can be Japan for analy
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	

other related e brought to yses.	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.	
	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.	
	The optimum fermentation temperature, prospective sludge- degrading microorganism, and liming effect for enhancing NH3 recovery from the sludge was elucidated	

The Japanese Side The Majaysian Side 11. Collect microalgae from various intal of Experts Services of the Malaysian Side Toms and conditions. 12. Storen, isolate and purify the collect distribution to collect microalgae. Planktonology Planktonology 13. Characterize microalgae for high control strategies. Not-the strategies. Sup-the strategies. Sup-the strategies. 14. Conduct incubation experiments using environments • Natural product chemistry Natural product chemistry Sup-the strategies. Sup-the strategies. 2.1. Conduct incubation experiments using environments • Natural product chemistry Natural product chemistry Sup-the reacting institutions 2.2. Concracter: and quanty the useful compounds. • Natural product chemistry Sup-the reacting institutions 2.3. Contracter: and quanty the useful compounds in cultured microalgae as in 2. • Contracterize and quanty the useful compounds. • Other specialists as needed 2.3. Contracterize and quanty the useful compounds. • Other specialists as needed • Other specialists as needed 3.4. Conduct plate culture technique and sudge extraction • Other specialists as needed • Other specialists as needed 3.4. Compound in culture destrated instate • Other specialists as needed • Other specia	Activities	Inp	Pre-Conditions	
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Project Title: The Project for Continuous Operation System for Microalgae Production Optimized for Sustainable Tropical Aquaculture (COSMOS) Dated: March 31, 2019 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)

Proiect Site: Peninsular Malavsia Model Site: N/A

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important
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.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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 deman compounds is
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 aquacu willing to coop the sustainable

t Assumption	Achievement	Remarks
nd for useful maintained		
ulture farms are berate in adopting e 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			

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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	1. More than two (2) types of useful compounds are	Report from aquaculture	Market demand for useful		
microalgae is adopted by	produced from cultured microalgae using recycled	farms	compounds is maintained		
aquaculture farms towards a	nutrients from aquaculture pond sludge.	Memorandum of	-		
sustainable aquaculture industry in	2. Three (3) or more aquaculture farms have	Understanding on the use			
Malaysia and/or other aquaculture	introduced mass culture of algae in Malaysia and/or	of mass-culture			
producing countries.	other tropical countries.	technology between the			
		private farms and			
		implementing institutions			
Project Purpose					
An energy-efficient mass-culture	"1. Annual algal biomass production of one (1) tonne	Project report and	Private aquaculture farms		
system of high value microalgae	or more per hectare is achieved.	publication	are willing to cooperate in		
using recycled nutrients from	2. Biomass yield per gigajoule of two (2) times or		adopting the sustainable		
aquaculture pond sludge is	more than the conventional raceway system is		technology		
established.	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) .				
Outputs					
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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	
2. Production of useful compounds of selected microalgae is enhanced (by controlling culturing conditions and life-cycle).	 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		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.	
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 CO₂ emission by life cycle assessment is reduced as compared to conventional sludge treatment methods. 	6. Project report and publication		

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

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Project Title: The Project for Continuous Operation System for Microalgae P	roduction Optimized	d foi	r Susta	ainal	ble T	ropic	cal A	qua	culture	e (CC	DSM	OS)							Monito	ring
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Planktonologist/ Project Leader (T. Toda)	Plan																SU			
Phycologyist 1 (K. Takabashi)	Plan																LITokyo			
	Actual	I															0 TOKy0			
Phycologyist 2 (M. Sato)	Actual	I															UTokyo			
Phycologyist 3 (T. Katayama)	Plan																UTokyo			
	Plan																, .			
Natural organic chemist/Soil chemist, GC-MAS	Actual	I															SU			
Analytical chemist 2 LC-MAS	Plan																			
	Plan							-									Taluca Talah			
Waste treatment scientist 1 (K. Nakasaki)	Actual	I															Tokyo Tech			
Waste treatment scientist 2 (M. Koyama)	Plan									<u> </u>							Tokyo Tech			
Chemical engineer/Bioreactor engineer 3 (T. Matsuvama)	Plan																911			
	Actual	1		_			_								_		50			
Chemical engineer/Bioreactor engineer 4 (J. Ida)	Actual	1															SU			
Water chemist 1 (A Imai)	Plan																NIES			
	Actual	1						-			_				_		11120			
Water chemist 2 (K. Komatsu)	Actual	I I															NIES			
Microbiologist (N. Kurosawa)	Plan																SU			
	Actual	•									-									
Photobiologist (V. Kuwahara)	Actual	I															SU			
Natural product chemist (M. Watanabe or Tominaga)	Plan										_						WOL			
	Plan																			
Electron Microscopist (M. Kuwata)	Actual	1															SU			
Advisor/ Phycologist 4 (K. Furuya)	Plan	_		_				_		<u> </u>					_		SU			
quipment	Actual	4 5	6789 **	11 12 1 2	3456	6789	10 11 12 1	2345	6789	11 12 1 3	2345	6789	11 12 1 2 3	34567	8 9 10 11 1	123				
Transport, installation and commissioning of equipment purchased in Japan	Plan																			
Training in Japan	Actual	4.5	678910	# 12 1 2	3456	3789	10 11 12 1 1	2345	6789	811121	2345	6789	11 12 1 2 3	4567	8 9 10 11 1	123				
Training at NIES	Plan		0.00			,					2010				00	120	NIES			
	Actual	1															NIE3			
Training at Utokyo	Actual																Tokyo Tech			
Training at Tokyo Tech	Plan																UTokyo			
	Actual	1	+			+						+		+			0 TOKyO			
Training at SU	Actual	ı –	++				+ +					+				+	SU			
n-country/Third country Training		4 5	6789	11 12 1 2	3456	6789	10 11 12 1 2	2345	6789	11 12 1 2	2345	6789	11 12 1 2 3	84567	89 10 11 1	123				
Workshop in Malaysia, held by Japanese Researchers	Plan			_																

Project Monitoring Sheet II (Revision of Plan of Operation)

Activ	ties	Yea	r	1st Ye	ar	2	nd Year	r	3rc	d Year	4	th Year	•	5th	Year		Responsible	Organization	A shisus a sata	Issue &
			I	П	II IV	Ι	п	IV	II	I II IV	I	ш	IV	II	Π	IV	Japan	GOM	Achievements	Countermeasures
Outpu	t 1: High value microalgae are isolated and suitable growth conditions in their life cycle and physiolog	gical attrib	utes ar	re dete	rmined	1 .														
	1-1. Collect microalgae from various inland and coastal water bodies in Peninsular Malaysia.	Plan	n al														UTokyo	UMT	This has been completed and a total of 201 isolates were collected from both seavater and freshwater sites of Terengganu, Pahang, Kedah, Perak, Selangor and Johor states.	
	1-2. Screen, isolate and purify the collected microalgae.	Plan	n al														UTokyo	UMT	All isolates have been purified, screened for high lipid/carotenoid using Nile red and identified molecularly using 18s rDNA.	
	1-3. Characterize microalgae for high contents of valuable compounds.	Plar	n al														UTokyo	UMT	Two microalgae species, Thalassiosira weissflogi and Isochrysis galbana were chosen as "high value microalgae" based on results from second screening.	
	1-4. Conduct incubation experiments using variable growth conditions.	Plan	al														UTokyo	UMT	Two microalgae species, Chlorella wugaris and Tetraselmis chui were chosen to check their variable growth conditions. The established methods for variable growth conditions will be applied to Thatssiosira weissflogii and lsochrysis galbana.	
Outpu	t 2: Production of useful compounds of selected microalgae is enhanced (by controlling culturing con	nditions an	nd life-o	cycle).																
	2-1. Conduct incubation experiments under controlled culture conditions to enhance productivity of useful compounds.	Plar	al														UTokyo	UMT	High oil production culture conditions established for <i>C. vulgaris</i> and <i>M. gracile</i> microalgae model. These conditions will be used for <i>Thalassiosira weissflogi</i> and <i>Isochrysis gabana.</i> Transcriptome profilling of the high-oil and nitrate-inducible genes completed. Further bioinformatic analysis is currently conducted at MGI.	
	2-2. Characterize and quantify the useful compounds in cultured microalgae as in 2-1.	Plan	n al														UTokyo	UMT	The methods for quantification is now established and will be used for Thalassiosira weissflogii and Isochrysis galbana.	

Outpu	t 3: Effects of fractions of growth-promoting soil extracts on selected microalgae and chemical prope	erties of the	e fractions a	are determined							
	3-1. Collect soil and sludge from various locations in Peninsular Malaysia.	Plan Actua	1					NIES	UNISEL	All samples have been collected (completed)	
	3-2. Study soil and sludge extraction methods.	Plan Actua	u l					NIES	UNISEL	This has been completed where the methods have been identified and established.	
	3-3. Examine and optimize the fractionation method of soil and sludge extracts.	Plan Actua	4					NIES	UNISEL	The right method has been identified and established (completed)	
	3-4. Conduct plate culture technique and examine the growth-promoting fractions from soil and sludge extraction.	Plan Actua	1					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.	
	3-5. Examine the chemical characteristics of the growth-promoting fractions and their effects on the physiological responses of microalgae.	Plan Actua	1					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.	
Outpu	t 4: Closed photobioreactor is scaled-up for outdoor culture.					1 . 1 .					
	4-1. Develop culture methods of selected microalgae in a small scale photobioreactor.	Plan	1					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- py 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.	
	4-2. Develop scaled-up novel photobioreactor for outdoor mass culture.	Plan	1					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.	
	4-3. Develop a multi-sequence system of operational photobioreactors.	Plan	1 1					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.	

Outp	ut 5: Technologies for recovery of nutrients from aquaculture pond sludge and utilization of the nutrier	nts for micro	balgae g	oroduci	tion	are dev	elope	d.												I	
	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°C) 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 outluring microalgal biomass and desalinating the compost, investigating the growth of some local and/or halo- tolerant crops.	
	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.	
Outp	It 6: Economic profitability and environmental compatibility of the system are verified.								3				.	- 1	: :	1 : :]					
	6-1. Analyze environmental impact and economic value of the production system by LCA	Plan																811	LIDM		
	and LCC.	Actual																50	UPM		
	6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.	Plan Actual																SU	UPM		
Duro	tion / Bhasing	Plan																			
Dula	tion / Findshig	Actual																			
Moni	toring Plan	Year	15	st Year		2nc	l Year		3rd	Year		4th Y	'ear		5th	Year		Rem	arks	Issue	Solution
Manit			II	Π	V	I II	Π			Π	N I	I		VI	I	Π	N	-			
worit	Lint Coordinating Committee	Plan	+ 5 0 / 8	J (J 11 12	123	- 5 6 7 8	No.	4	3/89	y ~ 1 12	1 2 3 4 5 No	or:o9™ .7		2 3 4 5	5789	w 11 12	1 2 3	No. of participants	50 (4th ICC)		
	Cubmington of Manifesting Chast	Actual Plan								HT			H					Submission deadli	ine: Oct 31st,		
		Actual Plan												-				2019 (Term 7)			
	Monitoring Mission from Japan	Actual																			
	Joint Monitoring	Actual																			
_	Post Monitoring	Actual																			
Repo	ts/Documents	Plan	45678	89101112	123	45678	9 10 11 12	12345	6789	9 10 11 12	12345	6789	1 11 12	2345	6789	10.11.12	123				
		Actual																			
	Project Completion Report	Actual																			
Public	Relations	Blan	45678	B 9 10 11 12	123	45678	9 10 11 12	12345	6789	9 10 11 12	12345	6789	11 12 1	2345	6789	10 11 12	123				
	Opening project's website	Actual																WWW. COSMOS-	<u>satreps, org</u>		
	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	1. More than two (2) types of useful compounds are	Report from	Market demand for	1. High value microalgae species have been shown to	Delay in Theme 3 and Theme
value microalgae is	produced from cultured microalgae using recycled nutrients	aquaculture farms	useful compounds	produce useful compunds under laboratory conditions.	4 due to unfavorable climatic
adopted by aquaculture	from aquaculture pond sludge.	Memorandum of	is maintained	These are 1. Anti-oxidants (UMT Group 2) and 3) Fatty acids	conditions affecting the
farms towards a	2. Three (3) or more aquaculture farms have introduced	Understanding on		(UMT Group 3). Detail chemical properties of the compunds	consruction of the SATREPS-
sustainable aquaculture	mass culture of algae in Malaysia and/or other tropical	the use of mass-		are being analysed.	COSMOS Demonstration site.
industry in Malaysia	countries.	culture technology		2. The mass-culture of high values microalgae will be	In mid-March the site was
and/or other aquaculture		between the private		established at the SATREPS-COSMOS Demonstration site	ready, but the outbreak of
producing countries.		farms and		in UPM as a model for farmers to adopt. Upon establishment	Covid 19 caused further delay
		implementing		of the outdoor bioreactor at the demo site, technologies will	as all Universities and offices
		institutions		be disseminated to farmers.	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	"1. Annual algal biomass production of one (1) tonne or	Project report and	Private aquaculture	1. Production of one tonne per ha has been achieved based	If we can go back to work at
mass-culture system of	more per hectare is achieved.	publication	farms are willing to	on in-door photobioreactor production. However, the oudoor	the demonstration site, the
high value microalgae	2. Biomass yield per gigajoule of two (2) times or more than		cooperate in	proudction has to be calculated after the outdoor production	ourdoor bioreactor should be
using recycled nutrients	the conventional raceway system is achieved for two (2)		adopting the	system has completed	able to be established by
from aquaculture pond	indigenous microalgae species.		sustainable	2. Not yet because of the delay in the installation of the	October 2020. From then, we
sludge is established.	3. More than one (1) tonne of aquaculture pond sludge is		technology	outdoor bioreactor due to climatic problem and COVID19	should have another year to
	reduced for every ten (10) kilograms algal biomass			pandemic	complete the project and
	production (dry weight basis) .			3. The ammonia from the pond sludge has been shown to be	achive all objectives.
				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).	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
Outputs					
1. High value microalgae	1-1. More than two (2) indigenous microalgae species with	1. Project report and	Biological and	A total of 212 isolates were collected from both seawater and	
are isolated and suitable	high contents of fatty-acid, antioxidant and other useful	publication	other related	freshwater sites of Terengganu, Pahang, Kedah, Perak,	
growth conditions in their	compounds are identified.		samples can be	Selangor and Johor states. All isolates have been purified,	
life cycle and	1-2. Three indigenous microalgae species: Chlorella		brought to Japan	screened for high lipid/carotenoid using Nile red and	
physiological attributes	vulgaris, Isochrysis galbana and Tetraselmis chuii with high		for analyses.	identified molecularly using 18s rDNA. Three indigenous	
are determined.	content of antioxidants at the best growth phase are			microalgae species: Chlorella vulgaris, Isochrysis galbana	
	identified.			and Tetraselmis chuii with high content of antioxidants are	
	1-3. Optimum growth conditions are determined for selected			identified at different growth phases. Based on the early	
	microalgae species.			stationary phase, these three microalgae were cultured	
	ů i			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	
2. Production of useful	2-1. Suitable culture conditions for increasing productivity of	2. Project report and		treatment. Two microalgae species, Thalassiosira	
compounds of selected	useful compounds are determined for selected microalgae	publication		weissflogii and Isochrysis galbana were chosen as	
microalgae is enhanced	species.			"high value microalgae" based on results from second	
(by controlling culturing	2-2. Productivity of useful compounds is increased by twenty	r		screening High oil production culture conditions	
conditions and life-cycle).	(20) percent as compared with the standard growth			established for C vulgaris and M gracile microalgae	
	condition.			model. These conditions will be used for Thalassiesira	
	2-3. Productivity of antioxidants is increased by 10 times			weigeflegij end legebrugig gelbeng. Tropporintemo	
	and 100 times of nitrate and phosphate treatments in			profilling of the high oil and nitrate inducible genera	
	Chlorella vulgaris, Isochrysis galbana and Tetraselmis			completed. Further bioinformatic analysis is currently	
	chuii.			completed. Further bioinformatic analysis is currently	
2 Effects of fractions of	2.1. Appropriate methods for soil extraction and fractionation	2 Project report and		Objectively verifiable indicator $(0)/(1)$ 2.1 has been achieved	
3. Effects of fractions of	are developed	publication		and the proparation of the soil extracts have been	
growth-promoting sol	2.2. Growth promoting offects of soil extracted fractions on	publication		completed. The incubation experiments have been	
microalgae and chemical	S-2. Growin promoting enects of soin-extracted fractions of			completed. The incubation experiments have been in taplu	
nicioalgae and chemical	2.2. Chamical characteristics of the apil outroated fractions			been developed and installed at UNISEL. The OVI 2.2 here	
fractions are determined	with growth promoting offects are evaluated			been developed and installed at UNISEL. The UVI 5.2 has	
inactions are determined.	with growth promoting enects are evaluated.			been achieved for soil samples from 6 sites (from a total of 9	
				sites) tested on TT species. Unditated fraction samples will	
				be given to OPM for further testing in small and large scale	
				promotions. 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 snotgun metagenomics approach was	
				successfully carried out. I ne preparation of manuscripts is	
				in progress.	

Narrative Summary	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
4. Closed	4-1. An experimental small-scale novel photobioreactor	4. Project report and		Culture experiments on Spirulina and Chlorella were carried	
photobioreactor is	whose biomass yield is two (2) ton per gigajoule, which is	publication		out by using the small-scale novel photobioreactor and	
scaled-up for outdoor	twenty (20) times higher than conventional reactors, is			achieved the yield of more than 2 Ton-Dry biomass per GJ,	
culture.	developed.			which is around 20 times high energy efficiency compared to	
	4-2. Scaled-up novel photobioreactor of more than one (1)			the value in a current raceway pond. Thus, the "Objectively	
	square meter with an automated driving system, which can			verifiable indicators of 4.1" in PDM has been completed. A	
	support a culture period of more than two (2) months, is			scale-up bag photobioreactor system was installed in a UPM	
	developed.			laboratory, and the culture experiment on indigenous	
	4-3. More than two (2) species of selected microalgae are			Chaetoceros strain, which produces high value compounds.	
	cultured outdoors in sequenced photobioreactors.			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	
				sequence outdoor system to achieve OVT 4.5.	
5. Technologies for	5-1. Technology for ammonia and phosphorus recovery	5. Project report and		lab-scale investigation of phosphate recovery and	
recovery of nutrients	from aquaculture pond sludge is established.	publication		desalination from the sludge compost under anaerobic	
from aquaculture pond	5-2. Technology to utilize ammonia and phosphorus as a			condition (Terms 6-8) revealed that the leaching of	
sludge and utilization of	low-cost alternative nutrient source is established.			phosphate is faster at higher temperature condition, although	
the nutrients for				the phosphate recovery at 55°C and 37°C condition became	
microalgae production				similar within three days. Increase of NH4+ concentration by	
are developed.				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	6-1. Calculated life cycle revenue generated from a	6. Project report and			
and environmental	production unit exceeds life cycle cost.	publication			
compatibility of the	6-2. The system does not negatively affect the current				
system are verified.	aquaculture production.				
	6-3. Total CO ₂ emission by life cycle assessment is reduced				
	as compared to conventional sludge treatment methods				
	, and the terreturn blocky a countern methodol				

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

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

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Note: Note: <th< th=""><th>Monitoring</th></th<>	Monitoring
AFF No. Parktonologist 1/ Project Leader (T. Toda) SU 1 Parktonologist 2 (M. Firshera) SU 1 Parktonologist 2 (M. Firshera) SU 2 Parktonologist 2 (M. Firshera) SU 7 SU Parktonologist 2 (M. Sato) UT 4 Parktonologist 2 (M. Sato) UT days UT d	Issue Sol
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Phycologyist 3 (Г. Katayama) UT 5 Pin 1	Yamada: I sorted this Expert list by Experties for easy reference.
Advisor/ Phycologist 4 (K. Furuya) SU 6 Pian Actual Actua	Short-term Expert: (Listed on the R/D)
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	2 Phycology 3 Molecular biology/ Microbiology
	4 Photobiology and optics of natural environments 5 Network product chemistry/ Network proprio
Natural product chemist (M. Watanabe or Tominaga), Watanabe (M. Watanabe	chemistry/Soil chemistry 6 Analytical chemistry
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	7 Water chemistry 8 Chemical engineering/ Bioreactor engineering 9 Waste treatment science
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Transport, installation and commissioning of equipment purchased in Plan	
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Training at NIES	
Training at Utokyo	1
Plan Image: Constraint of the second se	
Training at SU SU	
ntry/Third country Training	

Activities	Year	1st Ye	ar	2nd Y	ear	3rd Yea	ır	4th Year		5th Year	r	Responsible O	rganization	Achievemente	Issue &
		III	IV	III	II IV I	II II	IV I	II	N	и п	N	Japan	GOM	Achievenienis	Countermeasures
Output 1: High value microalgae are isolated and suitable growth conditions in their life cycl	e and phys	siological	attribut	es are de	termined										
1-1. Collect microalgae from various inland and coastal water bodies in	Plan													This has been completed and a total of 212 isolates were collected from both seawater	
Peninsular Malaysia.	Actual											UTokyo	UMI	states.	
	Dien													All isolates have been purified, screened for high lipid/carotenoid using Nile red and	
1-2. Screen, isolate and purify the collected microalgae.	Pian										-	UTokyo	UMT	identified molecularly using 18s rDNA.	
	Actual													Two missolace encoire. The local are unice flacility of local public self-annuare	
1-3. Characterize microalgae for high contents of valuable compounds.	Plan				11		111					UTokvo	UMT	chosen as "high value microalgae" based on results from second screening.	
	Actual										1				
														Two microalgae species, Chlorella vulgaris and Tetraselmis chuii were chosen to	
	Plan													conditions will be applied to Thalssiosira weissflogii and Isochrysis galhana	
1-4. Conduct incubation experiments using variable growth conditions.											-	UTokyo	UMT	Experiments with select isolates, T. weissflogii and I. galbana, have proceeded for	
	Actual										1			determination of the optimal growth in culture conditions manipulating temperature, light	
														intensity, salinity, and starvation of nitrate and phosphate.	
Output 2: Production of useful compounds of selected microalgae is enhanced (by controlling	ng culturin	g conditio	ons and	life-cycle	e).						· · · · ·				
	Plan													High oil production culture conditions established for C. vulgaris and M. gracile microalgae model. These conditions will be used for Thalassiosira weissflogii and	
2-1. Conduct incubation experiments under controlled culture conditions											1	LITeleve	LINAT	Isochrysis galbana. Transcriptome profilling of the high-oil and nitrate-inducible genes	
to enhance productivity of useful compounds.												Отокуо	UMI	completed. Further bioinformatic analysis is currently conducted at MGI. Establishment	
	Actual													of high-lipid/carotenoid production culture conditions is proceeding for the selected	
	Blan										-			The methods for quantification is now established and will be used for Thalassiosira	
2-2. Characterize and quantify the useful compounds in cultured	Fidil											UTokyo	UMT	weissflogii and Isochrysis galbana.	
microargae as in 2-1.	Actual														
Output 3: Effects of fractions of growth-promoting soil extracts on selected microalgae and	chemical	properties	of the	fractions	are deter	rmined.					· · · · ·				
3-1. Collect soil and sludge from various locations in Peninsular	Plan											NIES	UNISEL	All samples have been collected (completed)	
Malaysia.	Plan										-			This has been completed where the methods have been identified and established	
3-2. Study soil and sludge extraction methods.	Actual										-	NIES	UNISEL		
3-3 Examine and optimize the fractionation method of soil and sludge	Plan				1 1						ŝ.			The right method has been identified and established (completed). In addition to the	
extracts	Assessed										-	NIES	UNISEL	resin fractionation technique, the molecular size fractionation method using the UF	
	Actual													membrane installed in the centriruging tube has been established.	
	Plan										1			Malavsia have been conducted. In addition to 9 strains selected by Theme 1.4 strains	
3-4. Conduct plate culture technique and examine the growth-											-	NIES	UNISEL	that was not selected as the high-value microalgae candidates due to slow growth rate	
promoting fractions from soil and sludge extraction.	Actual													were incubated using growth promoting substances. Results suggest growth-	
														Characterization of dissolved examine matter from all soil extracts (S.E.) imported from	
	Plan													UNISEL has been completed by fluorescence analysis (EEM-PARAFAC). Through the	
3-5. Examine the chemical characteristics of the growth-promoting												NIES	UNISEL	combined plate incubation and fractionation experiments, it was determined that the	
fractions and their effects on the physiological responses of microalgae.	Actual													hydrophobic fraction, or low-molecular size fraction of S.E. effectively enhance algal	
Output 4: Clessed photobioropater is spaled up for outdoor outfure														9/0 mui.	
output 4. closed photobloreactor is scaled-up for outdoor culture.							1					1		Culture experiments on Spirulina and Chlorella were carried out by using the small-	
4.1. Develop culture methods of colocied microalizes in a small costs	Plan							• • • • •						scale novel photobioreactor and achieved the yield of more than 2 Ton-Dry biomass per	
nbotobioreactor											-	SU	UPM	GJ, which is around 20 times high energy efficiency compared to the value in a current	
	Actual										-			raceway pond. I hus, 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	
	Plan										1			culture experiment on indigenous Chaetoceros strain, which produces high value	
4-2. Develop scaled-up novel photobioreactor for outdoor mass culture.	A											SU	UPM	compounds, was operated continuously for more than 2 months. Thus, the "Objectively	
	Actual													verifiable indicators of 4.2" in PDM has been completed.	
														The construction of demonstration site in UPM was completed to install "Multi-	
	Plan													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	
4-3. Develop a multi-sequence system of operational photobioreactors.												SU	UPM	have to reconstruct the outdoor photobioreactor due to some damage related to flood	
														completed. More experiments are being carried out on the selected high microalgae	
	Actual													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	
											L			0.000 una 1 1017 pm 2020.	

Output 5: Technologies for recovery of nutrients from aquaculture pond sludge and utilizate	tion of the	nutrie	nts fo	micr	oalgae	product	tion are d	leveloped.									
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 [°] C) during fermentation. Also, THech 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 of arginclutural application. UPM started to examine the plant growth effect of the shrimp sludge compost, investigating the growth of some local and/or halo-tolerant errore.	
5-2. Establish a technology utilizing nutrients for microalgae production.	Plan Actual													Tokyo Tech	UPM	Trech, SU and UPM started to optimize a NH3 trapping/storage/supply method towards the efficient utilization of nutrients and CO2 semitted from sludge composing, for culturing high-value microaligal biomass. A two-stage gas absorption system, which (1) directly absorbs the majority of the emitted NH3 and CO2 from the composing reactor into the algal medium and (2) at rap 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 composing system was completed, and preliminary operation whole using compositing started. Tiffech 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 compositing system.	
Output 6: Economic profitability and environmental compatibility of the system are verified	d.																
6-1. Analyze environmental impact and economic value of the production system by LCA and LCC.	Plan Actual													SU	UPM		
6-2. Evaluate the influence of the installed algae production system on aquaculture pond production and the environment.	Plan Actual													SU	UPM		
Duration / Phasing	Plan Actual													-			
Monitoring Plan	Year	1 I	stYea IIII	TV IV	2nd II	lYear ⅢIN	3rd 7 I II	Year III IV	4 I	th Year II III	N I	5th Yea	ar IIV	Rem	arks	Issue	Solution
Monitoring		4567	89**	123	45678	9 10 11 12 1 2	345678	9 10 11 12 3 4	4567	8 9 11 11 12	12345	6789 ***	123	3			
Joint Coordinating Committee	Actual													No. of participants	: 50 (4th JCC)		
Submission of Monitoring Sheet	Plan																
Monitoring Mission from Japan	Plan																
laint Manitasing	Actual Plan		-														
	Actual Plan																
Post Monitoring	Actual																
Reports/Documents	Dian	4 5 6 7	8 9 18 11	123	4 5 6 7 8	9 10 11 10 1 2	345678	9 ** ** 1 2 3 4	4567	8 9 11 11 12	1 2 3 4 5	6789 ***	123	3			
	Actual																
Project Completion Report	Plan						+										
Public Relations		4567	8 9 10 11	123	45678	9 10 11 12 1 2	345678	9 ** ** 1 2 3 4	4567	8 9 11 11 12	12345	6 7 8 9 ** **	123	8			
Opening project's website	Plan													www.cosmos-	satreps.org		
Press release	Plan Actual																

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

Model Site: N/A

Period of Project: 6 years (2016.04 - 2022.03)

Project Site: Peninsular Malaysia

Narrative	Objectively Verifiable	Means of Verification	Important	Achievement	Remarks
Summary	Indicators		Assumption		
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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	 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. The mass-culture of high values microalgae will be established at the <i>demo site</i> 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.
An energy-efficient mass-culture system of high value microalgae using recycled nutrients from aquaculture pond sludge is established.	 Annual algal biomass production of one (1) tonne or more per hectare is achieved. Biomass yield per giga joule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 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. 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). Fabrication phase because of the delay in the installation of the multi-sequence system of operational photobioreactor) due to climatic problem and COVID19 pandemic. 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	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		1-1: Two indigenous microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> , have been chosen as high value microalgae with high content of lipid and carotenoid.	
conditions in their life cycle and physiological attributes are determined.	1-2. Optimum growth conditions are determined for selected microalgae species.	Project report and publication	Biological and other	1-2: On-going Optimum growth conditions are currently determined for the two selected microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> . 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	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species.	Project report and publication	related samples can be brought to Japan for analyses.	2-1: On-going (light, temperature, salinity conditions); Completed (nutrients condition). High oil production culture conditions were established for <i>Chlorella vulgaris</i> and <i>Messastrum gracile</i> microalgae model. Based on these findings, suitable culture conditions for inducing production of useful compounds are currently determined for the two selected microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> .	
controlling culturing conditions and life- cycle).	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
	3-1. Optimal methodologies for extraction and fractionation of growth enhancing substances are identified.	3. Project report and publication		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. Efficient microalgae culturing technique utilizing growth-enhancing substances extracted from soil and sludge is proposed.	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	Biological and other related samples can be brought to Japan for analyses.	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
	 4-1. 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. 4-2. Scaled-up bag CRADLE reactor of more than one (1) 	Project report and publication	, loounpilon	 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: Achieved in 2019 (Term 7) The scale-up novel bag photobioreactor system was installed in a UPM (Term 4) 	
	square meter with an automated driving system, which can support a culture period of more than two (2) months, is developed.			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. Closed photobioreactor is scaled up for outdoor culture.	4-3. More than two (2) species of microalgae are cultured outdoors in sequenced bag reactors.		Biological and other related samples can be brought to Japan for analyses.	 4-3: On-going (to be conducted from July 2021). The two species identified by Theme 1, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i>, 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., <i>Chaetoceros</i> gracilis, Isochrysis galbana, <i>Thalassiosira weissflogii</i>) 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	Objectively Verifiable	Means of Verification	Important	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. 5-2. Technology to utilize ammonia as a low-cost alternative nitrogen source 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. 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. 	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.
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
1-1. Collect microalg	ae from various inland and coas	tal water bodies in	The Japanese Side	The Malaysian Side	
Peninsular Malaysia 1-2. Screen, isolate 1-3. Characterize mi 1-4. Conduct incuba	and purify the collected microalga croalgae for high contents of valu tion experiments using variable g	ae. Jable compounds. Jrowth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: • Planktonology • Phycology • Molecular biology/	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	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incuba enhance productivity 2-2. Characterize an microalgae as in 2-1	tion experiments under controlled / of useful compounds. d quantify the useful compounds	d culture conditions to in cultured	Microbiology • Photobiology and optics of natural environments • Natural product chemistry/ Natural organic chemistry/ Soil	Running expenses necessary for the implementation of the Project (in the form of matching fund).	
 3-1. Collect soil and 3-2. Study soil and s 3-3. Examine and op extracts. 3-4. Conduct plate c fractions from soil ar 3-5. Examine the che and their effects on t 	sludge from various locations in ludge extraction methods. otimize the fractionation method of ulture technique and examine the of sludge extraction. emical characteristics of the grow the physiological responses of mi	Peninsular Malaysia. of soil and sludge e growth-promoting vth-promoting fractions icroalgae.	chemistry • Analytical chemistry • Water chemistry • Chemical engineering/ Bioreactor engineering • Waste treatment science • Other specialists as needed	Is	sues and countermeasures>
 4-1. Develop culture photobioreactor. 4-2. Develop scaled- 4-3. Develop a multi 5-1. Establish a tech sludge. 5-2. Establish a tech 	methods of selected microalgae -up novel photobioreactor for out -sequence system of operational nology for recovery of nutrients f nology utilizing nutrients for micro	in a small scale door mass culture. photobioreactors. rom aquaculture pond palgae production.	Equipment and equipment To be elaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.		
6-1. Analyze environ system by LCA and 6-2. Evaluate the inf aquaculture pond pr	mental impact and economic val LCC. luence of the installed algae proc oduction and the environment.	ue of the production	-		

Project Monitoring Sheet II (Plan of Operation)

PO version 1 (Approved JCC5, 28 August 2020)

Project Title: The Project	for Co	ontinu	ious	Ope	ration	Sy	/sten	n for	Micro	balgae	e Pro	ductio	on O	ptimiz	ed fo	or Su	stain	able	Trop	ical A	quad	ultur	e (CO	SM	10S)	Reported as of September 30, 2020	
	Pro	ject I	Dura	ation	1	st Y	'ear		2nc	d Year	r	3r	d Yea	ır		4th Ye	ear		5th	/ear		6th	Year		Remarks	Issue/ Remarks Solu	ution
ontract b	w JICA	and	Soka	Univ.			Tern	n 1		Ter	rm 2			Tern	n 3			T	erm 4								
Inputs	nitorin	a She	et (Re	eport)	Term	1	Tern	n 2 1	erm 3	Ter	rm 4	Term 5	5 Te	erm 6	Term	17	Term 8	3 Te	rm 9	Term '	0 Te	erm 11	Term	12			
		<u> </u>		Year	20	016			2017	-		2018	_		201	9		2	020	- I	_	2021	2	2022			
Expert		AFF	No.		4567	8 9 10	10 11 12 1	1234	5678	9 10 11 12	1234	5678	9 10 11	12 1 2 3	4567	78910	11 12 1 2	3456	6789	10 11 12 1	2345	678	9 10 11 12 1	23			
Planktonologist 1/ Project Lea	ler	511	1	Plan																					911	Since May 2020, planned dispatchment from Japan was suspended due to To follo	w the
(T. Toda)		30	<u>'</u>	Actual			╧┻┻																		30	Covid-19 pandemic to up-to-date. instruct	tion
Planktonologist 2 (M. Hirahara)	SU	2	Plan Actual					-					-	_						-			-	SU	and	tion
Displayers in sint 2.07. Telescore	->		-	Plan			+																		011	In order to contain the COVID-19 pandemic, the government of Malaysia	ie
Planktonologist 3 (Y. Takayan	a)	01	3	Actual																					50	Initiated the Movement Control Order (MCO), effective on 18 March 2020.	ment
Phycologist 1 (K. Takahashi)		UT	4	Plan Actual			4+	<u> </u>													_			-	UTokyo	period, until 12 May 2020.	
Dhugalagist 2 (M. Sata)			5	Plan																					LITelare		
Phycologist 2 (M. Sato)		01	5	Actual																					Отокуо	On 13 May, the Conditional Movement Control Order (CMCO) was issued.	
Phycologist 3 (T. Katayama)		UT	6	Plan Actual																					UTokyo	On 8 June, the Recovery Movement Control Order (RMCO) was issued.	
			-7	Plan																					011	On 25 March, the MCO was extended until 14 April.	
Phycologist 4 (IVI. Ontake)		01	1	Actual																					50	On 10 April, the MCO was extended until 28 April.	
Advisor/ Phycologist 4 (K. Fur	iya)	SU	8	Plan										-	_										SU	On 11 May, the CMCO was initiated as per 13 May until 9 June.	
			-	Plan																					011	On 7 June, the RMCO was initiated as per 10 June until 31 August.	
Microbiologist (N. Kurosawa)		50	9	Actual																					SU	On 28 August, the RMCO was extended until 31 December.	
Photobiologist (V. Kuwahara)		SU	10	Plan			<u> </u>			_				_			_								SU	source:https://www.mdbc.com.my/mco-updates/	
Natural product chemist (M. Watana	he or		ŕ	Plan																					Watanabe Ovster	On 14 Ontakan the ONOO was implemented with 07 Ontakan	
Tominaga), <u>Watanabe Oyster Labo</u>	atory	WOL	11	Actual																					Laboratory (WOL)	On 14 October, the CMCO was implemented until 27 October.	
Natural organic chemist/Soil		SU	12	Plan																					SU		
chemist, GC-MAS				Actual		_			-					-													
Analytical chemist 2 LC-MAS			13	Actual			\pm																				
Water chemist 1 (A Imai)		NIES	14	Plan																					NIES		
				Actual		-																					
Water chemist 2 (K. Komatsu		NIES	15	Actual			-																		NIES		
Chemical engineer/Bioreactor		SU	16	Plan																					SU		
engineer 3 (T. Matsuyama) Chemical engineer/Bioreactor				Actual Plan		-									_												
engineer 4 (J. Ida)		SU	17	Actual																					SU		
Waste treatment scientist 1 (K		TT	18	Plan			H																		Tokyo Tech		
Waste treatment scientist 2 (N			40	Plan										-											, 		
Koyama)		11	19	Actual																					Tokyo Tech		
(TNM Quyon)		TT	20	Plan Actual																	_			-	Tokyo Tech		
Electron Microscopist (M. Kuw	ata)	911	21	Plan																					911		
	uia)	00	21	Actual																					00		
Ms Mari Miller		NA	22	Actual																					Not available		
Mr. Masaru Yamada				Actual																							
Equipment				\langle	4 5 6 7	8 9 10	10 11 12 1	1234	5678	9 10 11 12	1234	5678	9 10 11	12 1 2 3	4567	78910	11 12 1 2	3450	6789	10 11 12 1	2345	678	9 10 11 12 1	23			
Transport, installation and con	missio	ning c	of	Plan																						The reactor (Theme 3) is to be delivered to the demo site in Malaysia in	
equipment purchased in Japai				Actual																						March 2021. The composting reactor (Theme 4) is needed to be assembled	
Training in Japan					4567	8 9 10	10 11 12 1	1234	5678	9 10 11 12	1234	5678	9 10 11	12 1 2 3	4567	78910	11 12 1 2	3450	6789	10 11 12 1	2345	678	9 10 11 12 1	23			
Training at NIES				Plan Actual			+																		NIES	Planned training in 2020 was cancelled due to the Covid-19 pandemic.	
Training at Utokyo			-	Plan Actual			—			_												To be			Tokyo Tech	I raining in 2021 to be confirmed later once the pademic is contained.	
Training at Tokyo Tech			Ľ	Plan			#															confir	med.		UTokvo		
Training at SU			ť	Plan																		<u> </u>	1.1	"	Q11		ļ
In-country/Third country Tro:	ing	1		Actual	1567	8.0	10.11.12	1224	5.6.7.9	0	1234	5670	0 10 11	01.0.0	150	7 8 0	11 12 1 0	315	8790	10, 11, 12, 4	2345	679	0 10 11 13 4	2.2		l l	ļ
Workshop in Malavsia, held by Japa	nese Re	search	iers	Plan	7007	3.3 1					1234			1 2 3		0.9.0	1 2	3430		1	- 3 4 3			2.3			
				n otuol										100 C													

	Project Du	ration		1st Y	ear		2nd \	Year		3rd	Year		4t	h Yea	ar		5th	Year		6	oth Yea	ar	Rem	narks	Issue/ Remarks Solution
Inpute	ontract btw JICA and Sok	a Univ.	\square		Term 1			Term	12			Term	3			Т	erm 4	4							
inputs	Monitoring Sheet (I	Report)	Terr	n 1	Term 2	Те	erm 3	Term	14 T	erm 5	Terr	m 6 .	Term 7	7 Te	erm 8	Ter	rm 9	Terr	n 10	Term	11 Te	erm 12	2		
		Year	2	2016		2	017		:	2018			2019			20)20			202	:1	2022	2		
Output 1: High value	microalgae are isolated	l and s	uitab	le gro	wth c	ondit	ions i	n thei	r life o	cycle a	ind p	hysio	logica	al attr	ibute	s are	e dete	ermir	ned.						
1-1. Collect microalg. and coastal water bo Malaysia.	ae from various inland dies in Peninsular	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
1.2. Correct inclute o		Actual																							proposal: 16 sites from seawater and 10 sites from freshwater (Term 5).
microalgae.	and purify the conected	Plan																					UTokvo		An isolates have been purned, screened for high lipid/carotenoid using vile 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
		Actual																							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).
1-3. Characterize mic of valuable compoun	croalgae for high contents ds.	Plan																					-UTokyo		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),
		Actual																							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).
1-4. Conduct incubat variable growth cond	ion experiments using itions.	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
Output 2: Production	of useful compounds (Actual	cted r	micro	algae i	is enl	hance	ed (bv	contr	olling	cultu	uring c	ondit	ions	and	ife-c	vcle)								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).
2-1. Conduct incubat	ion experiments under			T		T																			Not yet because of COVID19 pandemic. Establishment of high-lipid/carotenoid
manipulated culture of productivity of useful	conditions to enhance compounds.	Plan																					UTokyo	UMT	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).
		Actual																							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).
2-2. Characterize and compounds in culture	d quantify the useful ed 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 <i>Thalassiosira</i> weissflorii and <i>Isochrusis galbana</i>
		Actual																							

	Project Dur	ration		1st Yo	ear		2nd	Year		3rc	d Yea	r		4th	Year	r		5th	ı Yea	r		6th	Year		Ren	narks	Issue/ Remarks	Solution
Innuts	ontract btw JICA and Sok	a Univ	\square	-	Term 1	1		Term 2	2			Terr	m 3				1	Term	ı 4									
mputs	Monitoring Sheet (F	Report)	Terr	n 1	Term 2	2 Te	rm 3	Term 4	4 T	erm 5	i Te	rm 6	Ter	rm 7	Ter	rm 8	Te	erm 9	Te	rm 10	Ter	rm 11	Term	12				
		Year	2	2016		2	017			2018			20)19		Ļ	2	020			20	021		2022				
Output 3: Effects of	fractions of growth-prop	moting	i soil e	extrac	ts on	sele	cted r	hicroalg	gae :	and c	hemi	cal p	rope	erties	s of t	he fr	acti	ons	are	-		1	<u>т т</u>	- :		1	All samples have been collected/ completed (Term 7). For the application at the	1
locations in Peninsula	a Malaysia.	Plan																							NIES	UNISE	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 camplions at three	
		Actual																									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 Tarm 7).	
3-2. Study soil and sl	ludge extraction methods.	Plan																							NIES	UNISE	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 1 H + 2 H natural	
		Actua																									extraction, 105°C, 105°C two hours extraction, 121°C and 121°C two hours	
3-3. Examine and op method of soil and si	timize the fractionation udge extracts.	Plan																							NIES	UNISE	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	
		Actual																									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).	
3-4. Conduct plate cu identify the growth-er soil and sludge extra	ulture technique and nhancing fractions from ction.	Plan																							NIES	UNISE	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	
		Actual																									Thalassiosira weissflogii and Isochrysis galbana (selected high-value microalgae in SATREPS-COSMOS program), respectively. 1 new high-value strain <i>Chaetoceros</i> will be tested again using 9 soils extract.	
3-5. Examine the che the growth-enhancing effects on the physiol microalgae.	emical characteristics of g fractions and their logical responses of	Plan																							NIES	UNISE	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 0.C.F. this patiel fluored C) the protein like. The protein like, C-M: marine-humic	
		Actual																									INKE, C-F: TUNIC-EACID 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.	

	Project Du	ration		1st Y	ear		2nd Ye	ar	3rd	Year		4th Yea	ar		5th Y	'ear		6th \	Year	R	emarl	ks	Issue/ Remarks	Solution
Innuts	ontract btw JICA and Sol	a Univ.	\square		Term '	1	T	erm 2		Te	rm 3			Т	erm 4									
mputo	Monitoring Sheet (Report)	Terr	n 1	Term 2	2 Ter	rm 3 T	erm 4	Term 5	Term	6 Ter	m 7 Te	erm 8	B Ter	m 9	Term 10) Ter	rm 11	Term 1	2				
		Year	1	2016	_	20	017		2018		20	19		20	020		2	021	20	22		_		
Output 4: Closed pho	otobioreactor is scaled-	up for	outdo	oor cu	ilture.			_		<u> </u>			- 1		<u>г :: т</u>			1						
4-1. Develop culture microalgae in a smal	methods of indigenous I scale reactor.	Plan																		91		PM	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	
Note: A laboratory-so	ale photobioreactor	Actual																				1 101	value in a current raceway pond. Thus, the "Objectively verifiable indicators of 4.1" in PDM has been completed.	
4-2. Develop scaled- bioreactor for outdoo	up CRADLE photo- r mass culture.	Plan																		รเ	J U	PM	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 comoounds, was operated continuously for	
Note: A scale-up nov	el photobioreactor	Actual																					more than 2 months (Term 7).	
4-3. Develop a multi- bag reactors.	sequence of operational	Plan																					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	The outdoor photobioreacto r is being developed and
operational photobio	eactors	Actual																		- Sl	J U	PM	experiments were delayed due to CMCO.	to be delivered to the demo site in April 2021.
Output 5: Technolo	gies for recovery of nu	trients	from	aqua	cultur	re pon	d sludg	ge and u	utilizatio	n of the	e nutrie	ents for	mic	roalga	ae pro	ductio	n are	deve	loped.					
5-1. Establish techno nutrients from aquac microalgae productio	logy for recycling ulture waste for use in n.	Plan																					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	
		Actual																		Tok Teo	yo th	PM	clarified in lab-scale. The plant growth using the shrimp sludge compost is ongoing.	
5-2 Establish technol recycling waste from	ogy and method for the whole system.	Plan																					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																		Tec	yo xh U	PM		

	Project Dur	ation		1st Ye	ar	2r	nd Ye	ar	3	Brd Ye	ar		4th	Year		5	5th Ye	ar		6t	h Yea	ır	Ren	narks	Issue/ Remarks	Solution
Innute	ontract btw JICA and Sok	a Univ.	\square	Т	erm 1	· /	Τe	erm 2			Τe	erm 3				Tei	rm 4									
inputs	Monitoring Sheet (F	Report)	Terr	n 1 T	erm 2	Term	3 T	erm 4	Term	15 T	Ferm 6	6 Te	erm 7	Terr	n 8	Term	19 T	erm 1	0 Te	rm 1	1 Te	rm 12				
		Year	2	2016		2017	7		201	8		2	019			202	20		2	021		2022				
Output 6: Economic	profitability and enviror	nmenta	al con	npatib	ility of	the sy	stem	are ve	rified																	
6-1. Analyze environ	mental impact and	Plan			Í	Í																			To be condcuted in June 2021.	
LCA and LCC.	ie production system by	Actual																					50	UPM		
6-2. Monitor biologic	al production and	Plan																					01		To be condcuted in June 2021.	
installed with algae p	production system.	Actual																					30	UPIVI		
Duration / Phasing	l	Plan Actual																								
Monitoring Plar	1	\sim	456	7 8 9 10 1	12 1 2 3	4567	89 10 11	12 1 2 3	4567	89101	11 12 1 2	345	678	9 10 11 12	1 2 3 4	567	8 9 10	11 12 1 2	345	678	891011	12 1 2 3				
Joint Coordinating	Committee	Plan Actual																								
Submission of Mor	nitoring Sheet	Plan Actual																								
Monitoring Mission	n from Japan	Plan Actual						_			_															
Joint Monitoring		Plan Actual																								
Post Monitoring		Plan Actual																								
Reports/Documents			456	789101	11 12 1 2 3	4567	89 10 11	12 1 2 3	4567	' 8 9 ^{10 1}	11 12 1 2	2345	678	9 10 11 12	1234	567	7 8 9 10	11 12 1 2	2345	678	891011	12 1 2 3				
		Plan Actual																								
Project Completion	Report	Plan Actual																								
Public Relations		\geq	4.5 6	7 8 9 10 1	11 12 1 2 3	4 5 6 7	89 10 11	12 1 2 3	4567	89101	11 12 1 2	2 3 4 5	678	9 10 11 12	1 2.3	1567	7 8 9 to	11 12 1 2	2345	678	891011	12 1 2 3				
Opening project's websit	e	Plan Actual									-	Ŧ					\square			Ŧ						
Press release		Plan Actual																								

Theme	Photo	Terminology	Name and number in
		Official and Alternatives	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.

ANNEX - Terminology (The name of the rectors)

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	Objectively Verifiable	Means of Verification	Important	Achievement	Remarks
Summary Overall Goal	indicators		Assumption		
Mass-culture of high value microalgae is adopted by aquaculture farms towards a sustainable aquaculture industry in Malaysia and/or other aquaculture producing countries.	 More than two (2) types of useful compounds are produced from cultured microalgae using recycled nutrients from aquaculture pond sludge. 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	 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. The mass-culture of high values microalgae will be established at the <i>demo site</i> 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.	 Annual algal biomass production of one (1) tonne or more per hectare is achieved. Biomass yield per giga joule of two (2) times or more than the conventional raceway system is achieved for two (2) indigenous microalgae species. 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 photobioreactor) 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	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		1-1: Two indigenous microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> , have been chosen as high value microalgae with high content of lipid and carotenoid.	
conditions in their life cycle and physiological attributes are determined.	1-2. Optimum growth conditions are determined for selected microalgae species.	Project report and publication	Biological and other	 1-2: On-going Optimum growth conditions are currently determined for the two selected microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i>. 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	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species.	Project report and publication	related samples can be brought to Japan for analyses.	2-1: On-going (light, temperature condition); Completed (nutrients, salinity conditions). High oil production culture conditions were established for <i>Chlorella vulgaris</i> and <i>Messastrum gracile</i> microalgae model. Based on these findings, suitable culture conditions for inducing production of useful compounds are currently determined for the two selected microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> .	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
controlling culturing conditions and life cycle).	2-2. Productivity of useful P compounds is increased by putwenty (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.	June-July 2021. Processing soil samples for experimental use requires approximately 2-months to prepare.

Narrative Summarv	Objectively Verifiable Indicators	Means of Verification	Important Assumption	Achievement	Remarks
	3-1. Optimal methodologies for extraction and fractionation of growth enhancing substances are identified.	3. Project report and publication		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. Efficient microalgae culturing technique utilizing growth-enhancing substances extracted from soil and sludge is proposed.	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	Biological and other related samples can be brought to Japan for analyses.	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
	 4-1. 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. 4-2. Scaled-up bag CRADLE 	Project report and publication		 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: Achieved in 2019 (Term 7) 	
	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.			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. Closed photobioreactor is scaled up for outdoor culture.	4-3. More than two (2) species of microalgae are cultured outdoors in sequenced bag reactors.		Biological and other related samples can be brought to Japan for analyses.	4-3: On-going (to be conducted from July 2021). The two species identified by Theme 1, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> , 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., <i>Chaetoceros gracilis</i> , <i>Isochrysis</i> <i>galbana</i> , <i>Thalassiosira</i> <i>weissflogii</i>). 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. 5-2. Technology to utilize ammonia as a low-cost alternative nitrogen source 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). 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. 	 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.
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	Objectively Verifiable	Means of Verification	Important Assumption	Achievement
Summary	Activities		Assumption	Inputs
1-1. Collect microalga	ae from various inland and coas	tal water bodies in	The Japanese Side	The Malaysian Side
1-2. Screen, isolate a 1-3. Characterize mic	nd purify the collected microalg roalgae for high contents of val	ae. uable compounds.	<u>Dispatch of Experts</u> Long-term Expert: Project Coordinator	Services of the Malaysian Counterpart personnel and administrative personnel Suitable office space with necessary equipment
1-4. Conduct incubati	on experiments using variable (growth conditions.	Short-term Expert: Planktonology Phycology Molecular biology/ 	Supply or replacement of machinery, equipment, instruments, vehicles, tools, s parts and any other materials necessary for the implementation of the Project o than the Equipment provided by JICA
 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. 		 Photobiology and optics of natural environments Natural product chemistry/ Natural organic chemistry/ Soil 	Running expenses necessary for the implementation of the Project (in the matching fund).	
 3-1. Collect soil and s 3-2. Study soil and slip 3-3. Examine and option extracts. 3-4. Conduct plate cult fractions from soil and 3-5. Examine the chet fractions and their eff 	 1. Collect soil and sludge from various locations in Peninsular Malaysia. 2. Study soil and sludge extraction methods. 3. Examine and optimize the fractionation method of soil and sludge stracts. 4. Conduct plate culture technique and examine the growth-promoting actions from soil and sludge extraction. 5. Examine the chemical characteristics of the growth-promoting actions and their effects on the physiological responses of microalgae. 			
4-1. Develop culture i photobioreactor. 4-2. Develop scaled-i 4-3. Develop a multi-s	methods of selected microalgae up novel photobioreactor for out sequence system of operationa	e in a small scale door mass culture. I photobioreactors.	Equipment and equipment To be elaborated later. Training in Japan Necessary expenses, except for the running cost, for the	
5-1. Establish a techr sludge. 5-2. Establish a techr	nology for recovery of nutrients f	rom aquaculture pond oalgae production.	collaborative research activities.	
6-1. Analyze environr system by LCA and L 6-2. Evaluate the influ aquaculture pond pro	nental impact and economic va .CC. Jence of the installed algae prod duction and the environment.	lue of the production duction system on		

Remarks
Pre-Conditions
Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and
Malaysian implementing institutions

les, tools, spare ne Project other	are agreed between Japanese implementing institutions and Malaysian implementing institutions
in the form of	
<ls:< li=""></ls:<>	sues and countermeasures>

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

Model Site: N/A

Period of Project: 6 years (2016.04 - 2022.03)

Project Site: Peninsular Malaysia

Narrative	Objectively Verifiable	Means of Verification	Important	Achievement	Remarks
Summary	Indicators	Wearis of Vermoution	Assumption	Admictement	Kemarko
Overall Goal					
Mass-culture of	1. More than two (2) types of	Report from	Market demand for	1. High value microalgae species have been shown to produce useful compounds	The construction of the SATREPS-
high value	useful compounds are	aquaculture farms	useful compounds is	under laboratory conditions. These are Anti-oxidants (UMT Group 2) and Fatty	COSMOS Demonstration site was
microalgae is	produced from cultured	Memorandum of	maintained	acids (UMT Group 3). Detail chemical properties of the compounds are being	delayed unfavorable climatic
adopted by	microalgae using recycled	Understanding on the		analysed.	conditions in June 2019. The
aquaculture farms	nutrients from aquaculture	use of mass-culture			outbreak of Covid19 delayed the
towards a	pond sludge.	technology between		2. The mass-culture of high values microalgae will be established at the <i>demo site</i> in	project progress further. The
sustainable		the private farms and		UPM as a model for farms to adopt. Upon establishment of the multi-sequence	extension of the project duration
aquaculture	2. More than three (3)	implementing		system of operational photobioreactor (outdoor bioreactor), technologies will be	was agreed on the fifth JCC
industry in Malaysia	aquaculture farms have	institutions		disseminated to farms.	meeting in August 2020.
and/or other	introduced mass culture of			In Malaysia, some Aquaculture Companies showed their interest: (1) Blue Archipelago	
aquaculture	algae in Malaysia and/or other			Sdn Bhd, (2) Hannan Sdn Bhd, (3) RE Millenium Sdn Bhd (Term 4). In Japan, Shin	
producing	tropical countries.			Kami town in Goto island, Nagasaki, large-scale implementation is operational.	
countries.					
Project Purpose					
An energy-efficient	1. Annual algal biomass	Project report and	Private aquaculture	1. Production of one tonne per ha (1t/ha) has been achieved based on the scale-up	The pilot-scale nutrient recycling
mass-culture	production of one (1) tonne or	publication	farms are willing to	novel photobioreactor (in-door photobioreactor).	system is needed to be modified
system of high	more per hectare is achieved.		cooperate in		and tested as matter of urgency
value microalgae			adopting the	2. The biomass yield per giga joule of two (2) times or more than the conventional	(the system safety and the gas
using recycled	2. Biomass yield per giga joule		sustainable	raceway system for two (2) indigenous microalgae species production by the multi-	absorption system).
nutrients from	of two (2) times or more than		technology	sequence system of operational photobioreactors will be calculated upon completion of	
aquaculture pond	the conventional raceway			the ongoing experiment (scheduled in February 2022).	The ammonia from the pond sludge
sludge is	system is achieved for two (2)				has been shown to be suitable for
established.	indigenous microalgae species.			3. More than one (1) tonne of aquaculture pond sludge is reduced for every ten (10)	the microalgae culture (Two papers
				kilograms algal biomass production (dry weight basis) will be calculated upon	published in Q1 journals).
	3. More than one (1) tonne of			completion of experiment (scheduled in February 2022).	
	aquaculture pond sludge is				The whole integration at the demo
	reduced for every ten (10)				site and continued experiments are
	kilograms algal biomass				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	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		1-1: Two indigenous microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> , have been chosen as high value microalgae with high content of lipid and carotenoid.	
conditions in their life cycle and physiological attributes are determined.	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, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> . 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	2-1. Suitable culture conditions for increasing productivity of useful compounds are determined for selected microalgae species.	Project report and publication	Biological and other related samples can be brought to Japan for analyses.	2-1: On-going (light, temperature condition); Completed (nutrients, salinity conditions). High oil production culture conditions were established for <i>Chlorella vulgaris</i> and <i>Messastrum gracile</i> microalgae model. Based on these findings, suitable culture conditions for inducing production of useful compounds are currently determined for the two selected microalgae species, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i> . 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.	
conditions and life- cycle).	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
Summary	3-1. Optimal methodologies for extraction and fractionation of growth enhancing substances are identified.	3. Project report and publication	Assumption	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. Efficient microalgae culturing technique utilizing growth-enhancing substances extracted from soil and sludge is proposed.	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	Biological and other related samples can be brought to Japan for analyses.	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 smalland 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, <i>Thalassiosira weissflogii</i> and <i>Isochrysis galbana</i>, 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., <i>Chaetoceros gracilis, Isochrysis</i> <i>galbana, Thalassiosira weissflogii</i>). 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
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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	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.
	ammonia as a low-cost alternative nitrogen source is established.			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) 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
1-1. Collect microalg	ae from various inland and coas	tal water bodies in	The Japanese Side	The Malaysian Side	
1-2. Screen, isolate 1-3. Characterize mi 1-4. Conduct incuba	and purify the collected microalg croalgae for high contents of val tion experiments using variable o	ae. uable compounds. growth conditions.	Dispatch of Experts Long-term Expert: Project Coordinator Short-term Expert: • Planktonology • Phycology • Molecular biology/	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	Terms and conditions to conduct collaborative research activities are agreed between Japanese implementing institutions and Malaysian implementing institutions
2-1. Conduct incuba enhance productivity 2-2. Characterize an microalgae as in 2-1	tion experiments under controlle / of useful compounds. d quantify the useful compounds	d culture conditions to s in cultured	Microbiology • Photobiology and optics of natural environments • Natural product chemistry/ Natural organic chemistry/ Soil	Running expenses necessary for the implementation of the Project (in the form of matching fund).	
 3-1. Collect soil and 3-2. Study soil and s 3-3. Examine and op extracts. 3-4. Conduct plate c fractions from soil ar 3-5. Examine the ch fractions and their ef 	sludge from various locations in ludge extraction methods. otimize the fractionation method ulture technique and examine th nd sludge extraction. emical characteristics of the grow fects on the physiological respon	Peninsular Malaysia. of soil and sludge e growth-promoting wth-promoting nses of microalgae.	chemistry • Analytical chemistry • Water chemistry • Chemical engineering/ Bioreactor engineering • Waste treatment science • Other specialists as needed		sues and countermeasures>
 4-1. Develop culture photobioreactor. 4-2. Develop scaled. 4-3. Develop a multi 5-1. Establish a tech sludge. 5-2. Establish a tech 	methods of selected microalgae -up novel photobioreactor for out -sequence system of operationa nology for recovery of nutrients for nology utilizing nutrients for micr	in a small scale door mass culture. photobioreactors. rom aquaculture pond oalgae production.	Equipment and equipment To be elaborated later. Training in Japan Necessary expenses, except for the running cost, for the collaborative research activities.		
6-1. Analyze environ system by LCA and 6-2. Evaluate the inf aquaculture pond pr	mental impact and economic va LCC. luence of the installed algae pro oduction and the environment.	lue of the production duction system on			

Project Monitoring Sheet II (Plan of Operation)

PO version 1 (Approved JCC5, 28 August 2020)

Project Title: The	Project for Co	ontinu	lous	Oper	ation	Syst	em	for Mic	roal	jae P	roduc	tion C	Optim	ized f	or Su	ustain	able	Trop	bical .	Aqua	acultu	ire (CC	Reported as of September 30, 2021	
	Pro	ject [Dura	ation	1st	: Yea		2nd	Year		3rd Y	'ear		4th Ye	ar	5t	h Yea	r	6t	h Ye	ar	Remarks	Issue/ Remarks	Solution
Innuto	ontract btw JIC	A and	Soka	Univ.		Ter	m 1		Terr	n 2		Tei	rm 3				Т	erm 4	4					
inputs	Monitorin	g She	et (R	eport)	Term 1	1 Ter	m 2	Term 3	Terr	n 4 Te	erm 5	Term 6	Terr	m7Te	erm 8	Term	9 Ter	m 10	Term	11 Te	rm 12			
				Year	201	16		2017		2	018		20	19		202	0		202	1	2022			
Export	MCO(Movement	Contro	ol Oro	der)	5.6 7.8	Q 10 11 12	123	456781	3 10 11 12	2345	6789	0.11.12	3456	7.8.0 10 11	123	4567	8 9 10 11 1	123	4 <mark>5 6 7</mark>	B 9 10 11	1 2 3		Listed below is the Movement Control Orders (MCOs) to contain the Covid-19 outbreaks	
Planktonologist 1/ Pr	oject Leader		NO.	Plan	5078	9 10 11 12	123	4.5678	9 10 10 4	2345	0789		3 4 5 6	7 8 9 * 1	123	4 3 6 7	0 9	123	4 5 6 7	5.9 10 11	-123	011	Since May 2020, planned dispatchment from Japan was suspended due to Covid-19	To follow the
(T. Toda)	,	SU	1	Actual																		SU	pandemic to up-to-date.	instruction
Planktonologist 2 (M.	. Hirahara)	SU	2	Plan Actual		_			+	_	+ + +											SU	Movement Control Order (MCO), effective on 18 March 2020. The MCO order was	and regulation from the
Planktonologist 3 (Y.	Takayama)	UT	3	Plan Actual																		SU	extended three times, each for additional two week period, until 12 May 2020. On 13 May, the Conditional Movement Control Order (CMCO) was issued.	government
Phycologist 1 (K. Tak	kahashi)	UT	4	Plan																		UTokyo	On 8 June, the Recovery Movement Control Order (RMCO) was issued.	
Phycologist 2 (M. Sa	ito)	UT	5	Plan																		UTokyo	On 10 April, the MCO was extended until 18 April.	
Phycologist 3 (T. Kat	tavama)	UT	6	Plan																		UTokyo	On 13 April, the MCO was extended until 12 May. On 11 May, the CMCO was initiated as per 13 May until 9 June.	
			-	Actual Plan									-									0100,00	On 7 June, the RMCO was initiated as per 10 June until 31 August.	
Phycologist 4 (M. Oh	ntake)	UI	7	Actual																		SU	source:https://www.mdbc.com.my/mco-updates/	
Advisor/ Phycologist	sor/ Phycologist 4 (K. Furuya) SU biologist (N. Kurosawa) SU					4																SU	On 14 October, the CMCO was implemented until 27 October.	
Microbiologist (N. Ku	biologist (N. Kurosawa) SU biologist (V. Kuwahara) SU																					SU	On 8 November, the CMCO was extended until 9 November.	
Photobiologist (V/ Ku	iwabara)	SU	10	Plan																		SU	On 7 December, the CMCO was extended until 20 December.	
Natural product chemist ((M. Watapaha ar	WO	10	Actual																		Watanaha Quatar	On 1 January 2021, the RMCO was extended until 14 January.	
Tominaga), <u>Watanabe O</u>	yster Laboratory	L	11	Actual									-									Laboratory (WOL)	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.	
Natural organic chem	I product chemist (M. Watanabe or Iga), <u>Watanabe Oyster Laboratory</u> L al organic chemist/Soil SU st CC MAS																					SU	On 21 January, the MCO was extended until 4 February.	
chemist, GC-MAS				Actual						_									_				On 2 February, the MCO was extended until 18 February.	
Analytical chemist 2	LC-MAS		13	Actual																			On 2 March, the MCO was replaced by the CMCO from 5 to 18 March.(for KL and	
Water chemist 1 (A.	lmai)	NIE	14	Plan Actual																		NIES	Selangor). On 16 March, the CMCO was extended until 31 March (for KL and Selangor).	
Water chemist 2 (K.	Komatsu)	NĬE	15	Plan																		NIES	On 30 March, the CMCO was extended until 14 April.	
Chemical engineer/B	Bioreactor	S		Actual Plan																			On 12 April, the CMCO was extended until 28 April.	
engineer 3 (T. Matsu	uyama)	SU	16	Actual																		SU	On 27 April, the CMCO was extended until 17 May.	
Chemical engineer/B engineer 4 (J. Ida)	sloreactor	SU	17	Plan Actual																		SU	On 6 May, the MCO was declared once again until 6 June.	
Waste treatment scie	entist 1 (K.	TT	18	Plan																		Tokvo Tech	On 11 June, the FMCO was extended until 28 June.	
Nakasaki) Waste treatment scie	entist 2 (M.		10	Actual Plan																			On 28 June, the FMCO was extended until clear the target of 4,000 new cases/ day.	
Kovama)	,	11	19	Actual																		Tokyo Tech	and Selandor from 3 to 16 July.	
(T N M Quven)	cientist 3	TT	20	Plan Actual																		Tokyo Tech	From 10 September, Selangor joined Putrajaya and Kuala Lumpur in transitioning to	
Electron Microscopis	st (M. Kuwata)	SU	21	Plan																		SU	Phase Two of the National Recovery Plan (NRP)	
JICA Project Coordin	nator			Actual Plan																			From 1 October, Selangor, Putrajaya and Kuala Lumpur entered Phase Three of	
Ms. Mari Miller	later	N.A.	22	Actual																		Not available	the National Recovery Plan (NRP).	
Mr. Masaru Yamada				Actual		0	4.0.0	450704		0.045	0700		0450	7.0.0		4507	0.0	4.0.0	4.5.0.7					
Transport, installation	n and commiss	ionina	of	Dian	10078	9 10 11 12	1,2.3	4 3 6 7 8 3	9 10 11 12	2345	0189	0 11 12 1 2	3430	7 8 9 10 11	1 Z 3	4 3 6 7	891111	4123	4 3 6 7	5 9 10 11	*123		The reactor (Theme 3) was delivered to the demo site in Malavsia on 14th	
equipment purchased	d in Japan	- 0	-	Fian							+ +		-				_						October 2021. The composting reactor (Theme 4) was assembled as of	
				Actual																			March 2021 and is needed to be tested before functioning.	
Fraining in Japan				Plan	5678	9 10 11 12	123	456789	9 10 11 12	2345	6789	0 11 12 1 2	3456	7 8 9 10 11	123	4567	8 9 10 11 1	123	4567	B 9 10 11	123		Diamod training in 2020 was cancelled due to the Could 10 pendemia	
Training at NIES				Actual																		NIES	Planned training in 2020 was cancelled due to the Covid-19 pandemic.	
Training at Utokyo	ing at Utokyo		-	Actual																		Tokyo Tech	4	
Training at Tokyo Te	ech		-	Actual																		UTokyo	1	
Training at SU			-	Plan Actual																		SU		
n-country/Third cou	ntry Training				5678	9 10 11 12	123	456789	9 10 11 12	2345	6789	0 11 12 1 2	3456	789 10 11	12 1 2 3	4567	8 9 50 11 5	123	4567	B 9 10 11	123			
Researchers	eiu by Japanese			Actual																			Workshop on centrifuge and photo bio-reactor was conducted at the demo site (2021.10).	

	Project Du	ration	1s	st Year		2nd	Year	3rd	Year		4th Ye	ear	5t	h Year	•	6th	Year	Ren	narks	Issue/ Remarks	Solution
Innuto	ontract btw JICA and Sol	ka Univ.	\square	Terr	m 1		Term 2	·	Te	rm 3				Te	rm 4						
inputs	Monitoring Sheet (Report)	Term	1 Terr	m 2 .	Term 3	Term 4	Term 5	Term	6 Terr	m 7 T	erm 8	Term	9 Term	n 10 T	Ferm 11	Term 1	2			
		Year	20	16		2017		2018		20	19		202	0		2021	202	22			
Output 1: High value	microalgae are isolate	ed and s	suitab	le aro	wth o	onditi	ons in t	heir life	cvcle	and p	hvsiol	ogica	al attri	butes a	are						
1-1. Collect microalg and coastal water bo Malaysia.	ae from various inland dies in Peninsular	Plan																	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:	
		Actual																		16 sites from seawater and 10 sites from freshwater (Term 5).	
1-2. Screen, isolate a microalgae.	and purify the collected	Plan																–UToky	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) <i>Chlorella sorokiniana</i> , (2) <i>Cymatosiraceae</i> sp., (3) <i>Oocystis</i> <i>heteromucosa</i> , (4) <i>Oocystis marssonii</i> , (5) <i>Nitzschia capitellata</i> , (6) <i>Thalassiosira</i>	
1-3. Characterize mic contents of valuable	croalgae for high compounds.	Plan																UTokv	UMT	This has been completed and two microalgae species, <i>Thalassiosira weissflogii</i> and <i>lsochrysis galbana</i> 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).	
		Actual																		Six (6) isolates from UMT and UPM identified earlier [<i>Chaetoceros gracilis</i> (UPM), <i>Chlorella</i> sp. (UMT), <i>Chlorella vulgaris</i> 1 (UMT), <i>Chlorella vulgaris</i> 2 (UPM), <i>Isochrysis galbana</i> (UPM), <i>Tetraselmis suecica</i> (UMT)] have been also characterized for the useful compounds (Term 8).	
1-4. Conduct incubat variable growth cond	ion experiments using litions.	Plan																	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	
		Actual																		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.	
Output 2: Production	of useful compounds	of sele	cted I	microa	Igae	is enh	anced (by con	rolling	cultu	ring c	ondit	ions a	nd life	-			1	1	Net yet because of COV/ID10 pendemia. Establishment of high ligid/corretoroid	
manipulated culture of productivity of useful	Dut 2: Production of useful compound . Conduct incubation experiments unden nipulated culture conditions to enhance ductivity of useful compounds.																	JToky	UMT	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 <i>T. weissflogii</i> , 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 <i>Chlorella vulgaris</i> UMT-M1. Nitrate starvation and inducible conditions for	
2-2. Characterize and compounds in culture	 Characterize and quantify the useful npounds in cultured microalgae as in 2-1 																			Ankistrodesmus gracilis was successfully established (Term 8). Productivity of useful compounds is currently determined for the cultured microalgae as in 2-1. The established methods for quantification are now used for <i>Thalassiosira</i>	
		Actual																–UToky	UMT	weissflogii and Isochrysis galbana. For I. galbana, DHA production has been increased more than 20% by reducing phosphate (1/4 from the Control).	

	Project Du	ration	1	st Year	2n	d Year	3rd \	Year	4th	Year	5th	Year	6th \	(ear	Ren	narks	Issue/ Remarks	Solution
Innuts	ontract btw JICA and Sok	ka Univ.	\square	Term	1	Term 2		Terr	n 3			Term	4					
inputs	Monitoring Sheet (I	Report)	Term	n 1 Term	2 Term	3 Term 4	Term 5	Term 6	Term 7	Term 8	Term 9	Term 10	Term 11	Term 12	2			
		Year	2	016	2017	7	2018		2019		2020		2021	202	2			
Output 3: Effects of	fractions of growth-pro	omotin	g soi	l extract	s on sel	ected mic	roalgae	and che	emical p	ropertie	s of the	<u>}</u>			_	1		DEMARKO
3-1. Collect soil and locations in Peninsul	sluage from various a Malaysia.	Plan													NIES	UNISEL	All samples have been collected/ completed (1erm /). 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	Including a second seco
		Actual															(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).	Malaysia in Term 11.
3-2. Study soil and s methods.	ludge extraction	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	
		Actual															extraction, 105°C, 105°C two hours extraction, 121°C and 121°C two hours extraction (Term 7).	
3-3. Examine and op method of soil and si	timize the fractionation udge 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	
		Actual															tractionation 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).	
3-4. Conduct plate conduct plate conduct plate growth-e soil and sludge extra	ulture technique and nhancing fractions from ction.	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 Iscothrysis galbana (selected high-value microalgae in SATREPS-COSMOS	
		Actual															program), respectively. 1 new high-value strain <i>Chaetoceros</i> will be tested again using 9 soils extract.	

	Project Dur	ation	1:	st Year		2nd Year	3rd Year	4th Ye	ear	5th Year	6th Ye	ear	Rem	narks	Issue/ Remarks	Solution
Innuto	ontract btw JICA and Sok	a Univ.	\square	Term	1	Term 2	2 Te	rm 3		Term	4					
inputs	Monitoring Sheet (F	Report)	Term	1 Term	2 Tei	rm 3 Term 4	Term 5 Term	6 Term 7 T	erm 8	Term 9 Term 1	0 Term 11 Te	erm 12				
		Year	20	016	20	017	2018	2019		2020	2021	2022				
3-5. Examine the chu the growth-enhancin effects on the physic microalgae.	emical characteristics of g fractions and their logical responses of	Plan											NIES		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 the OFF.	
		Actual											NILS	UNISEL	Inke, C-P: TUNC-acid like and C-P: numic-acid like). Ine percentages of the C-P 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.	
Output 4: Closed ph	otobioreactor is scaled-	up for	outd	oor cult	ure.									_		-
4-1. Develop culture microalgae in a smal	methods of indigenous Il scale reactor.	Plan											SU		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	
Note: A laboratory-so	cale photobioreactor	Actual											50	OT M	current raceway pond. I hus, the "Objectively verifiable indicators of 4.1" in PDM has been completed.	
4-2. Develop scaled- bioreactor for outdoo	up CRADLE photo- or mass culture.	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	
Note: A scale-up nov	el photobioreactor	Actual													months (Term 7).	
4-3. Develop a multi- bag reactors. Note: The multi-sequ	-sequence of operational uence system of	Plan											811		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	A multi- sequence of operational bag reactor is
operational photobio	reactors	Actual											50	UPM	CMCO.	developed and to be delivered to the demo site in October

	Project Dur	ation	1st	Year	1	2nd Y	ear	3rd	Year		4th Y	ear	5	th Ye	ear	6	th Ye	ar	Rem	narks	Issue/ Remarks	Solution
Innute	ontract btw JICA and Sok	a Univ.	И	Term	1	Т	erm 2		Т	erm 3				•	Term	4						
inputs	Monitoring Sheet (F	Report)	Term 1	Term	2 Ter	m 3 1	Ferm 4	Term 5	Term	6 Te	rm 7 1	Ferm 8	Term	n 9 Te	erm 10	Term	11 Te	erm 12				
		Year	201	6	20	17		2018		2)19		202	:0		202	21	2022				
Output 5: Technolog	gies for recovery of nut	rients f	from aq	uacult	ure p	ond s	ludge	and util	izatio	n of tl	ne nuti	rients	for m	icroa	algae	prod	uctio	n are		•		
5-1. Establish techno nutrients from aquac microalgae productio	ology for recycling ulture waste for use in on.	Plan																			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	
		Actual																	Tokyo Tech	UPM	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).	
5-2 Establish technol recycling waste from	logy and method for the whole system.	Plan																	Tokyo		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																	Tech	UPM		
Output 6: Economic	profitability and enviro	onment	tal com	patibili	ity of	the sy	/stem a	are veri	fied.													
6-1. Analyze environ	mental impact and	Plan																			The system scale was determined as "40 shrimp ponds (common scale for small-scale	
economic value of th LCA and LCC.	e production system by	Actual																	SU	UPM	similing failing to economically treat the slouge. They scenarios were constructed in which 100%, 50%, and 25% of the recovered ammonia were used in PBR, respectively (Term 11).	
6-2. Monitor biologica environmental prope	al production and rties in aquaculture	Plan																	911		To be condcuted in February 2022.	
pond installed with al	Igae production system.	Actual																	00	01 101		
Duration / Phasing		Plan Actual																				
Monitoring Plan	n		456789	10 11 12 1 2	23456	789	11 12 1 2 3	456789	10 11 12 1	2345	678910	11 12 1 2	34567	8 9 10 1	1 12 1 2 3	4567	8 9 10 11	1 1 2 3				
Joint Coordinating	Committee	Plan																				
Submission of Mon	itoring Sheet	Plan																				
Monitoring Mission	from Janan	Actual Plan																				
loint Monitoring	nom vapan	Actual Plan																				
		Actual Plan																				
Post Monitoring		Actual																				
Reports/Documents		Plan	456789	9 10 11 12 1 2	23456	78910	11 12 1 2 3	456789	10 11 12 1	2345	578910	11 12 1 2	34567	8 9 10 1	1 12 1 2 3	4567	8 9 10 11	1 12 1 2 3				
		Actual											\square									
Project Completion	Report	Actual																				
Public Relations			456789	10 11 12 1 2	23456	78910	11 12 1 2 3	456789	10 11 12 1	2345	578910	11 12 1 2	34567	8 9 10 1	1 12 1 2 3	4567	8 9 10 11	1 12 1 2 3				
Opening project's website	e	Plan Actual																				
Press release		Plan Actual											+									

3. Tentative Plan after COSMOS Project

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



Activity					20)22								20	23								20	24								202	5								20	26				
Activity	1	2	3	4 5	5 6	7	8 9	ə 10	11 1	2 1	2	3	4 5	6	7	8 9	10	11 1	12	1 2	3	4 5	6	7	8 9	ə 10	11	12 1	2	3 4	l 5	6	7 8	9	10 1	1 12	! 1	2	3 4	1 5	6	7	89	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																																								Τ						
Community outreach: development for B40 communities																																														
Demonstration Site & Donated Eq	luip	ome	ent																																											
On-going research and maintenance																																						\square		Τ						
Collaboration development with industry and research access																																														
Algal biorefinery plant development																																														
Microalgae & aquaculture hub																																						μŢ								_
Fish culturing and horticulture expansion; blue-culturing	;																																													