# THE LAKE VICTORIA COMPREHENSIVE ECOSYSTEM AND AQUATIC ENVIRONMENT RESEARCH FOR DEVELOPMENT PROJECT (LAVICORD)


## FINAL REPORT

## AUGUST 2016

# TABLE OF CONTENTS

# FOREWORD

**Prof. Julius Nyabundi**
**Vice Chancellor**
**Maseno University**

World fish production has grown tremendously during the last fifty years. While capture fisheries (wild) production leveled off in the mid-eighties, the aquaculture sector maintained an average growth rate of 8.7% worldwide since 1970. Most of the net growth in fish production over the first twenty years has come from aquaculture especially in developing countries. Aquaculture has in fact been the fastest growing sector in food production as well as for rural livelihood improvement and agricultural income earning worldwide for the past two decades. In contrast, Lake Victoria, the second largest lake in the world has been recording a decline in fish production since the last forty years. Similarly, the uptake of aquaculture technologies as a source of fish production in Kenya especially in Lake Victoria basin has not been as rapid as expected. Therefore, we need to find a way to produce more fish for the growing need of fish for the escalating world population.

It is against this background the LAVICORD project has been initiated by Maseno University and Nagasaki University and our other collaborators. Now, the project has come to an end, after years and two more extensions for two months.

Observing the achievements of the LAVICORD project, I appeal to the Japanese team to continue supporting the project through another funding. This is because, inspite of its short duration, the project accomplishes a lot and have touch the lives of people they worked with. The extension or another phase of the project could be a great chance for us to transfer the technology that LAVICORD developed to more stakeholders and riparian communities.

I especially refer to the technology developed by the aquaculture team, the culture of Nile perch and tilapia has tremendous application. We need to develop an affordable and efficient technologies in fish production. Also, based on the results of this project, the prevailing decline in fish stock in Lake Victoria could serve as a wakeup call to scientists and riparian communities to work together towards generating timely solutions. We at Maseno University revamped this fundraising activities to attract more donors and funding agencies to support the second phase of LAVICORD.

# MESSAGE

**Prof. Shigeru Kitamine**

**President**

**Nagasaki University**

I applaud the achievements of LAVICORD, in spite of its short duration, and I am very much satisfied of the progress of the Project and I looked forward to more collaborative activities. It was observed that the Lake Victoria region has been facing many environmental challenges, especially in resource exploitation and water security. These were affecting the socio-economic stability of riparians, hence the need for immediate solutions. It was observed that LAVICORD had generated viable scientific knowledge and interventions that could resolve these problems. Wider implementation of these outcomes was yet to be achieved alongside further research to cover persisting gaps in knowledge.

Revisiting international collaboration, LAVICORD is a viable model for research and development since different countries across the globe face similar challenges, for example, global warming. This model avails a wider range of research expertise within a short period of time and ensures quicker technology transfer. LAVICORD had applied this approach to achieve its objectives. In terms of capacity building, LAVICORD has accomplished its objectives by training young and vibrant Kenyans to be the next scientists who are aware of the problems of Lake Victoria.

I strongly used professors and scientist to work together and develop joint research proposals in order to continue this kind of project in Lake Victoria. Meetings or conference like this could be a great venue and opportunity to come up with ideas that could move LAVICORD forward. Furthermore, I am hoping to have more of this joint projects, the collaboration between Maseno University and Nagasaki University not only in the field of engineering and fisheries, but also in other field including medical and environmental studies. I further point out that European, American and Asian countries were growing faster than African countries because of huge investment in scientific research collaboration. Such collaborations were not only accelerating socio-economic development but they are also capable of transforming a country into a scientific powerhouse. It is my hope that Kenya will continue to grow in tremendously in terms of research for country's fast development.

# MESSAGE

## Hon. Charles Sunkuli

**Principal Secretary**

**Ministry of Environment and Natural Resources**

First of all, let me congratulate all the staff of LAVICORD Project for the success of the project. I observed that Lake Victoria basin was a major population center, supporting Kenya's main inland fishery industry and livelihoods of millions of riparians. Prevailing environmental problems were therefore a major concern to our Ministry whose mission include protection, restoration, conservation, development and management of the environment and natural resources. Lake Victoria region was therefore an area of key interest to the Ministry.

Revisiting the success of the project, I see that LAVICORD Project had generated lots of scientific knowledge that could be used to spur socio-economic growth and inform policy. However, I see that there is a need to conduct more research, and apply the findings research findings. Further, I noted that the project has been working in just a few areas within Kisumu, hence the need for scale-up, and that the next step should be consolidation of the research findings and dissemination to stakeholders. Support from the Government of Kenya and Government of Japan was called upon as well as input from the county governments and public participation.

I know research is very important and critical for in promotion of sustainable use of natural resources and conservation. LAVICORD had extensively applied and relied on research to achieve its objectives Therefore, there is need for more research, adding that resulting information should be used guide people on how to effectively manage available natural resources. Research was also identified as an important tool in addressing pressing social challenges being experienced in Africa, including poverty and disease. Highlighting the importance of participation of Kenyans in research, I encourage all of you to develop young mind to be research-oriented so that they could think of good solutions to local problems. I commend the success of this project to both Japanese and Kenyans who worked together to achieve one a common goal.

# MESSAGE

## Ms. Yui Takashima

**Second Secretary**

**Embassy of Japan**

Firstly, I would like to thanked all the researchers for their enormous contribution in LAVICORD Project, that through their efforts, the Japanese and Kenyan Governments had once again reaffirmed their commitment towards human advancement through scientific research.

LAVICORD Project offered the Kenyan and Japanese researchers a good opportunity to work together and learn from one another. As I am aware of, one of the major challenges in Kenya have been experienced in other parts of the world and working in such a model enabled faster and efficient implementation of projects which have been successfully adopted in those regions. The Japanese Government will continue foster socio-economic development through science funding.

I observed the role that academia in resolving problems facing Lake Victoria basin and its resources. I affirmed that academic insight based on extensive research and evidence was crucial for formulating effective policies that could drive development in Kenya. I expect that this symposium will provide an opportunity for discussion of the issue of water pollution and engineering and fisheries sciences in the view of prevailing environmental problems facing the world, particularly Africa.

Nagasaki University will celebrate its 50$^{th}$ anniversary this year, and I am also reminded of Sixth Tokyo International Conference on African Development (TICAD VI) that will be held in Nairobi in August. Today's meeting here in Kisumu will be a great venue for us to discuss on issues that we could brought TICAD.

Lastly, I encouraged you to come up with new research topics that can be explored jointly by Kenyan and Japanese scholars for the benefit of local communities and general well-being of the people of Kenya.

# MESSAGE

## Prof. Yoshio Ichinose

**Director**

**Nagasaki University International Tropical Medicine**

LAVICORD project is particularly focused on the problems faced by the people living around Lake Victoria. Therefore, there are a call for more funds to support such kind research activities in order to help communities who are dependent on Lake Victoria. I am particularly concern on the high level of pollution and eutrophication in the lake that could threatened millions of people within the lake basin to become jobless and hungry when present problems persist. Aside from fishing, other income generating activities such as agriculture is also dependent on the lake water.

I am also particularly concern on the source of clean drinking water for the over 35million people living within the lake basin as a major crisis that required efficient and affordable water purification technologies such as the bio-fence. The frequent outbreak of Cholera Lake region could be attributed to lack of clean water and poor waste disposal methods. Resolving such problems would therefore require a joint approach from all stakeholders in all disciplines so as to inform one another sufficiently on the cause and effects of specific challenges. I therefore strongly urge researchers, policymakers and other development stakeholders to work together and speed up their efforts in order to avert a major crisis in Lake Victoria.

As LAVICORD ends, I would like to say thank you for great cooperation and participation in this project. Without your cooperation, this project could not accomplished as much as what it had accomplished, and to all supervisors who are untiringly teach future researchers and country's leaders, I would like to commend this success to you. I hope we could build a healthy, clean ans sustainable world for our children and future generation.

# MESSAGE


**Prof. Willington Otieno**

**Deputy Director**

**RESTECH**

As Lake Victoria Comprehensive Research for Development (LAVICORD) draws to a close, it gives me great pleasure to reflect on its achievements, challenges and opportunities. The research on Lake Victoria was anchored on real problem affecting many people. The Lake Victoria supports livelihoods of about 50 million people in East Africa of whom about 30% live in Kenya. Lake Victoria research enabled institutional collaboration amongst several universities in Kenya and Nagasaki University from Japan. This is a model that harnessed the best scientific talent available from the various universities in Kenya to solve a common socio-economic problem such as Lake Victoria water quality and fish population decline

In undertaking the research task, the scientists have employed the best scientific tools and methodologies available in the market. This was achieved through quickly assembling scientific equipments, chemicals to create a functional laboratory; as well as identifying appropriate field sites along Lake Victoria. Taking into account the need for future scientific manpower, it was decided at very early stages to recruit competitively young and gifted Kenyan first degree graduates to work in the project. The research assistants were required to register for a master's degree on topics related to the project. At the expiry of the project, almost all the 12 research assistants have been awarded master's degree, some of whom are proceeding with their doctoral studies.

LAVICORD Project has recorded several publications to its credit. Four Scientific Manuscripts have been submitted and three of them accepted in internationally refereed journal. LAVICORD has produced several publications: *The 2014 Launch Report; two Scientific Conference Proceedings, 2015&2016 and Seminar/Symposium Report 2016.*

The success story of LAVICORD is one that provides a viable framework and model for international cooperation in research. It is our hope that the firm a foundation that has been laid will provide a strong basis for further support to advance scientific research on Lake Victoria for the betterment of mankind.

# THE LAVICORD PROJECT

The Lake Victoria Basin and its resources is a source of livelihood for millions of riparians in East Africa with an estimated population of at least 50 million people. The lake supports Africa's largest inland fishery activities, hence a source of food and income for its riparians and an important source of export goods for the country. However, these resources have heavily been overexploited over time and are slowly losing sustainability, threatening economic stability while exposing riparians to social and economic challenges through losing its profitability due to poor post-harvest structures. Availability of clean water has also remained a problem in the region, exposing riparians to a range of water borne diseases and poor hygienic conditions. These problems are further compounded by steady population increases and consequent over-dependence on the lake for sustenance. In response, The Lake Victoria Comprehensive Ecosystem and Aquatic Environment Research for Development Project (LAVICORD) is a multidisciplinary project which integrates modern technologies of water engineering and fisheries to address environmental and socio-economic problems of the riparian communities living around Lake Victoria and enhanced awareness in resource conservation. LAVICORD is under the mandate of the Ministry of Environment and Natural Resources of Kenya Government to achieve sustainable development for Vision 2030. LAVICORD was initiated by Maseno University, Kenya and Nagasaki University, Japan. Kenya Marine and Fisheries Research Institute (KMFRI), Moi University, Centre for Research and Technology Development (RESTECH) are the co-collaborators.

***Objectives***

The overall purpose of the project is to enhance knowledge and apply modern technology for enhanced fisheries production, water quality and ecosystem integrity of Lake Victoria for as a sustainable resource for riparian communities. Specifically, the project aims to:

- Review and synthesize existing data and information on the environmental problems relating to Lake Victoria and store these data in a common resource center for students and researchers;
- Establish systems and procedures that will ensure aqua health and improve water security;
- Address the lake biodiversity problems through proper fisheries management and aquaculture;
- Improve fish post-harvest system for value addition and hygienic management for public health and safety; and
- Capacity building through training and seminars.

Since LAVICORD addresses different issues, it is divided into three components, each component has different specific objectives and experts:

**Component 1: Literature review and aqua health research**

- Creation of Lake Victoria ecosystem database in the last 20 years and creation of resource center for students and researchers;
- Understanding the Lakes' ecosystem by applying eco-hydraulic simulation models; and
- Understanding levels of pollution in the Lake and finding ways to improve aqua and human health status of the community.

Research Team: Prof. Akihide Tada, Prof. Job Jondiko, Prof. Hideake Nakata, Prof. Shigenobu Takeda, Assoc. Prof. Yu Umezawa, Assoc. Prof. Seiji Suzuki

***Component 2: Water engineering***

- Development of a bio-fence enclosure system to remove toxic cyanobacteria from drinking water;
- Development of a sustainable wastewater recycling and water distillation system; and
- Establish an aqua health network among the riparian communities in the lake region.

Research Team: Prof. Tomoaki Itayama, Prof. Yuichiro Shibata, Prof. Senya Kiyasu, Dr. Crispin Kowenje, Prof. Simiyu Sitati, Dr. Joel Kibiiy, Mr. Abraham Chirchir

***Component 3: Fisheries Sciences***

- Introduce sustainable fishing technologies, different aquaculture practices, and post-harvest technologies;
- Introduce aquaponics system; and
- Enhance the community awareness on resource conservation.

Research Team: Prof. Yoshiki Matsushita, Mr. Kenneth Werimo, Prof. Atsushi Hagiwara, Prof. Yoshitaka Sakakura, Prof. Osamu Arakawa, Prof. Eliud Waindi, Dr. Dickson Owiti, Assoc. Prof. Hisashi Ichikawa, Dr. Helen Marcial

***Duration of the Project***：January 2014 – August 2016

***Project Budget***：141,223,250KES

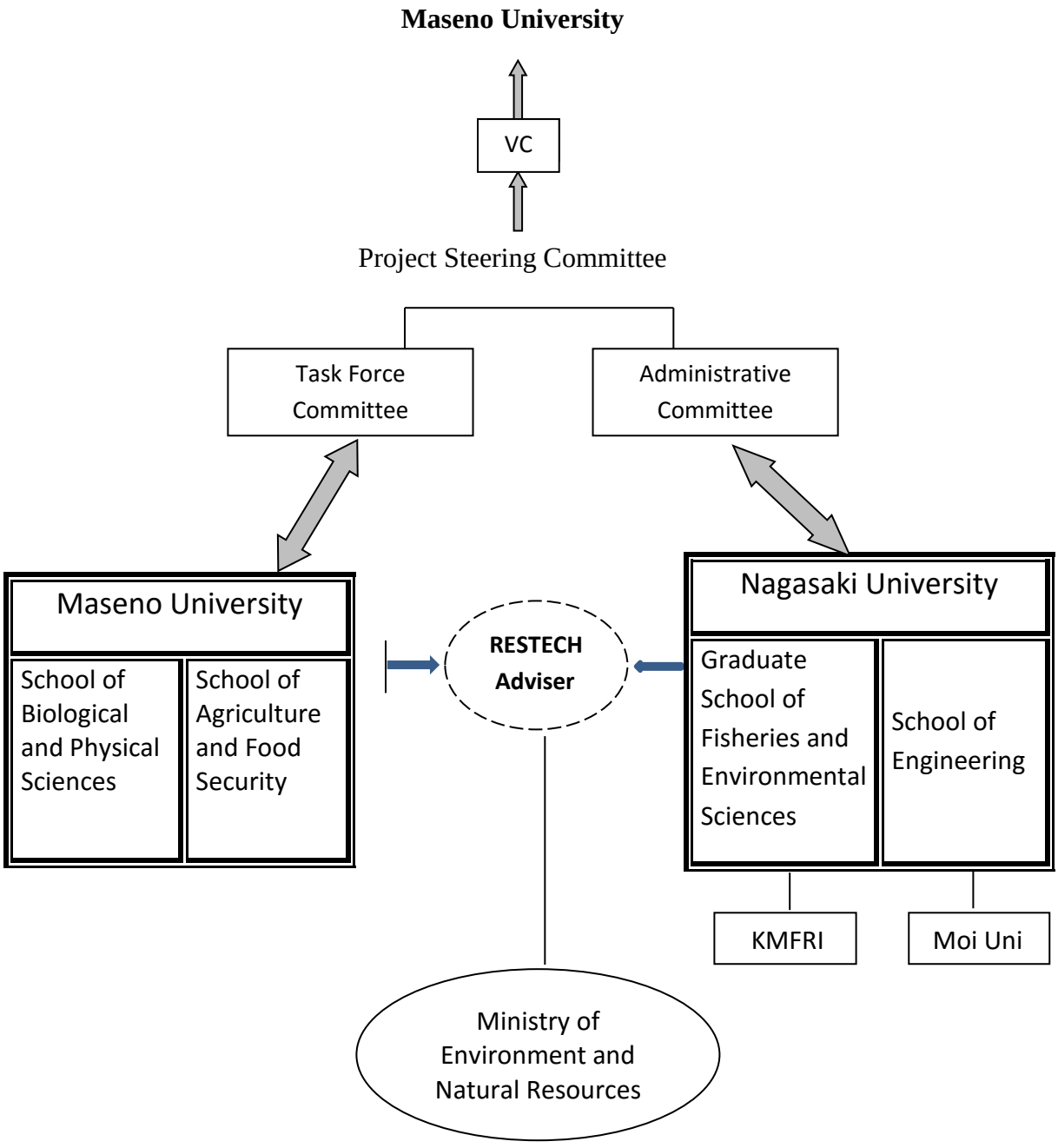
***Research Sites*****：** Varsity Plaza, Kisumu (Office/main station), Mbita, Homa Bay, Kendu Bay, Winam Gulf, Ogal Beach, Wichlum Beach, Dunga Beach, Honge Beach, Mageta Island, Maseno University (Siriba Campus), Moi University, Kenya Marine Fisheries Research Institute (KMFRI), Kegati and Kisumu stations

***Meetings/Conferences*****:**

1) Launching ceremony – 3rd February 2014, Kisumu Hotel
2) Tracking One Year Progress – 11th May 2015, Kisumu Hotel
3) Providing Solutions Towards Sustainable Fish Production and Provision of Clean Water from Lake Victoria – 7th June 2016, Kisumu Hotel
4) Two Years Progress and Future Prospects – 22nd July 2016, Acacia Premier, Kisumu

The project employed 11 research interns, supported 1 PhD research; 10 Master research thesis from both Kenya and Japan.

## Organizational Structure of the Project



# ACCOMPLISHMENT REPORT

## COMPONENT 1

| | |
|---|---|
| Component Supervisor: | Akihide Tada |
| Deputy Component Supervisor: | Job Jondiko |
| Component Coordinator: | Hideaki Nakata, Ruth Owiga, Shigenobu Takeda |
| Deputy Component Coordinator: | Yu Umezawa, Seiji Suzuki |
| Research Coordinator: | Akira Morikawa |
| Intern Research Assistant: | Steve Omari, Lilian Otoigo, Gertrude Shisanya |

**Study 1. Review and analysis of existing information on aquatic environment, ecosystems and land use**

After collecting reviews and analysis of existing information concerning the aquatic environment, ecosystems and land use in the Lake Victoria Basin, the resource center was established in the City Campus of Maseno University. The total number of them is 659 and the details are as follows:

Component-1: 301, Component-2: 93, Component-3: 124, Others: 141

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## Study 2. Monitoring and survey of aquatic ecosystems and water environments of Lake Victoria and its surroundings

### *Introduction*

LAVICORD is a development project that has been developed in response to water environmental and social-economic problems facing the Lake Victoria region. It is a multidisciplinary project that has combined water engineering science, public health, computer science & technology and fisheries sciences. In particular, this project is divided into three components that address problems facing Lake Victoria fisheries and clean water shortage problems.

### *Material and Methods*

The target area of this research is Nyanza Gulf, the major gulf in the Kenyan side of Lake Victoria, and the rivers flowing into the gulf. All research surveys were undertaken in collaboration with Beach Management Units (BMUs) to illustrate the water environment of the gulf. During each survey, a fishing boat was rented at each BMU for monitoring water quality and collecting water samples at sampling locations in the Lake (○) and the rivers (●) as shown in Fig. 1.These surveys were conducted in regular sampling (every two weeks at the rivers and within Nyanza Gulf near Kisumu, referring to Table1) regional sampling (every three months at all sampling locations, referring to Table2) from June 2014 to September 2015.

Fig. 1 Research Sites in LAVICORD Project

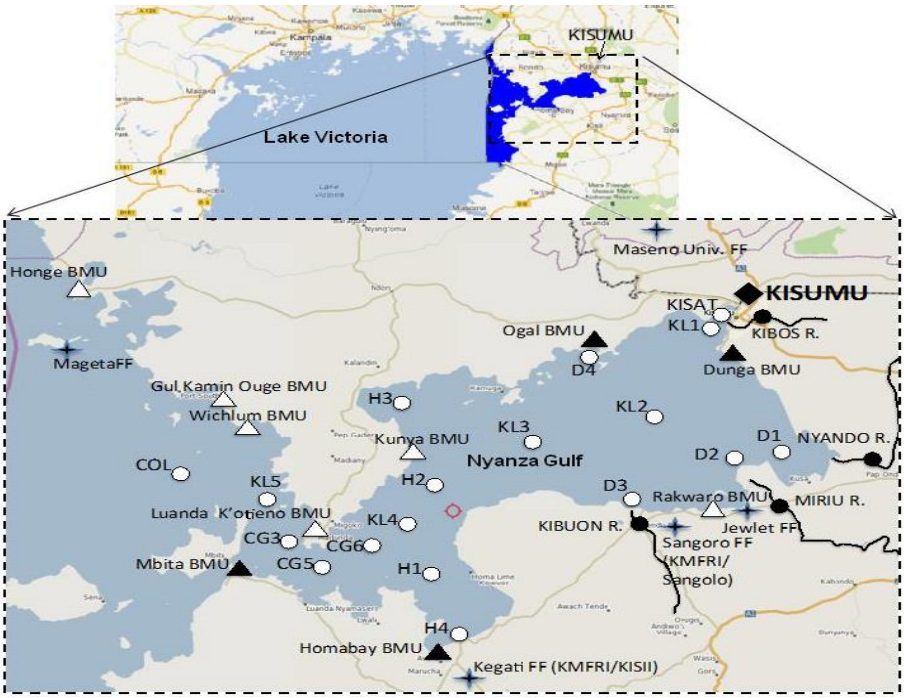



Table-1 Water Quality Observations & Water Sampling over a Wide Area

| Name of BMU | Approximate Distance from Kisumu (Km) | as hrs | Sampling Locations | Total hours required for sample collection |
|---|---|---|---|---|
| Lwang'ni Beach | 1km | 0.1h | D4-KL1-KISAT | 3h |
| Dunga B.M.U. | 4.7km | 0.4h | D1-D2-D3-KL2 | 4h |
| Homabay B.M.U. | 105km | 2h | H1-KL4-H2-H3-KL3-H4 | 6.5h |
| Mbita B.M.U. | 150km | 3h | COL-KL5-CG3-CG5-CD6 | 5h |
| River Sampling | | | KIBUON-MIRIU-NYANDO-KIBOS | 3.5h |

| Year | Observation Period | Year | Observation Period |
|---|---|---|---|
| 2014 | 24th of June – 27th of June | 2015 | 24th of March – 27th of March |
| 2014 | 31st of August – 2nd of September | 2015 | 23rd of June – 25th of June |
| 2014 | 2nd of November – 5th of November | 2015 | 21st of September – 24th of September |
| 2015 | 11th of January – 14th of January | | |

Table-2 Water Quality Observations & Water Sampling in Neighboring Waters of Nyanza Gulf & Four Rivers.

| Year | Observation Period | Year | Observation Period |
|---|---|---|---|
| 2014 | 24th of June – 27th of June | 2015 | 24th of February – 26th of February |
| 2014 | 9th of July – 10th of July | 2015 | 10th of March – 11th of March |
| 2014 | 22nd of July – 23rd of July | 2015 | 24th of March – 25th of March |
| 2014 | 5th of August – 6th of August | 2015 | 8th of April – 10th of April |
| 2014 | 19th of August – 20th of August | 2015 | 21st of April – 23rd of April |
| 2014 | 31st of August – 2nd of September | 2015 | 5th of May – 7th of May |
| 2014 | 16th of Sep. – 17th of September | 2015 | 19th of May – 23rd of May |
| 2014 | 30th of September – 2nd of October | 2015 | 3rd of June – 5th of June |
| 2014 | 14th of October – 16th of October | 2015 | 16th of June – 18th of June |
| 2014 | 2nd of November – 5th of November | 2015 | 23rd of June – 25th of June |
| 2014 | 19th of Nov. – 21st of November | 2015 | 1st of July – 3rd of July |
| 2014 | 2nd of December – 4th of December | 2015 | 11th of August – 13th of August |
| 2014 | 16th of Dec. – 18th of December | 2015 | 25th of August – 27th of August |
| 2015 | 11th of January – 14th of January | 2015 | 8th of September – 10th of September |
| 2015 | 27th of January – 28th of January | 2015 | 21st of September – 24th of September |
| 2015 | 10th of February – 11th of February | | |

In order to monitor on-site water quality parameters; a multi-probe water quality sensor was used at each sampling location. Namely, measuring water quality indexes are water temperature, turbidity, Chlorophyll-a, dissolved oxygen, pH and conductivity. Moreover, TSS, Chlorophyll-a, T-N,T-P, COD, $NO_3$, $NO_2$, $NH_4$, $PO_4$, Cyanotoxin microcystin (by HPLC and PP2A enzyme assay) were analyzed at the Aqua Laboratory in Kisumu.

Flow current fields near the mouth of Nyanza Gulf were measured at several places using Acoustic Doppler Current Profiler (ADCP) as shown in Fig. 2. These activities were carried out from the 19th to the 21st of August in 2015, and from the 5th to the 8th of January in 2016.


Fig. 2 Monitoring Flow Current at the mouth of Nyanza Gulf using ADCP

***Results and discussions***

No stratification of water temperature was observed on the 1st of September in 2014 at both inside and outside of the gulf since water was well mixed vertically, while the vertical distribution of turbidity at each point has specific spatial trend, as shown in Fig.3.

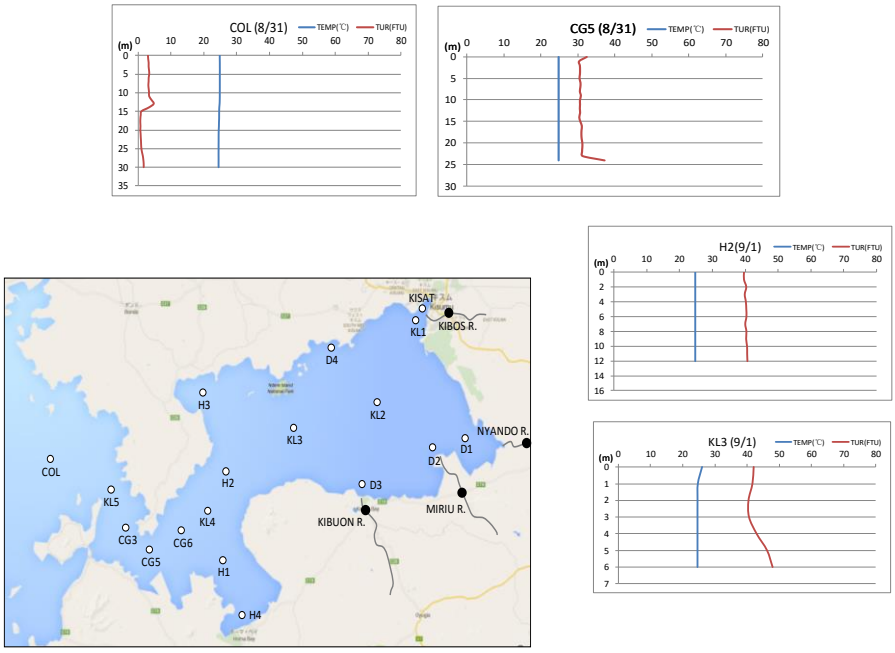



Fig. 3 Vertical Distributions of Water Temperature and Turbidity (COL, CG5, H2, KL2)

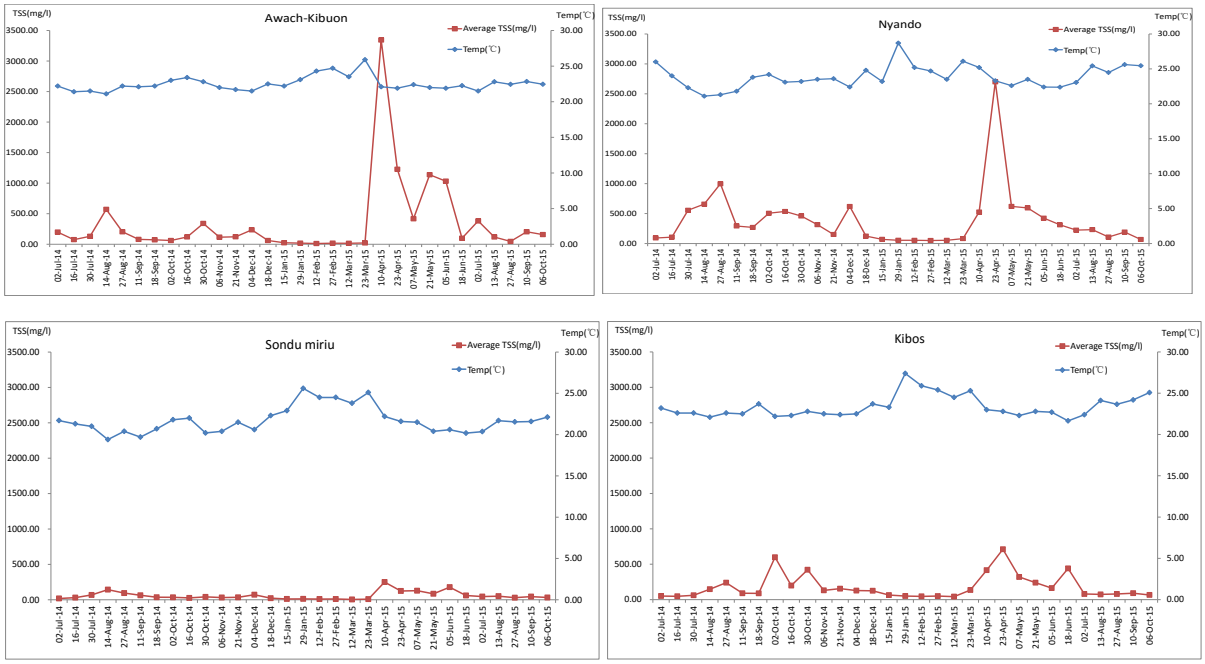
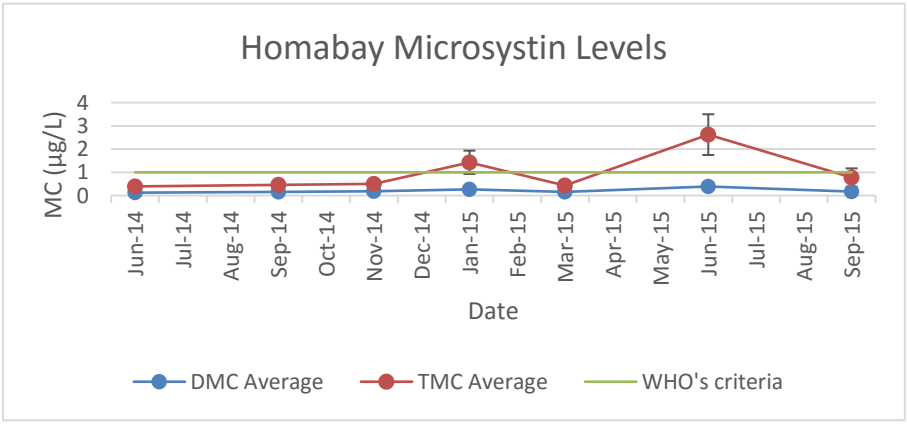



Fig. 4 Temporal changes in both water temperature and TSS at four rivers (Awachi-Kibuon River, Sondu-Miriu River, Nyando River, Kibos River)

The temporal changes in water temperature at all four rivers (Awachi-Kibuon River, Sondu-Miriu River, Nyando River, Kibos River) were very small around 25℃. On the other hand, higher values in TSS were found out between March and June in 2015 at all rivers, as referring to Fig.4. It was thought that the rapid increment of TSS was related to precipitation at the upper stream or in the catchment area.

Higher microcystin concentration (by PP2A enzyme assay) than WHO guideline (1 $\mu$g/L) were observed at sampling points near to Kisumu as shown in Fig.5.

Moreover, the annual fluctuation in water level were measured at both Dunga and Mbita, as shown in Fig.6.



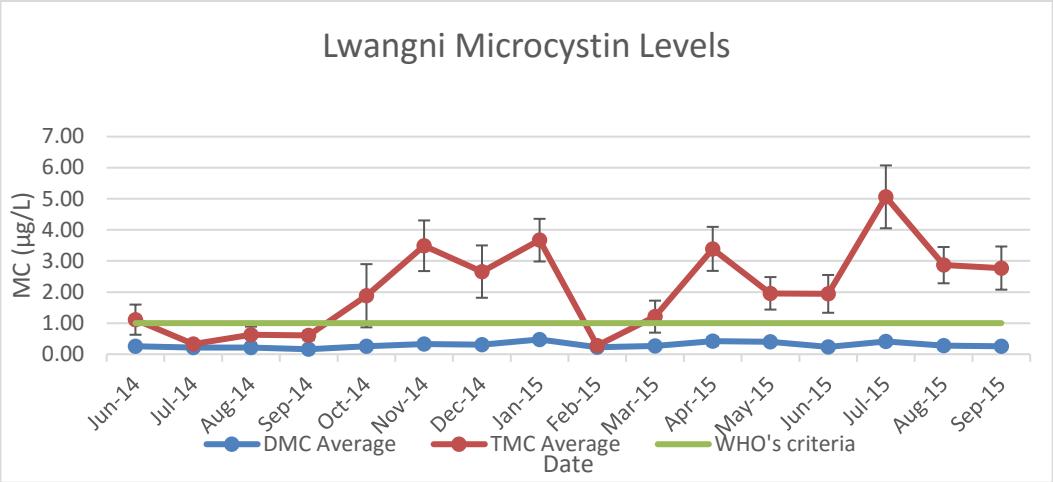



Fig. 5 Temporal Changes of Microcystin Concentration at both Homa bay and Lwang'ni

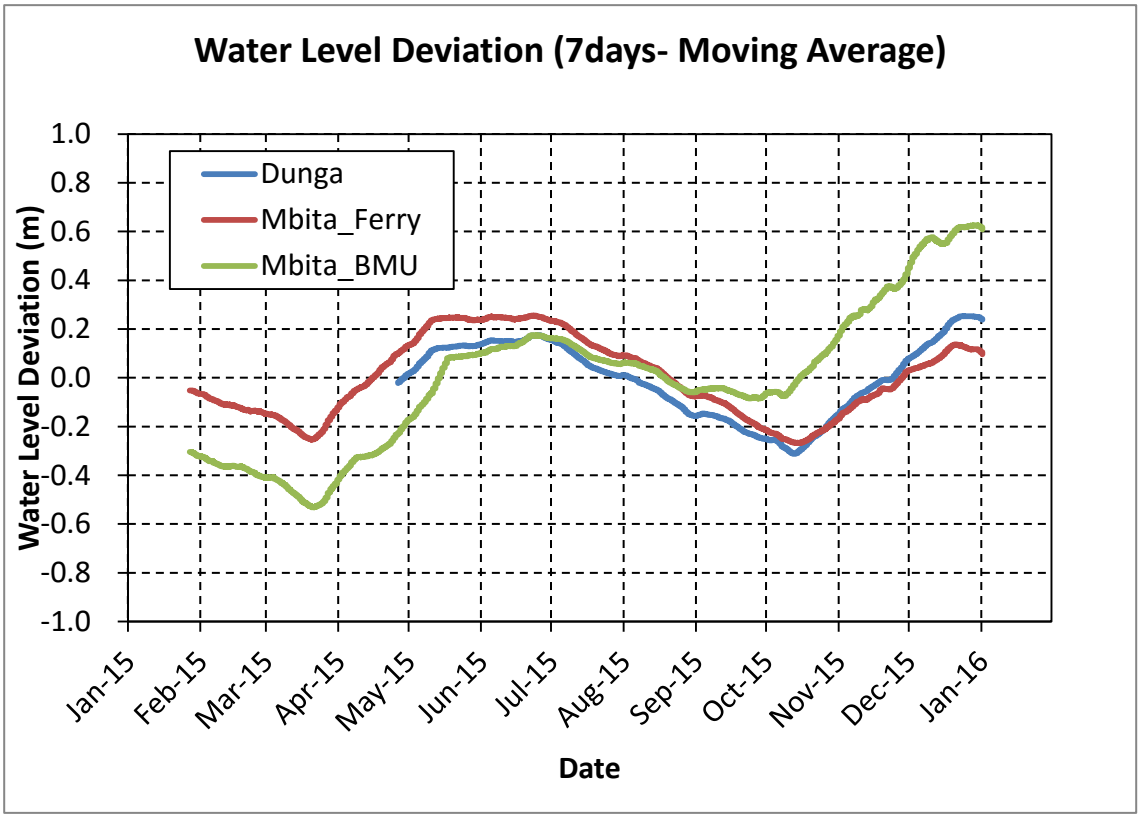



Fig. 6 Water Level Deviation from February in 2015 to January in 2016

**Study 3. Heavy Metals in Environmental Matrices of Lake Victoria Kenya**

***Objective***

Metal contamination of the lake's fish and environment has been pointed out previously among the threats facing the lake. The environmental and human health effects of pollution and hence exposure to heavy metals are known and of great ecotoxicological concern globally. An example is the health effects of organic mercury (methyl mercury, ethyl mercury or dimethyl mercury) which have been well documented following the history of the Minamata disease.

This preliminary investigation aimed at elucidating the current status of heavy metal contamination using improved analytical techniques.

***Material & Methods***

Lake sediments were obtained from different locations in Lake Victoria, Kenya for heavy metal detection and quantitation using Energy Dispersible X-Ray Spectrophotometer for heavy metal measurement.

Fish tissue samples were obtained from specimens of two fish species (*Lates niloticus* – Nile Perch and *Oreochromis niloticus* – Nile Tilapia) from Lake Victoria, Kenya. Preparation and analytical procedures were performed at the laboratories of the Graduate School of Fisheries Science and Environmental Studies in Nagasaki University under the scientific exchange program of the Japan Society for the Promotion of Science (JSPS) in July 2015.

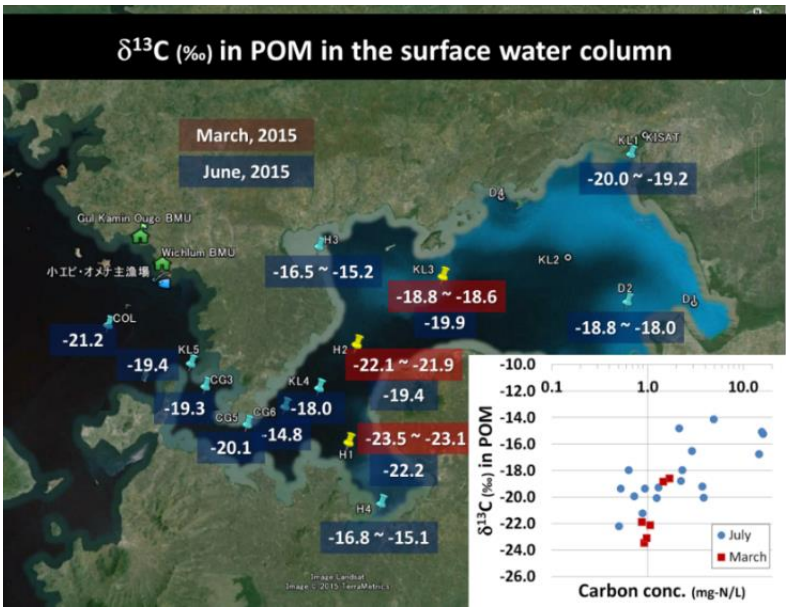



Fig.1 Sampling locations for fish in Lake Victoria

Surface water samples were collected throughout Nyanza Gulf in March and June 2014, and filtered on the combusted glass fiber filter (GF/F, 0.7 mm) for the analyses of several chemical components in particulate organic matter (POM).

Carbon and nitrogen contents (mg/L), carbon and nitrogen stable isotopes ($d^{13}C$, $d^{15}N$) were determined using an elemental analyzer (Flash EA) coupled with isotope-ratio mass spectrometer (IRMS: Delta plus XP). For example, the variation of $d^{13}C$ in POM had negatively correlated with carbon content in POM.

This phenomenon may be explained by the different source of particulate organic carbon (e.g., terrestrial and/or autochthonous), or may suggest that carbon content increased due to the autochthonous phytoplankton, which had up-taken dissolved inorganic carbon with isotopic fractionation.

The spatial variation of $d^{13}C$ and $d^{15}N$ in POM may be reflected to those values in the organisms at the higher trophic level, such as zooplankton and fishes, if this variation is almost constant in time and the spatial migration of the organisms are limited, as shown in the followings figure.

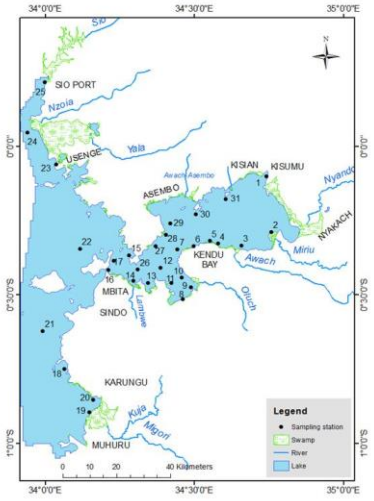



Fig .2 Sampling locations for sediments  Photo 2  Energy Dispersible X-ray detector

Fish tissues (liver, muscle and gill) were processed through wet digestion for ICP AAS metal readout of Al, Mn, Fe, Ni, Cu, Zn, Ga, Sr, Ln, Pb, Bi as well as Ti, V, Co, Ni, Cd. Another part of the tissues was processed by Wet Digestion Method for total mercury analysis in biological samples using Cold Vapour Atomic Absorption Spectrometry.

Pre-dried and pulverized lake sediments were analyzed for heavy metals using Energy Dispersible X-ray detection and quantitation technique whose principle is the dispersion of the incident x-ray by the individual metal elements.

***Results and discussions***

Following the ICP AAS procedure on fish tissues, Ti, V, Co, Ni, Cd were not detected in any of the samples on the other hand Mg and Ca were detected in all the samples with some of the values too high for machine quantification. The observed high values of Mg and Ca in the fish tissues may be explained by the fact that the two elements constitute a significant constituency of the animal tissues and may not point at contamination, as shown in Fig.3.

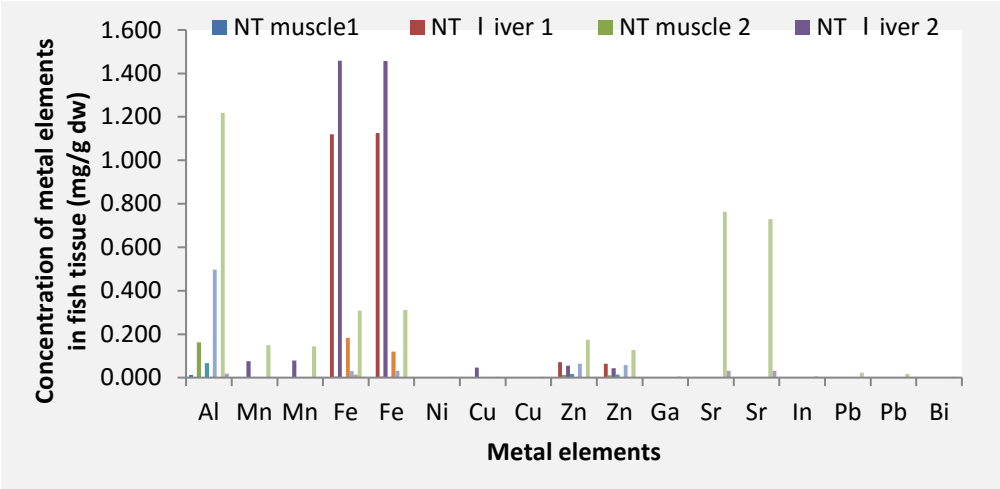



Fig.3 ICP AAS detected heavy metals concentrations in fish tissues

Nile Perch samples generally had more mercury accumulation in the tissues compared to Nile Tilapia. In Nile Perch tissue samples it was not clear which one between the liver and the muscles showed a higher tendency to accumulate mercury. The Nile perch gill had least mercury among the Nile perch samples.

In Nile Tilapia, the same pattern was observed among the different tissue samples (Fig.4).

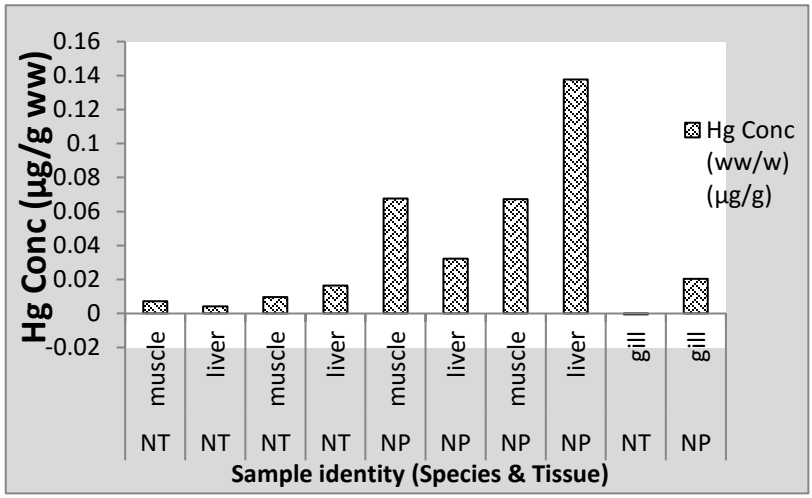



Fig.4 Concentrations of Hg in fish tissues following the cold vapour AAS measurements

Fe is the predominating element in all stations except Kendu Bay and Asat sites while Ca is the least in sediment samples (Fig.5).

The most predominant element is Mn while Zn was least concentrated in the sediment samples in all but Homa Bay sampling station. Homabay sampling station recorded the highest concentrations of all elements except Mg, Sr and Zn, s shown in Fig.6. This pattern suggests an association of high quantities of sediment metal in more urbanized areas (associated with industries and transport infrastructure).

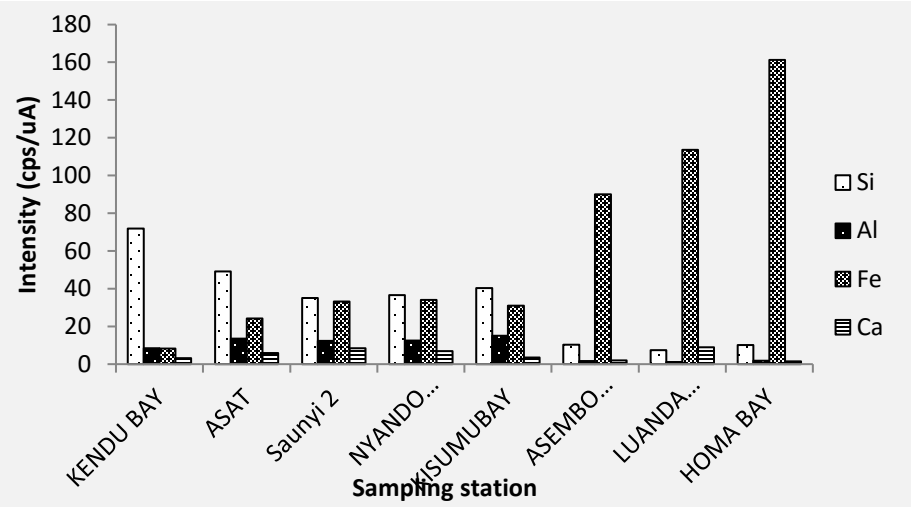



Fig. 5 Sediment concentrations of Si, Al, Fe and Ca

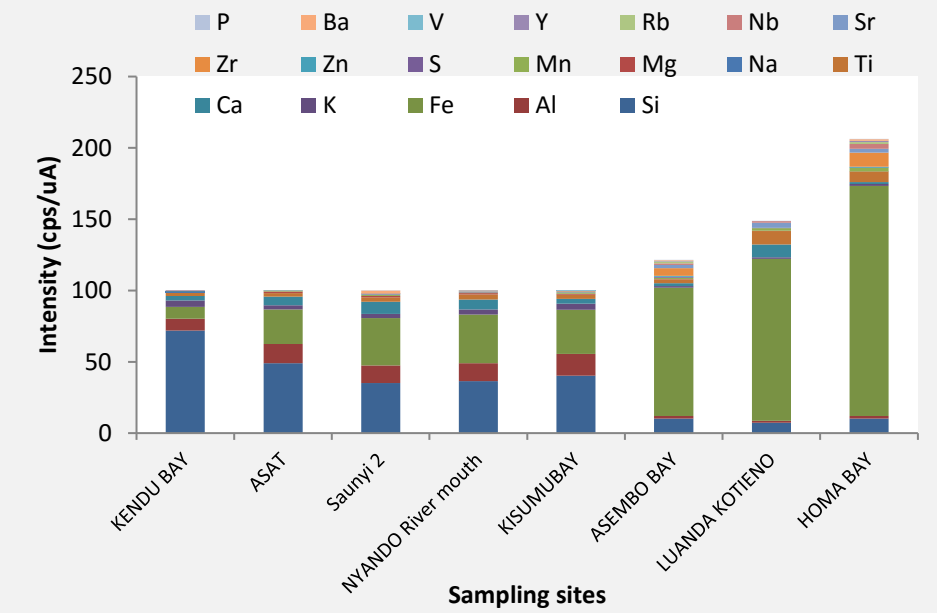



Fig. 6 Sediment concentrations of metal elements

***Conclusions and recommendations***

The lake environment has detectable quantities in the fish and sediments. The levels of metals detected in fish tissues may not indicate adverse contamination since all fell below the international standards.

More elaborate studies should be conducted following these improved procedures and include more samples and sample sites.

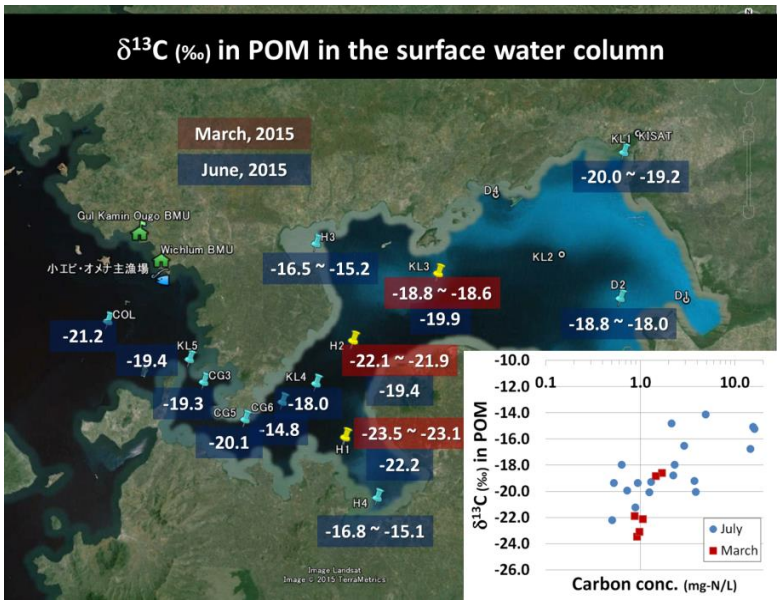
**Study 4. The Spatial variation of $\delta^{13}C$ in the surface water column**

Surface water samples were collected throughout Nyanza Gulf in March and June 2014, and filtered on the combusted glass fiber filter (GF/F, 0.7 mm) for the analyses of several chemical components in particulate organic matter (POM).

Carbon and nitrogen contents (mg/L), carbon and nitrogen stable isotopes ($d^{13}C$, $d^{15}N$) were determined using an elemental analyzer (Flash EA) coupled with isotope-ratio mass spectrometer (IRMS: Delta plus XP). For example, the variation of $d^{13}C$ in POM had negatively correlated with carbon content in POM.

This phenomenon may be explained by the different source of particulate organic carbon (e.g., terrestrial and/or autochthonous), or may suggest that carbon content increased due to the autochthonous phytoplankton, which had up-taken dissolved inorganic carbon with isotopic fractionation.

The spatial variation of $d^{13}C$ and $d^{15}N$ in POM may be reflected to those values in the organisms at the higher trophic level, such as zooplankton and fishes, if this variation is almost constant in time and the spatial migration of the organisms are limited, as shown in the followings figure.



## Study 5. Hydraulic Computer Simulation Model of Nyanza Gulf

### *Introduction*

In Nyanza Gulf, significant eutrophication has occurred for the past forty years. In order to recover the fish population and to conduct environmental preservation, understanding the characteristics of water quality, flow structure and material transport is crucial. In this study, in order to realize the flow structure and material transport, we conducted numerical simulations of flow structure from Jun, 2014 to May, 2015. The results indicate that seasonal wind variation determined the characteristics of flow structure. Moreover, there is a large time phase difference of flow in Nyanza Gulf as a result of its topography.

### *Methods*

The model which we used in this study is a Quasi-3-dimensional hydrodynamic model. We assumed pressure to have a barotropic condition because the difference of water temperature in the vertical direction was smaller than that in the horizontal direction. Fig.1 shows the simulated area and the bottom topography of Nyanza Gulf. The length of the east-west direction is 83 km and that of the north-south direction is 55 km. We set 166×110 invariable grids horizontally and 10 variable grids vertically. The simulation period was one year from Jun, 2014 to May, 2015.

In the boundary conditions, the wind and the river discharge were considered. We obtained one hour average wind data sets from NOAA Climate Database and used monthly average discharge data[1)]. Fig.2 shows monthly average flow discharge in Awach Kibuon, Nyando and Sondu Miriu Rivers. Around Nyanza Gulf, the flow discharge from the rivers increased from April to November. Especially, the discharge was at its maximum in May and at its minimum in December. Fig.3 shows that the wind rose at Kisumu in December, 2014 and May, 2015. The west wind was dominant from December to April, but in May the east wind started to blow until November.

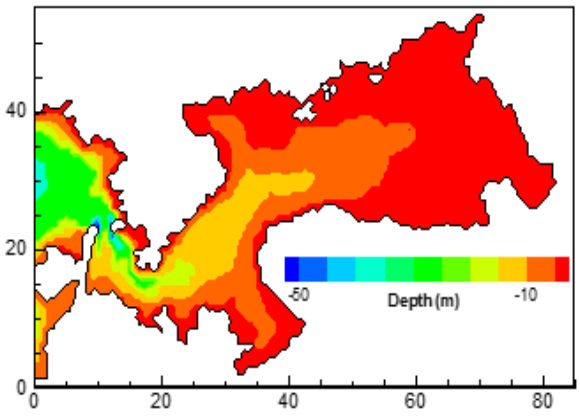



Fig.1 Bottom topography in Nyanza Gulf

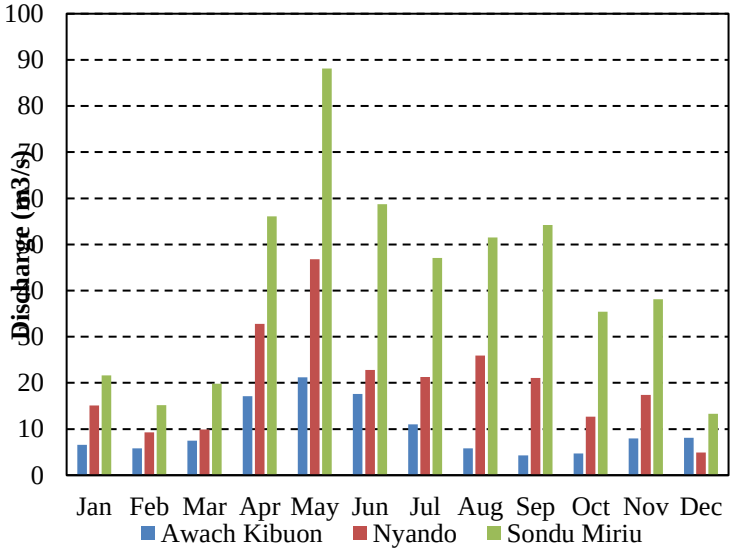
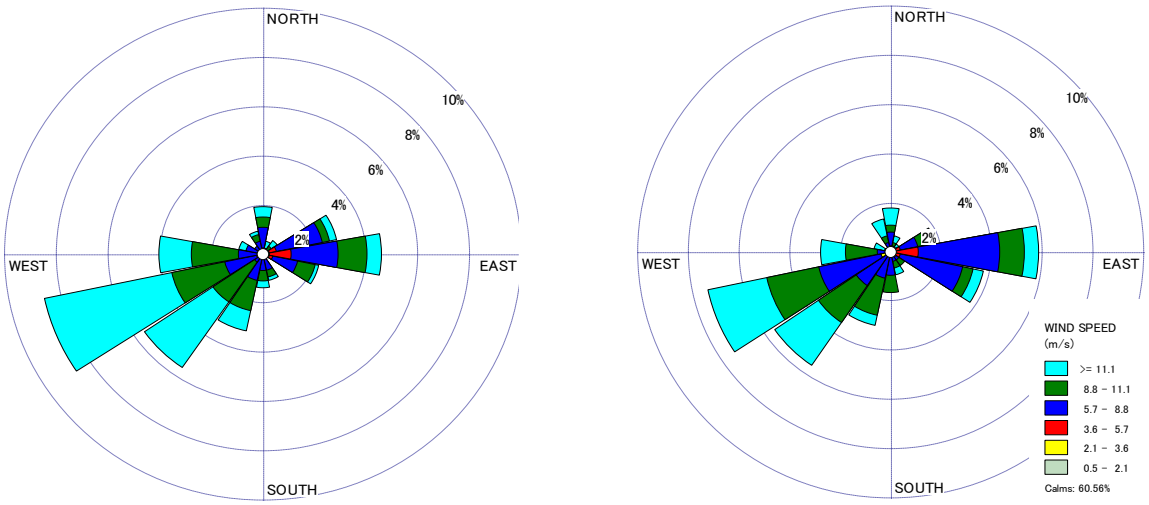



Fig.2 Monthly Average Flow Discharge




**a) December, 2014** **b) May, 2015**

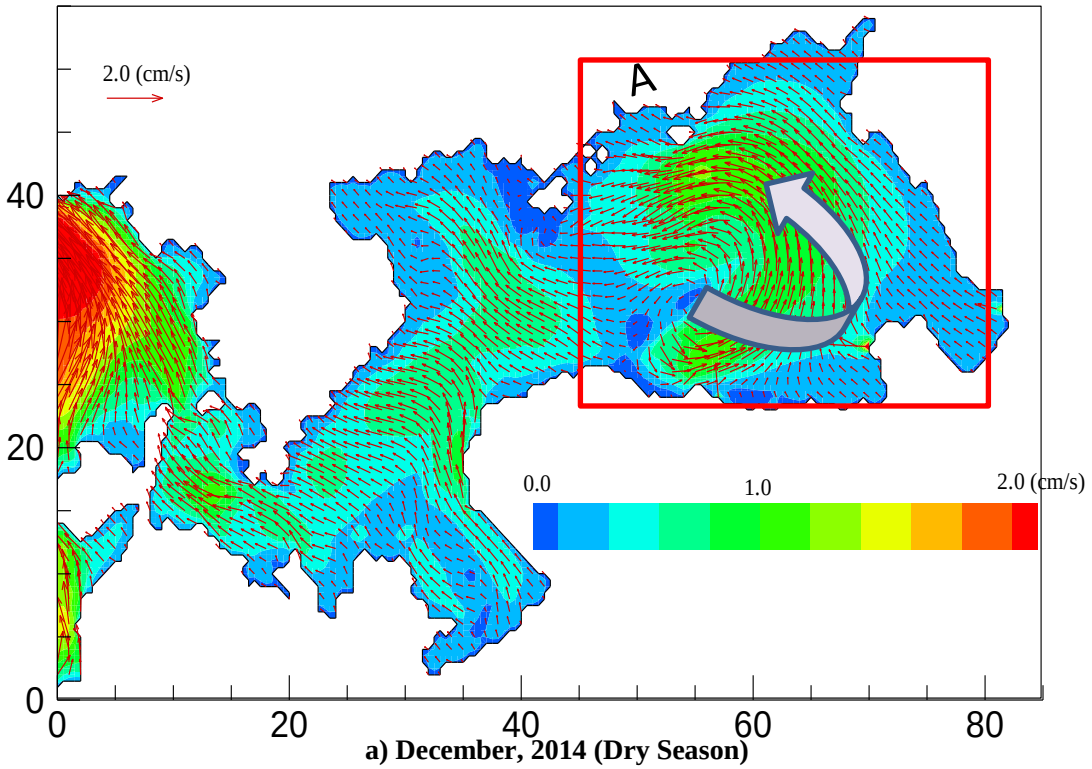
Fig.3 Wind Roses at Kisumu

***Results and Discussions***

Fig. 4 shows the monthly average of flow structure at the surface of Nyanza Gulf, which resulted from the numerical simulation. Generally, it tends to flow toward Lake Victoria from Nyanza Gulf, throughout the year, due to the flow discharge from the watershed. In the dry season, large circulation of flow appeared in area-A. On the other hand, in the rainy season, strong west flow appeared along both the northern shore and the southern shore which were affected by the east wind and the strong flow discharge from these rivers. The results indicate that pollutants from not only the Nyando but also Sondo Miriu Rivers are transported by flow to the north-east area. This causes the deterioration of water quality and results in large blue-green algae blooms.

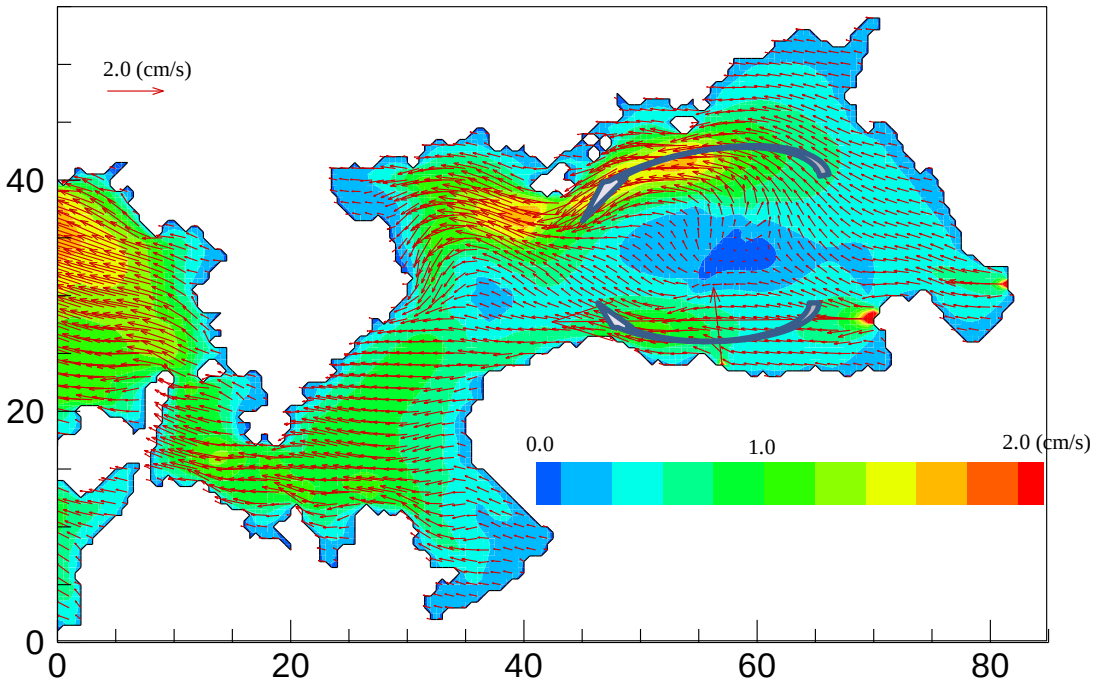
Fig.5 shows the time series of flow structure according to wind influence. In December, 2014 from 11:00 to 15:00 strong east wind blew continuously. However, after 15:00 the wind calmed down. During the strong east wind condition, water on the surface of the gulf strongly flowed to the west and outflowed at the left side of the gulf's mouth cross-section. After one hour from the time the wind had stopped, west flow weakened in area-A followed by the weakening of outflow at the gulf's mouth cross-section. Then, the water begun to return to area-A because of the difference in water level between the west side and the east side of the gulf. Next, the water around area-B moved to the inner part of gulf. Finally, the water around the gulf's mouth (area-C) had started to move toward the inner gulf. It is conceivable that this large time phase difference of flow between west, center and east side of the gulf has been caused by its topography.

Reference; 1) J. O. Z. Abuodha, R. E. Hecy: Water Quality and Ecosystem Status, Lake Victoria Environment Report, Lake Victoria Environment Management Project, November, 2005.



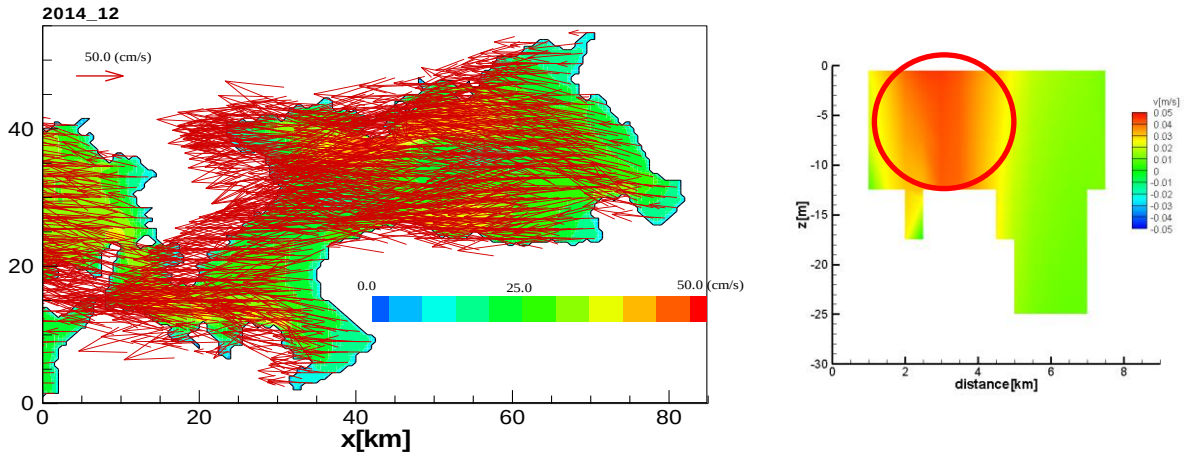

**a) December, 2014 (Dry Season)**

Fig.4 Monthly average of flow structure at surface

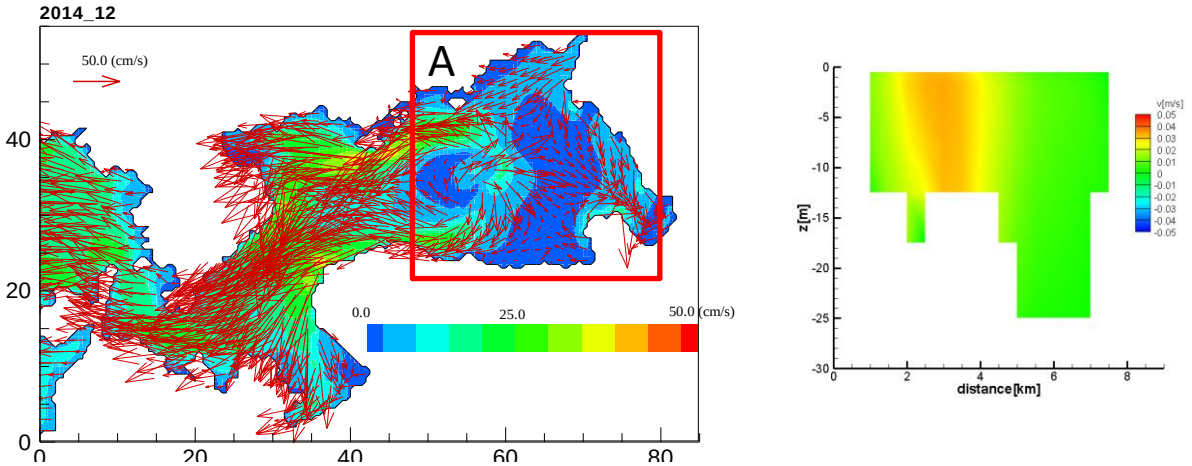



**b) May, 2015 (Rainy Season)**

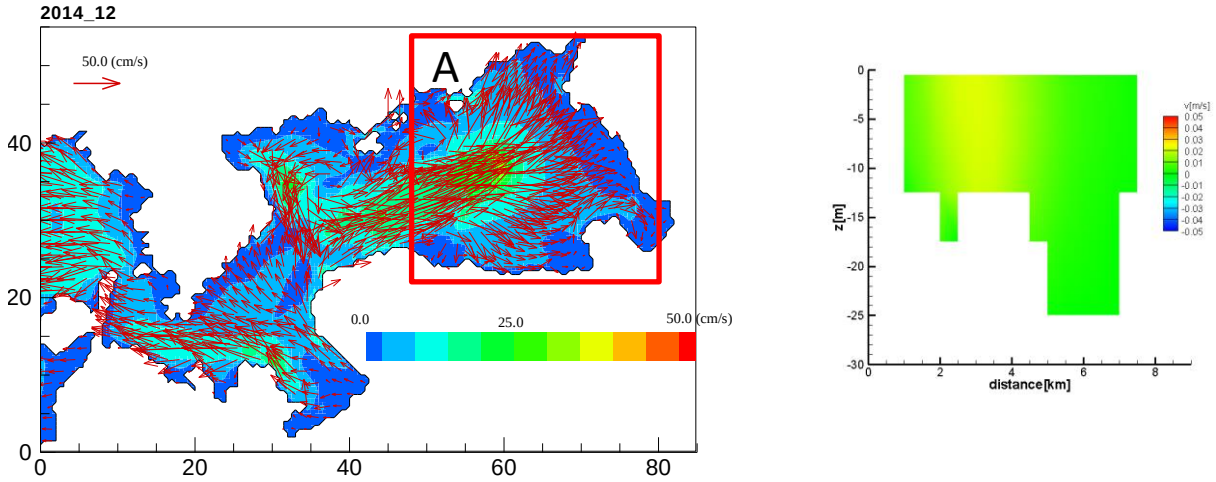
Fig.4 Monthly average of Flow structure at surface




a) December 3, 2014 at 15:00

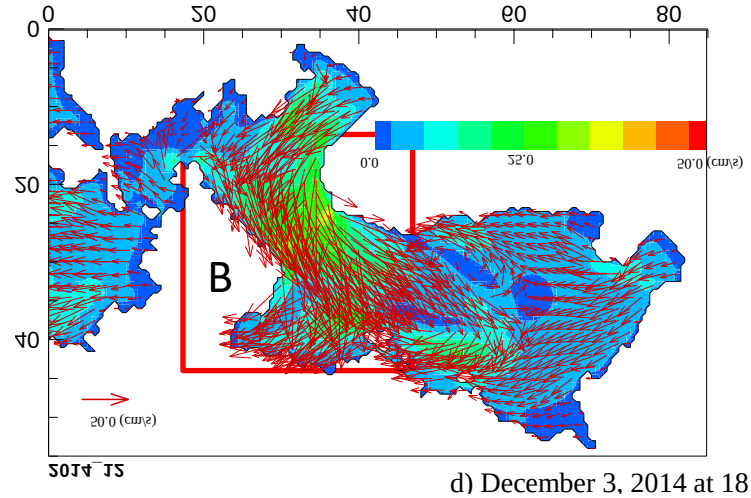



b) December 3, 2014 at 16:00

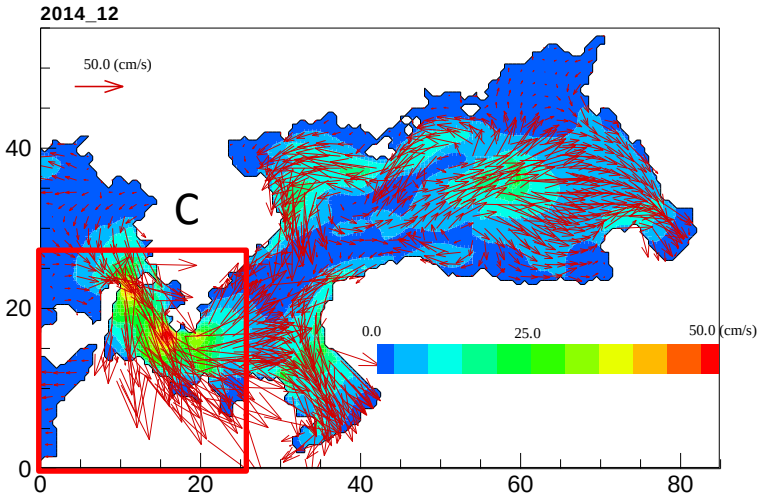


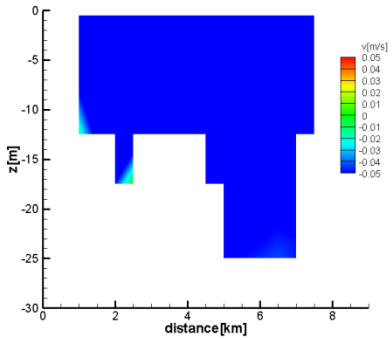

c) December 3, 2014 at 17:00

Fig.5 Time series of flow structure according to wind influence (left figure: surface, right figure: cross section )




d) December 3, 2014 at 18:00




e) December 3, 2014 at 19:00

Fig.5 Time series of flow structure according to wind influence (left figure: surface, right figure: cross section)

**Study 6. An assessment of health risk of toxic cyanobacteria in drinking water in Nyanza gulf, Lake Victoria, Kenya**

Lake Victoria is an important source of drinking water to the riparian communities. Cyanobacterial blooms have been reported in Lake Victoria. Cyanobacteria toxins such as microcystin produced by some species of cyanobacteria are potentially harmful to human health. Only 20% of the Kenyan rural population has access to safe water but for both Nyanza and Western provinces, it is only 8% (LBDA, 2004). The World Health Organization (WHO) released the provisional guideline value of microcystin-LR to be 1 µg/L. Although studies have shown the presence of MC-

LR, the level in household waters already stored for drinking is not known. Microcystin concentrations in Lake Victoria water, household waters already stored for drinking and the health risk of toxic cyanobacteria in the Nyanza Gulf of Lake Victoria, Kenya is unknown, which this study sought to establish.

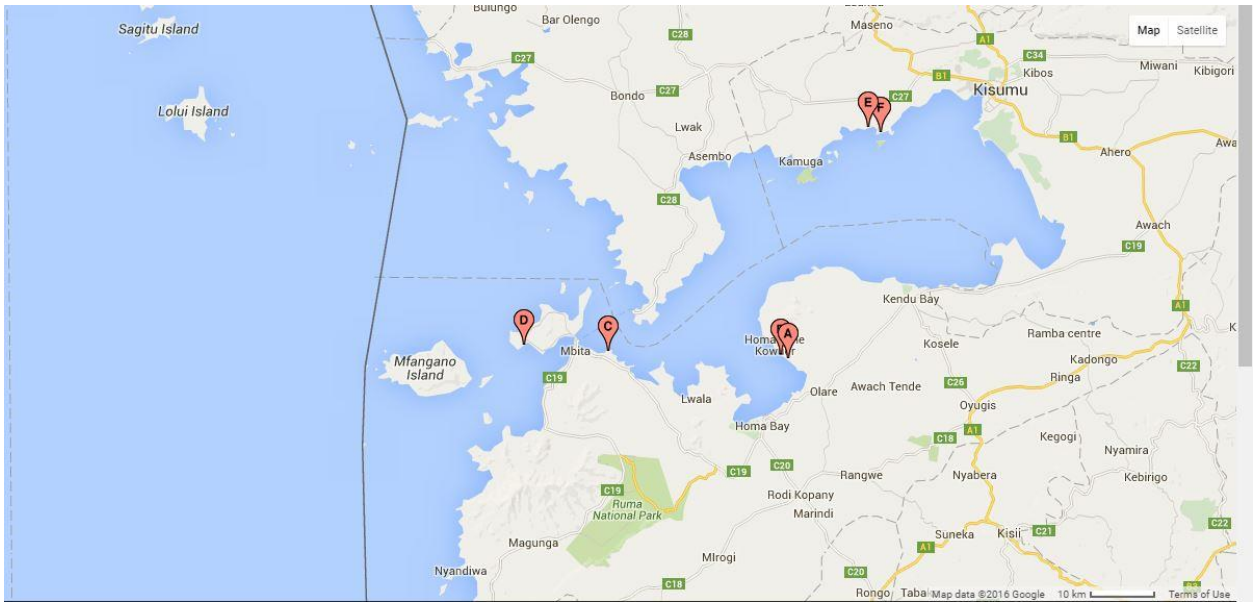



Fig. 1 Nyanza Gulf with sampling sites

*Materials and methods*

The study was done along Nyanza gulf, Kenya from May to October 2015 in six (6) beaches. Qualitative and experimental approaches were adopted. Questionnaires were administered to obtain household water information. The targeted sample size was 127 water samples from 6 beaches and an equal number from 30% of 422 households from the beaches. Water samples were collected from the community water collection points within the beaches along Lake Victoria and the households once a month for six months. Microcystin presence was identified by Protein Phosphatase 2A (PP2A) enzyme assay and quantitative microcystin levels was measured by High Performance Liquid Chromatography (HPLC).

*Results and discussions*

Microcystin was detected in all the beaches sampled. Figure 2 shows the monthly trend of microcystin along the gulf. The general trend showed lower levels in household samples in the average for 6 months compared to the respective beaches as shown in Figure 3. This can attributed to the treatment methods used for removal of cyanobacteria. The Health Risk value (the definition is shown in the legend of Table 1) reported in all beaches. Beach samples showed the highest risk. The average health risk was 22 times in beach samples and 9 times in household water for the TDI (Total Daily Intake) level of microcystin.

A high proportion of the respondents (97%) use the water for drinking as shown in Fig. 4. Chlorination was reportedly the most common method of water treatment (82%) as shown in Figure 5. However, the effectiveness of water treatment in removing cyanobacteria is low as microcystin were detected in both water samples collected from the beaches as well as from the households. This could mean the treatment methods are not effective against cyanobacterial toxins.

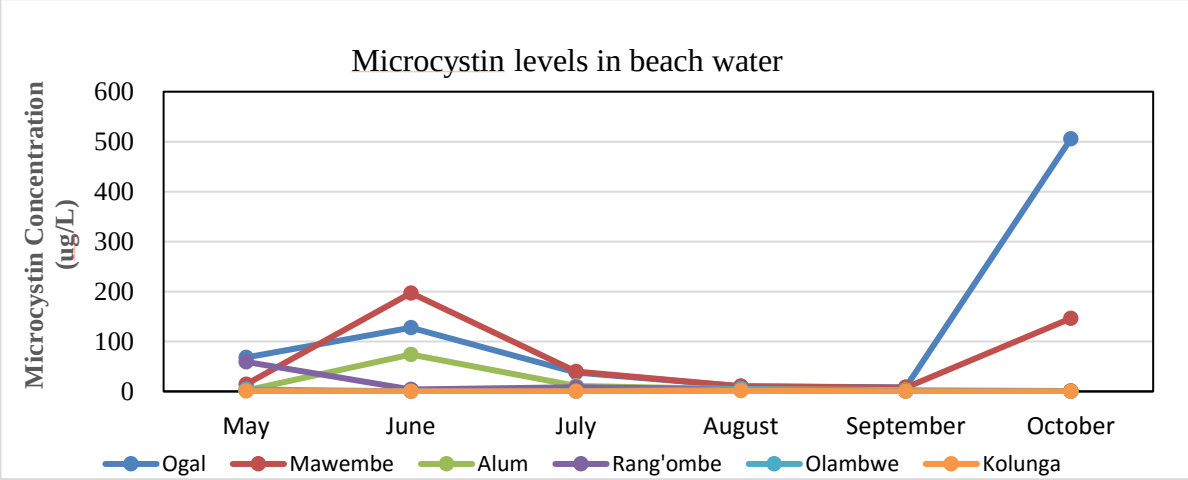



Fig 2: Monthly fluctuation of microcystin in Lake water

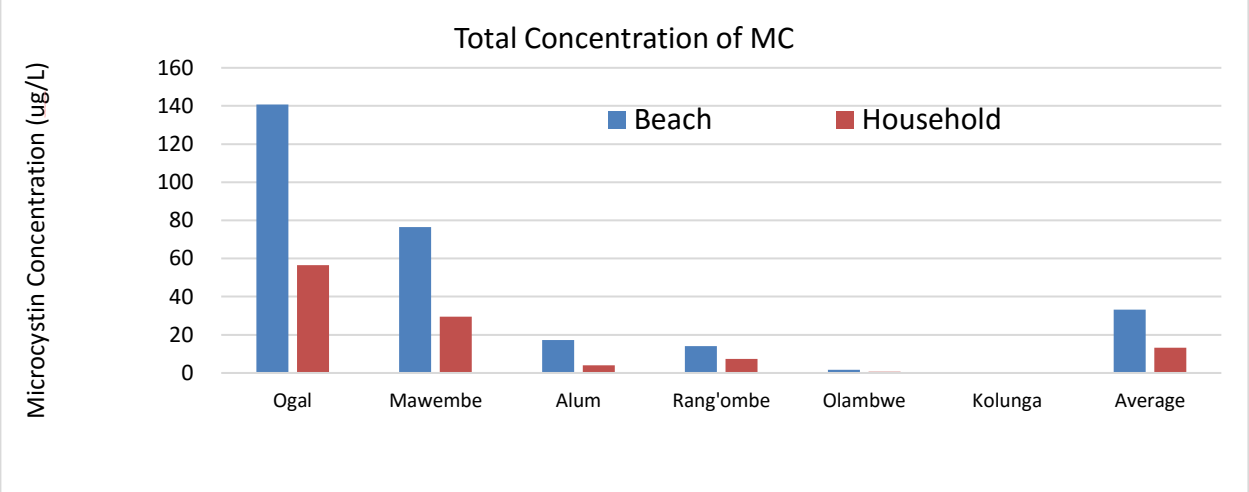



Fig 3: Average Concentration of Microcystin at each beach and household

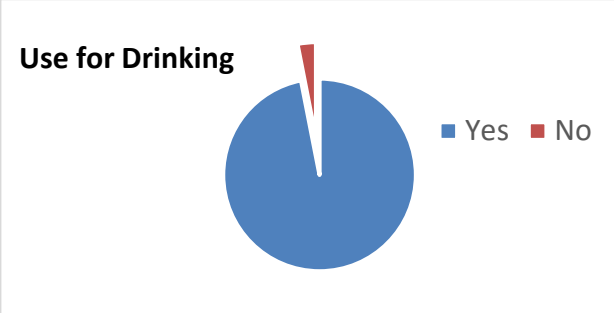



Fig 4: Proportion of respondents drinking lake water

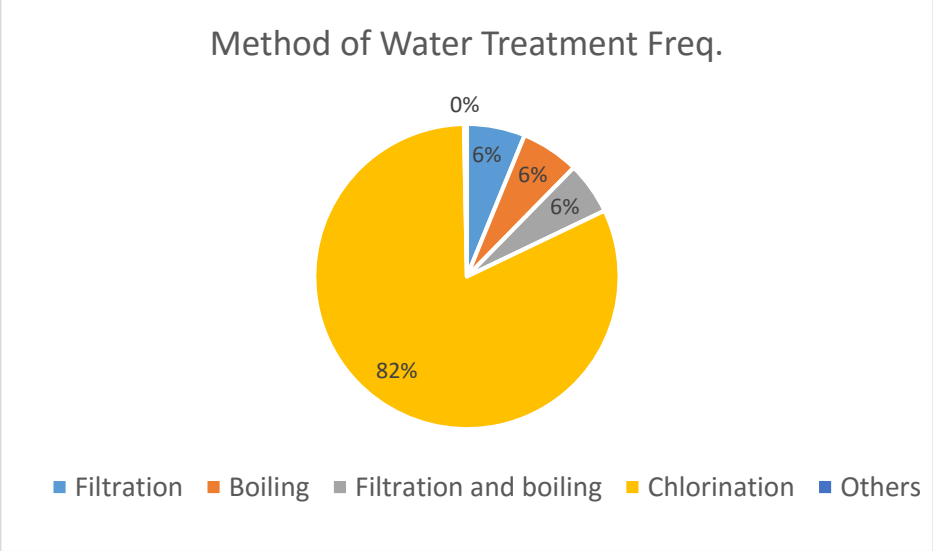



Fig 5: Method for treatment before use

Table 1: Health Risk value of Microcystin in Nyanza Gulf

| Beach Name | Beach | Household |
|---|---|---|
| Ogal | 96 | 39 |
| Mawembe | 52 | 20 |
| Alum | 11 | 3 |
| Rang'ombe | 10 | 5 |
| Olambwe | 1 | 0.4 |
| Kolunga | 0.2 | 0.1 |
| Average | 22 | 9 |

The health risk value in the table represents a relative value as a ratio based on tolerable daily intake (TDI) of microcystin-LR set by the WHO.
To calculate the value, we assumed that a person of 60kg body weight drank 2 litres of water a day.

*Conclusion*
Chronic exposure to low concentrations of microcystins in drinking water is a serious problem to public health in the Nyanza gulf and may contribute to promotion of cancer in humans. Strategies of dealing with MCs from lake water used for the drinking water supply should involve a regular monitoring of the cell numbers of toxigenic cyanobacteria in the raw water. Ways of removing cyanobacteria cells should be adopted. Public awareness through the media has to be fostered. The installation of in-situ filtration units such as the biofence that can be used for water purification should be considered.

# COMPONENT 2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Researchers/Collaborators: Dr. Yuichiro Shibata, Prof. Senya Kiyasu, Dr. Chrispine Kowenje, Prof. Simiyu Sitati, Dr. Joel Kibiiy, Mr. Chirchir Abraham

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## Introduction

Many African countries have been struggling with various water environmental issues such as shortage of water, contamination of water sources and deterioration of water environment. Kenya is, of course, no exception. Therefore we focus on the development of appropriate technologies, showing as follows, for improvement water safety issues for installing Nyanza Gulf of Lake Victoria and the basin area.

1) Development of "Bio-fence" for water purification of eutorophicated lake water.

One of the acute problems is a toxigenic cyanobacteria due to the eutrophication of Nyanza Gulf. Several species of cyanobacteria such as *Microcystis* sp. produce microcystin that is a very strong hepatotoxin. The bio-fence is a system to provide clean and safe water by removing cyanotoxin microcystin in lake water.

2) Development of "On-site Water Reuse System"

This system was developed to reduce the risk of water shortage and work for water collection by children in particular. Especially, this system will install in households and schools for the reuse of the discharged gray. The proposed system was composed of two parts. One was the biological treatment part using the slanted chamber system in which crashed bricks gravels and charcoal gravels were stuffed as carrier media. Especially, the charcoal gravels were made from corncob. The other was the membrane filtration system to remove pathogenic bacteria completely. The filtration by membrane can be involved by gravity (syphon system).

3) Development of a measurement tool of water quality mobile phone system for Aqua Health Network

The ready-to-use kit for analysis of water quality (Nitrate, Nitrite and ammonia) will be developed. Each pollutant can be quantified by digital camera of mobile phone. Such data collected by mobile phone (smart phone) will be immediately sent to a server computer in a central office.

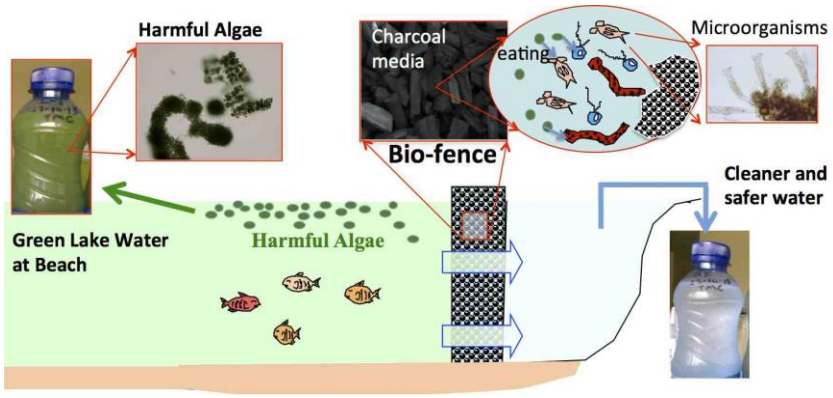
### Study 1. Development of "Bio-fence"

***Background***

Several researchers reported on the occurrence of toxigenic cyanobacteria such as *Microcystis* sp. in Nyanza Gulf. The monitoring for cyanobacteria and the evaluation of the risk of microcystin for inhabitants are important topics in component 1 of LAVICORD. According to the results from the component 1, inhabitants at shore of Nyanza Gulf have been facing a risk by the cyanotoxin microcystin, because many of them use the collected lake water as drinking water without enough treatment to reduce cyanotoxin microcystin. Boiling of water can't decompose microcystin, and what is worse boiling can extract microcystin in the toxic cyanobacterial cell into water. They may drink a cup of tea containing microcystin.

In component 2, we have to provide an appropriate water treatment system to improve such situations of inhabitants. The bio-fence, which is an appropriate system in developing countries due to low cost, is a system to provide clean and safe water by removing cyanotoxin microcystin in eutrophicated lake water. A basic design of Bio-fence was proposed where a water area will be surrounded with the bio-fence consisted with bio-carriers such as crashed charcoals, which are a habitat for predator of toxic cyanobacterial cells and degradation bacteria of microcystin. Figure 1 shows the concept and the principle. The cyanobacterial cells and microcystin from the contaminated outside water can be removed by pumping up with a hand, a foot or a machine through the bio-carriers of the bio-fence. The inside clean water area must be suitable for safe water resource without contamination of cyanotoxin microcystin. The idea of Bio-fence was firstly examined in Thailand. In this experiment, a floating type Bio-fence was installed in a fish aquaculture pond. The system had been continuously purifying the pond water for one and half years. The average removal of cyanobacteria is more than 80% with maintenance-free.

Concept of Bio-fence




The floating type bio-fence in Thailand

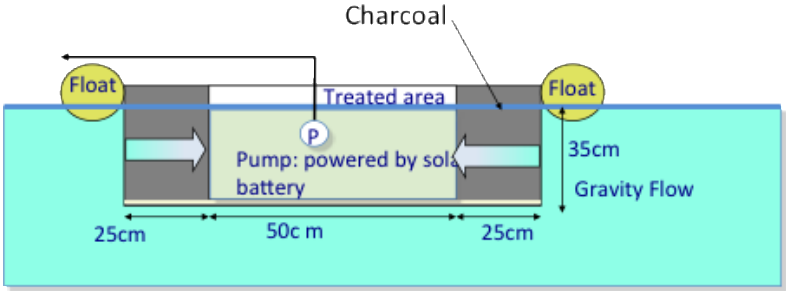



Figure 1. Concept of Bio-fence system and the floating type Bio-fence for the experiment in Thailand. Harmful algae is mainly toxic cyanobacteria in Nyanza Gulf. Microorganisms such as rotifer, protozoa and bacteria decompose toxic cyanobacterial cells and cyanotoxin.


Figure 2. The floating type Bio-fence protected by the breakwater made of timber plates and poles.

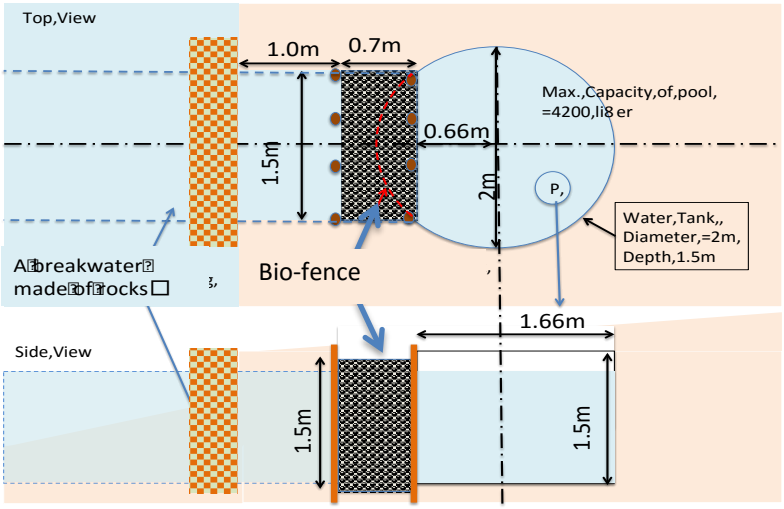



Figure 3. The design of fixed type Bio-fence. A breakwater was also constructed at the front of the bio-fence for the protection from the strong wave.


Figure 4. The photograph of the constructed fixed type Bio-fence at Ogal beach. Left side photographs of waters in plastic bottles shows a typical treatment effect by this Biofence (October/2015), where BF shows the treated water by Biofence, then L1, L2, L3 show the outside lake water at several places near Biofence.

***Results and Discussion***

**Float Type Bio-fence**

At first, we assigned the place for the experiment at Ogal beach. Then the Ogal BMU cooperates our experiment. Then we designed and produced the floating type Bio-fence for Ogal beach, because the result of removal of cyanobacteria was obtained in the previous experiment in Thailand, as mentioned in the introduction. However it was thought that the wave in Nyanza Gulf was apparently stronger than that in the fishpond. Thus, we constructed a breakwater to protect the floating Bio-fence from waves as shown Figure 2. The first experiment started from April/2015. However, the floating bio-fence was broken one and half month later due to the strong wave and the some defects in welding work in Bio-fence. The best removal for Chl-a and TSS were 60% and 53%. with the flow rate of 5L/min in average by the small submerged pump powered by the solar cell and the battery. The flow results were worse than the previous results in Thailand even if the shortness of the operation was considered. Bio-fence swung by the wave because the timber breakwater could not well protect Bio-fence from the strong waves.

**Fixed type Bio-fence**

It was found that the float type bio-fence did not sufficiently perform the removal of cyanobacteria as we expected. Thus we changed the design of Bio-fence to the fixed type as shown in Figure 3. The constructed bio-fence was shown in Figure 4. The pump system was applied the same system in the floating type Bio-fence. The same solar cell and the same battery were also used. This Bio-fence can supply treated water of $2m^3$ a day. The experiment was operated from September/2015~ March/2016. The results were sufficiently better than the previous experiment until December/2015 as shown Figure 5 and Figure 6. The summary of the results of the water were presented in the Figure 7. The treated water was very transparent water under the best condition during October to December as shown in Figure 4.

The removal of total suspended solid (TSS) was 93% in average. The removal of Chl-a was 97%. Chl-a normally correlates the total phytoplankton biomass. In Ogal beach, almost Chl-a was from cyanobacteria such as *Microcystis* sp. Removal of microcystin was 94%. The average concentration of microcystin in the treated water was 0.92µg/L as microcystin-LR equivalent (by PP2A enzyme assay) which was less than 1 µg/L microcystin-LR which is the tentative guideline value of drinking water by WHO.

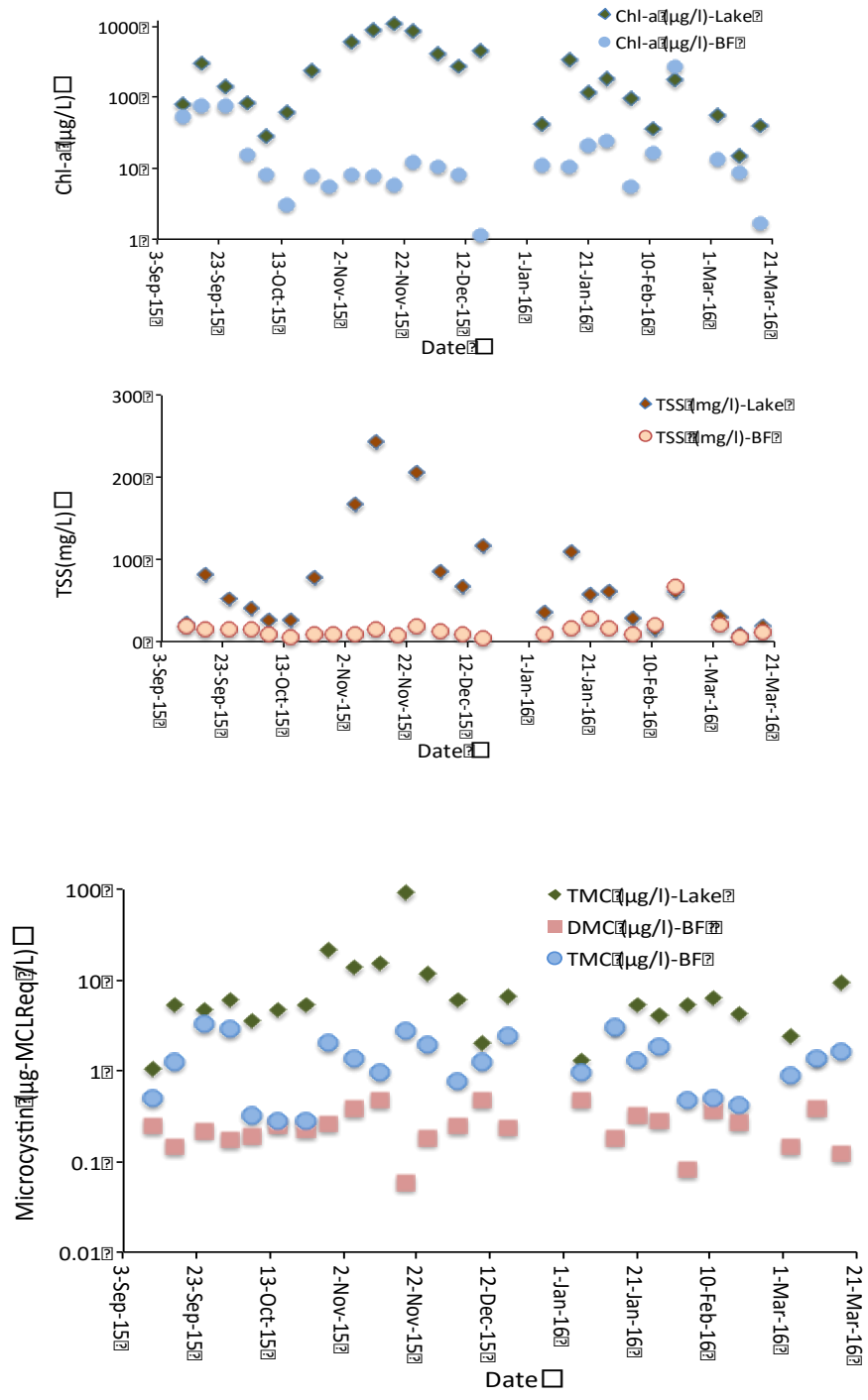



Figure 5. The temporal changes of TSS, Chl-a and Microcystin (TMC and DMC) in lake water (-Lake) and treated water by Biofence (BF). TMC includes microcystin in cell and dissolved microcystin (DMC) in water. MCLReq means equivalent concentration for all microcystin analogues in the PP2A assay where microcystin-LR was used as standard.

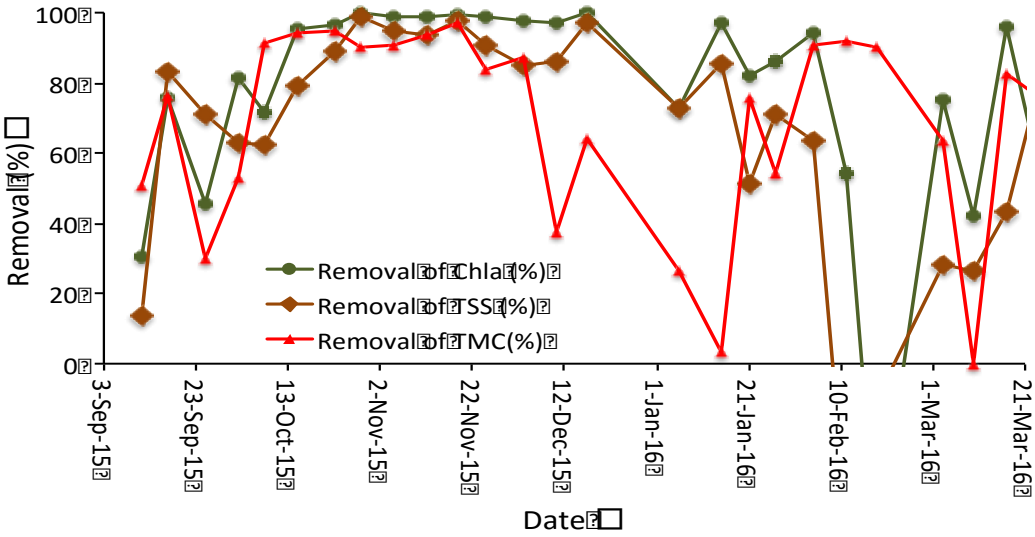



Figure 6. Temporal changes of TSS, Chl-a and microcystin (TMC)

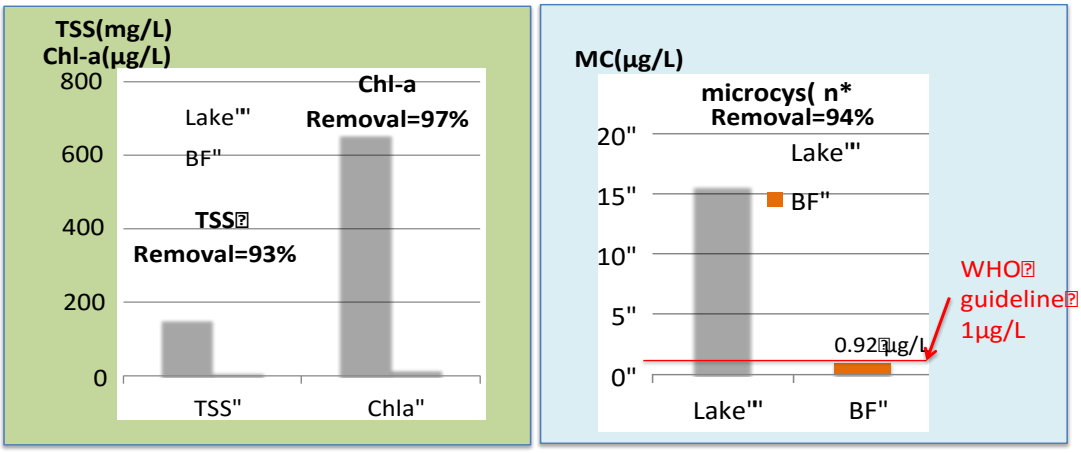



Figure 7. TSS, Chl-a and microcystin in the average and the average removal values from September and December 2015.

Unfortunately, from the end of December, the water level of Nyanza Gulf was increasing rapidly. Then, the level of water exceeded the height of the breakwater at the front of the bio-fence. Thus, Bio-fence did not well perform the removal of cyanobacteria, because the wave struck on the bio-fence directly. The water level was higher than the expected water level because of the strong rainfall in the Lake Victoria basin. When we design the practical bio-fence system, it is very important to construct the breakwater with the enough height and the sufficient strength.

Chl a is normally used for a surrogate of phytoplankton biomass in limnology. Although it, of course, includes cyanobacteria and toxigenic cyanobacteria, it was important to evaluate the performance of bio-fence for the removal of cyanobacteria and toxic cyanobacteria. Moreover, our chief target cyanotoxins was microcystin. Thereofore microcystin production cyanobacteria, especially Microcystis sp. had to be evaluated in the lake water and the treated water by the bio-fence.

For this purpose, the real time PCR method was applied to quantify total cyanobacteria and toxigenic cyanobacteria Microcystis sp. Real time PCR can quantify the copy number of specific

gene in the extracted DNA template from lake water sample. We extracted DNA by use of extraction kit (NucleoSpin Soil Macherey-Nagel, Co Ltd.). Then we measured phycocianin gene (*PC* genes), which is possessed by all cyanobacteria, as the indicator of total cyanobacteria by real time PCR method. Then we measured *mcyB* genes which is one of the microcystn synthesis genes by real time PCR method (Multiplex TaqMan method).

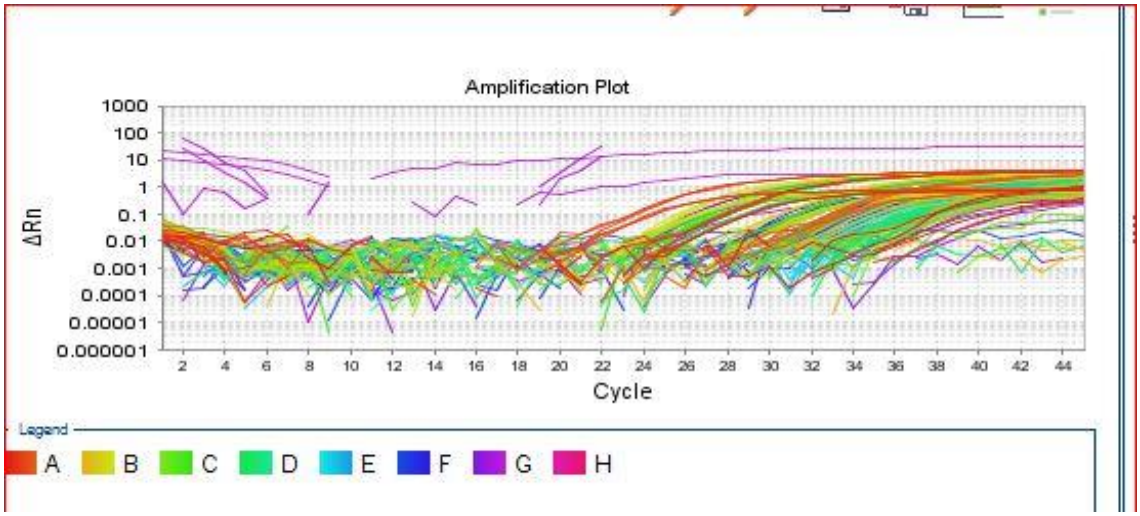



Figure 8. Amplificaton curve for each DNA tempale including samples and standards. Cycle means PCR cycle number, then vertical axies means the relative fluorescence intensity in the amplification of each DNA template. Quantitec probe PCR kit mix (Qiagen) was used for the real time PCR according to the instruction manual.

mcyB>Primer is 30F: CCTACCGAGCGCTTGGG, 108R:GAAAATCCCCTAA AGATTCCTGAGT), TaqMan probe is FAM-CACCAAAGAAACACCCGAATCTGAGAGG-TAMRA

PC> 188F:GCTACTTCGACCGCGCC, 254R:TCCTACGGTTTAATTGAGACTA GCC, TaqMan probe is Hex-CCGCTGCTGTCGCCTAGTCCCTG-BHQ-2

Figure 8 shows the amplification plot. Each target gene has specific DNA sequence for the identification of the gene by the PCR primer and TaqMan probe with fluorescence dye. Faster inclement of the fluorescence in PCR cycle means the high concentration of target gene in DNA template. Thus the target gene copy number can be calculated by this fact. Figure 9 shows that the copy number of PC were very similar to that of mcyB. Thus, it was clarified that almost cyanobacteria in Ogal beach was toxic *Microcystis* sp. Moreover, the Bio-fence could remove such toxic *Microcystis* sp. (cell) as well as chl-a that represents the total phytoplankton biomass. We conclude that the Bio-fence can remove both microcystin and toxic *Microcystis* cell simultaneously.

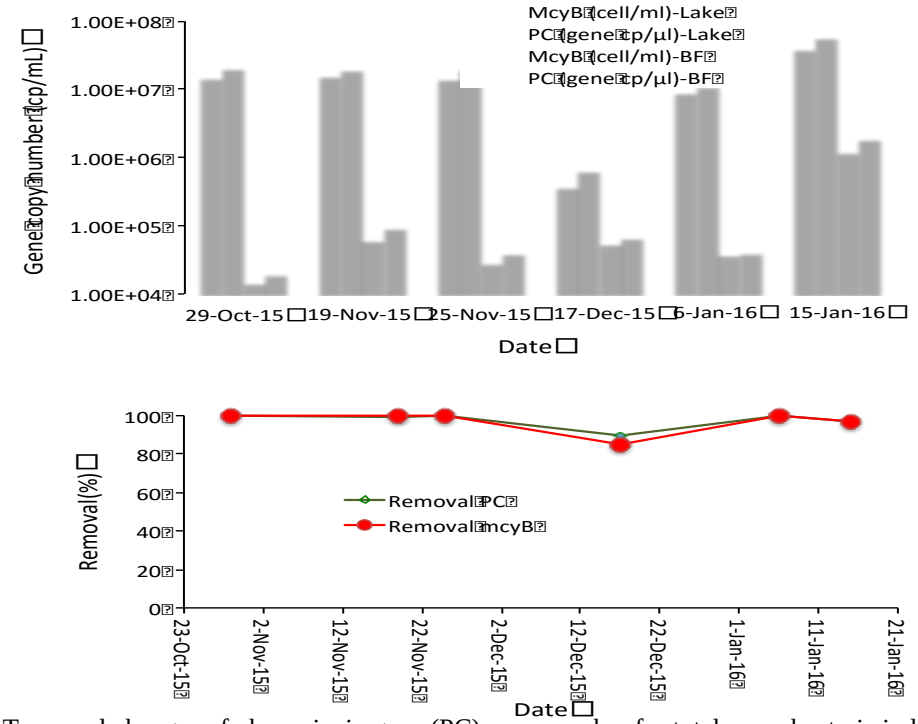



Figure 9. Temporal changes of phycocianin gene (PC) copy number for total cyanobacteria in lake water and treated water in the bio-fence and mcyB gene (McyB) copy number for toxigenic cyanobacteria *Microcystis* sp. measure by by real time PCR. Also removal (%) of mcyB gene (Toxigenic *Microcystsis* sp.) and PC gene (Total cynoabacteria) was plotted in the below.

## Practical new Bio-fence at Ogal Beach

We started the construction of the pratical Bio-fence at Ogal Beach for riparian in the BMU. This new Bio-fence system never use the electric pump for drawing the water. Instead of the electric pump, we designed the siphon system and a hand or a foot pump system. The construction of the new bio-fence was started in March 2015. The work plan was as follows:

1) Construction of main breakwater

Stones were put inside chain link secured between cedar poles. The height is about 3m high and width 50 cm. Stones put on both sides of the water break to reduce the power of water waves reaching the bio-fence. Barbed wire was put around the protruding cedar poles to secure the area on top of the water beak from people accessing and walking on it.

2) Digging of holes for the 3000L and 5000L tanks

Holes were dug (6 ft for the 3000L and 7ft for the 5000L tank). The 3000L tank was fixed next to the charcoal pocket. The 5000L tanks installed about 1M away from the 3000L tanks to act as storage tanks for the clean water. The community will draw water from the storage tank using hand pump

3) Digging and construction of charcoal pocket of Bio-fence

The charcoal pocket was dug to the same depth as the 3000L tanks (6ft). A wooden frame (1m x 1m x 3m) was constructed and installed into the hole. A wooden plate covered with polythene was

fitted into the charcoal pocket to a depth of 5ft. to prevent water from going over the charcoal during the periods of extremely high water levels.

4) Crushing of charcoal and arrangement into charcoal pocket
Charcoal was broken into medium size (about 3cm) and arranged in the charcoal pockets

5) Construction of channel
A channel that brings water to the charcoal pocket from the lake was dug and plastered with cement. The channel is about 1m long and about 1m wide.

6) Construction of the small water breaks in front of each Biofence
Smaller water breaks were constructed in front of each Bio-fence to further reduce the power of waves.

7) Building of concrete around the tanks
Concrete walls were built around each tank to secure them in the holes and prevent hem from floating when the water is removed. The concrete would also prevent the soil from collapsing into the hole in which the tank is installed.

8) Installation of the siphon system
Water will flow from the 3000L tanks to the 5000L tank by gravity using a pipe (siphon system).

9) Installation of hand or foot pump
The community will draw water from the 5000L storage tanks using a foot or hand pump. This will be decided by the community once the construction of the Bio-fence is completed.

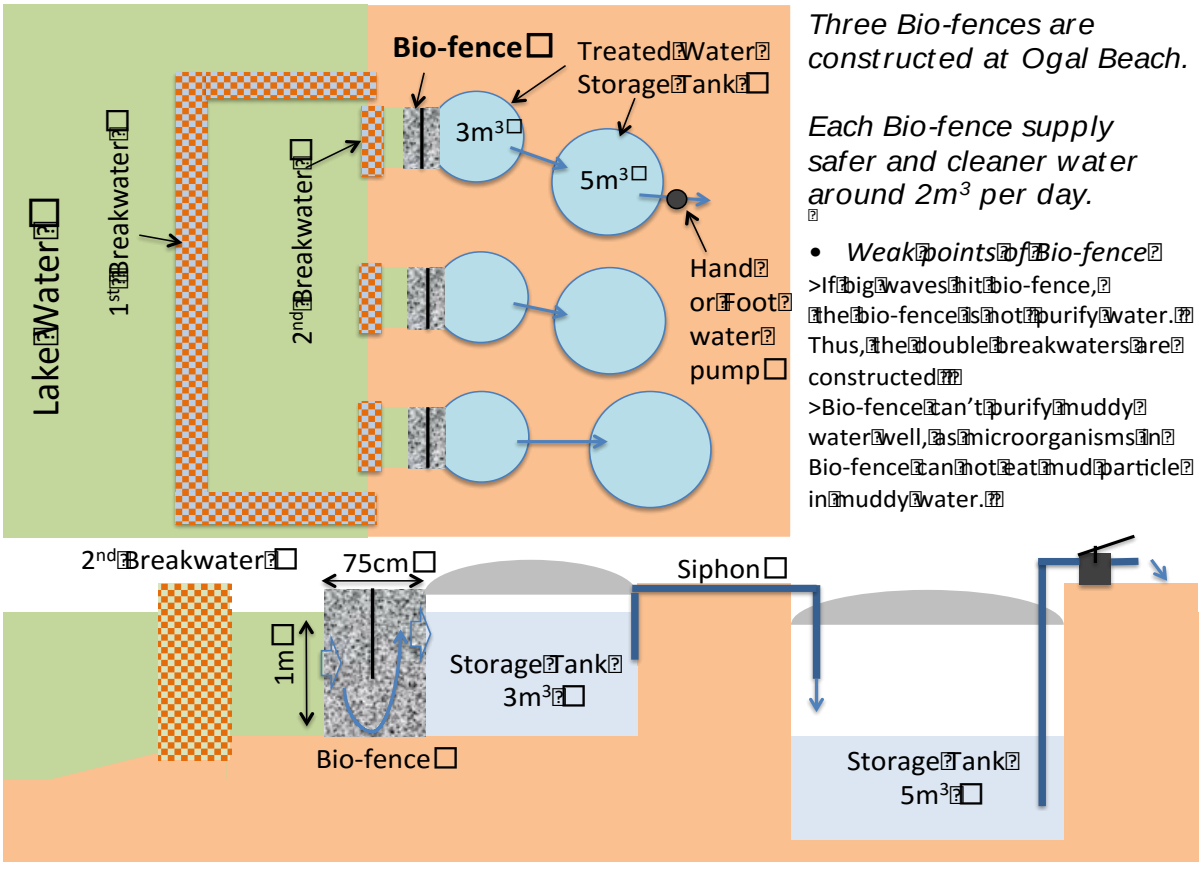



Figure 10. Design of new Bio-fence for practical use at Ogal Beach


Figure 11 New breakwaters and the previous bio-fence.

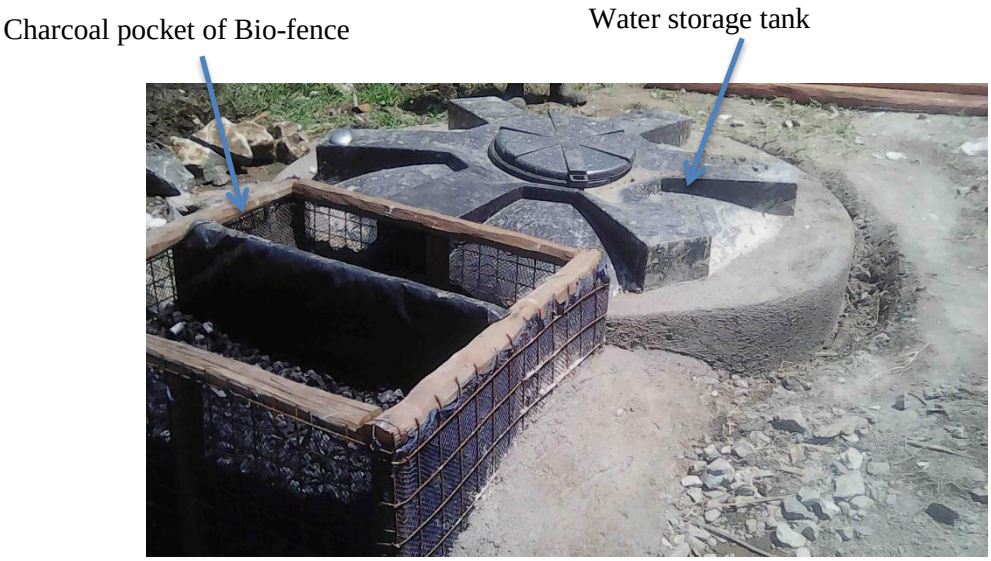



Figure 12. The new Bio-fence under the construction

The design of the new practical bio-fence is shown in Figure 10. Two new bio-fences construct besides the previous Bio-fence. The previous bio-fence will be improved to the siphon system bio-fence without the electric pump. The photograph of the new breakwaters and the previous bio-fence are shown in Figure 11. Then Figure 12 shows the new Bio-fence under the construction.

We will transfer the new three bio-fence system to Ogal BMU. The three Bio-fence will supply the treated water $6m^3$ a day in total. If we assume one family fetches water of 60L a day in average, the three bio-fence can supply the water to 100 families.

The purpose of the development of Bio-fence is to reduce the health risk from the cyanotoxin. The treated water was transparent and it was certificated that the level of microcystin was under the WHO guideline value. However, we have to measure the heavy metal concentration to ensure the

safe of the treated water. AAS (Atomic Absorbance Spectrometer) can be applied for the measurement of heavy metal. Moreover, the microbial safe of water have to be examined. Thus we will measure several kinds of heavy metal in near future. Then general bacteria and fecal coli will measured as the standard of portable water. Moreover we can test the pathogenic bacteria such as *Vibrio Cholera* in the water by use of PCR technique. Sometimes *Vibrio Cholera* was detected at the root of Water Hyacinth. Actually drifting water hyacinth colonies accumulate at Ogal beach frequently. We expect Bio-fence may reduce such water bone disease bacteria.

**Study 2. Development of "On-site Water Reuse System"**

***Background***

Many unsafe water resources such as shallow wells, small rivers and swamps have been used in the basin of Lake Victoria though the microbiological contamination in the water resources often occurred. For instance, several wells, in which fecal coliform was detected, had a high possibility of becoming a cause of outbreak of cholera as like the outbreak in Nyanza province in 2008. One of the bacterial contamination sources was a latrine near the shallow well. It was found that the latrines cause nitrite and nitrate pollution. Nitrite and nitrate in drinking water should be less than 3ppm (0.2 ppm under long-term exposure condition) and 50ppm respectively, because high-concentration of nitrite and nitrate cause the blue baby syndrome. Moreover, a borehole water poisoning for livestock due to extreme high concentration of the nitrate and the nitrite happened in Kargi in Marsabit district in 2000. The nitrite of 50ppm and the nitrate of 420 ppm were detected in a well water respectively. Especially we have to focus on the situation to access safe water for school or dispensary in the basin area.

Moreover we have to consider that women and children of poor have been in the heavy labor for daily water collection. They consume a long time in a day due to the water collection work. Children lose the opportunity for their school education. Hence, the reduction of the labor for water collection must contribute to give the opportunity for their education. The on-site water recycle system which we developed can minimize the risk from the shortage of water in dry season in order to free the children and women from heavy labor of the water collection. Of course, it has to be effective for removal pathogens from the water.

This on-site water recycle system is developed to reduce the risk of water shortage and work for water collection by children in particular. The proposed system, by which gray water discharged from households and schools can be circularly used, is composed of two parts shown as shown in Figure 13.

1) Slanted chamber treatment system for biological treatment (see Figure 14)

The biological treatment system using crashed bricks (ceramic) carriers for wastewater (gray water) can be applied for the treatment of wastewater of a household for reuse. Ceramic carriers can enhance development of effective microorganisms for water purification. Charcoal made of agricultural wastes such as corn stems is mixed with the crashed bricks in order to absorb chemical

pollutants such as detergent in gray water. The two kinds of the carriers play an important role to develop the high performance water treatment system.

2) Membrane filtration by Hollow fiber microfiltration (see Figure 17)

Development of the low cost membrane filtration system is an important part of the water reuse system. It can remove pathogenic bacteria completely. The hand pumping mechanism is tested to give bubbling air for washing the membrane surface, while the filtration by membrane can be involved by gravity (syphon system).

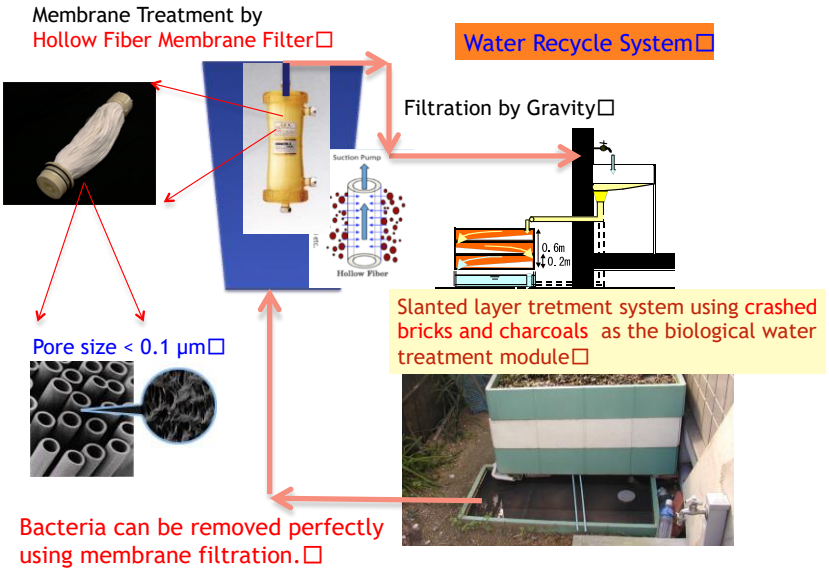



Figure 13. Concept of the on-site water recycle system

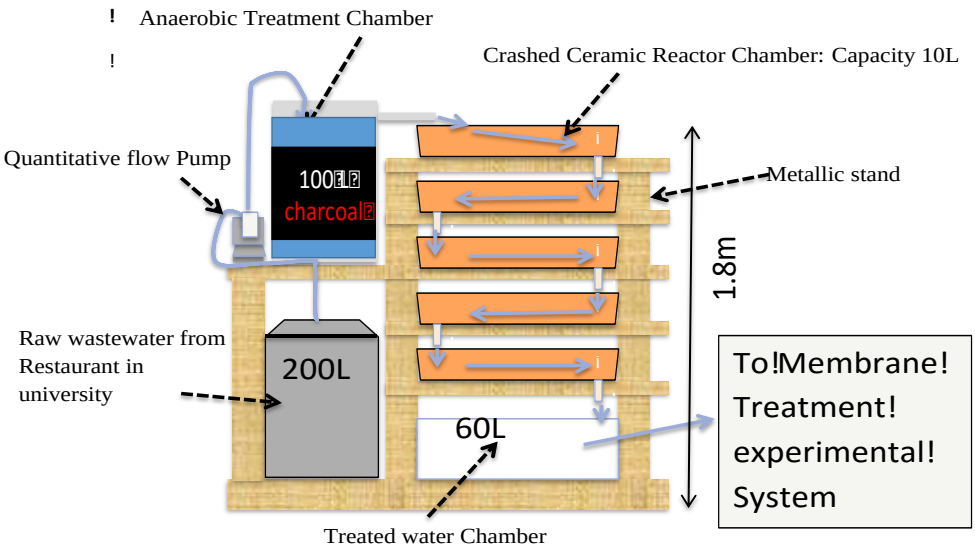



Figure 14. Schematic figure of the on-site water recycle system for the experiment in Moi University.

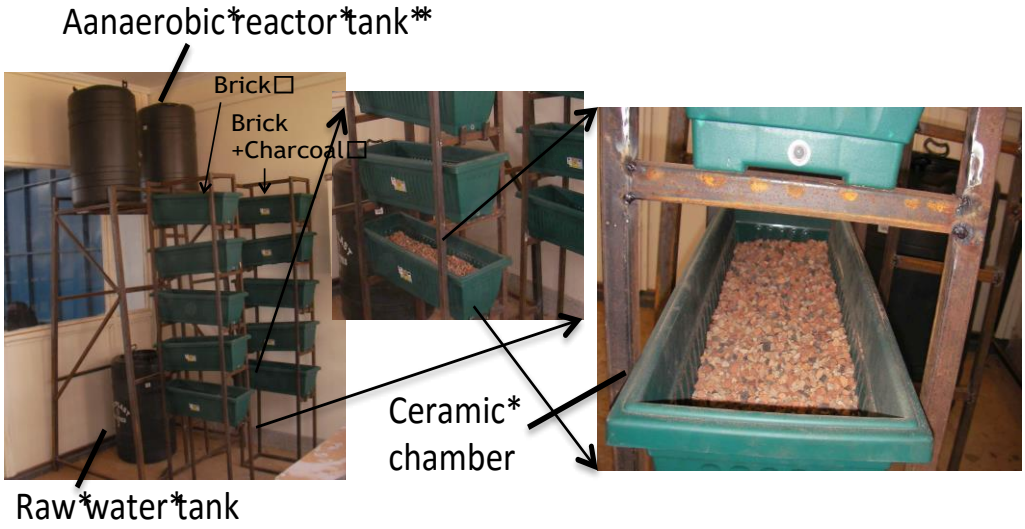



Figure 15. Photograph of the on-site water recycle system in Moi University

***Results***

**Slanted chamber treatment system**

The experiment of the on-site water recycle system was performed in Moi University (Laboratory in Civil Engineering). Figure 14 shows the schematic figure of the on-site water recycle system for the experiment conducted in Moi University. Figure 15 shows the photograph. Two treatment systems were installed. One was the slanted chamber filled with the media of ceramic gravels as bio-carriers, and the other was the chamber filled with the mixture media of ceramic gravels and charcoal gravels made from corncob. The capacity of the chamber was 10 L. Five chambers were vertically ordered as shown in Figure 14 and Figure 15. The hydraulic retention time (HRT) was 12~24 hours for five chambers in total. Anaerobic treatment chamber (45L) filled with charcoal gravels was set as first part of the treatment system before the slanted chamber part.

The treated water by the slanted chamber system was transparent than the raw water (gray water from restaurant in Moi university) as shown in Figure 16. The average removal of BOD, NH4 and PO4 were summarized in Table 1. Apparently the reactor system filled with the mixed media (B+C) shows better performance of BOD removal than the system filled with the crashed bricks (B). Actually, BOD of effluent water of the system (B+C) in Table 1 show 2mg/L in average which is sufficiently low value for the use as recycle water. Also ammonia removal (nitrification) of the system (B+C) was better than the system (B) in removal. But the ammonia removal by the both system was worse than BOD removal. Phosphorus was also removed because charcoal and brick might adsorb PO4-P.


Figure 16. Comparison between raw water (gray water from the university restaurant) and the treated water by the slanted chamber system.

Table 1. Average removal by the slanted chamber system

B: Crashed bricks media
B+C: Mixed media crashed bricks and charcoal gravels

| Water quality | BOD5 | NH4 | PO4 |
|---|---|---|---|
| Removal (%) of B | 97.6<br>Effluent ~13 mg/L | 54.4 | 79.7 |
| Removal (%) of B+C | 99.6<br>Effluent ~ 2mg/L | 62.9 | 83.5 |

**Membrane filtration**

The schematic diagram of the membrane filtration system in the experiment is shown in Figure 17. Then the photograph of the membrane filtration system is shown in Figure 18. The membrane treatment unit using syphon system, that is the filtration was driven the water head difference (gravity force).

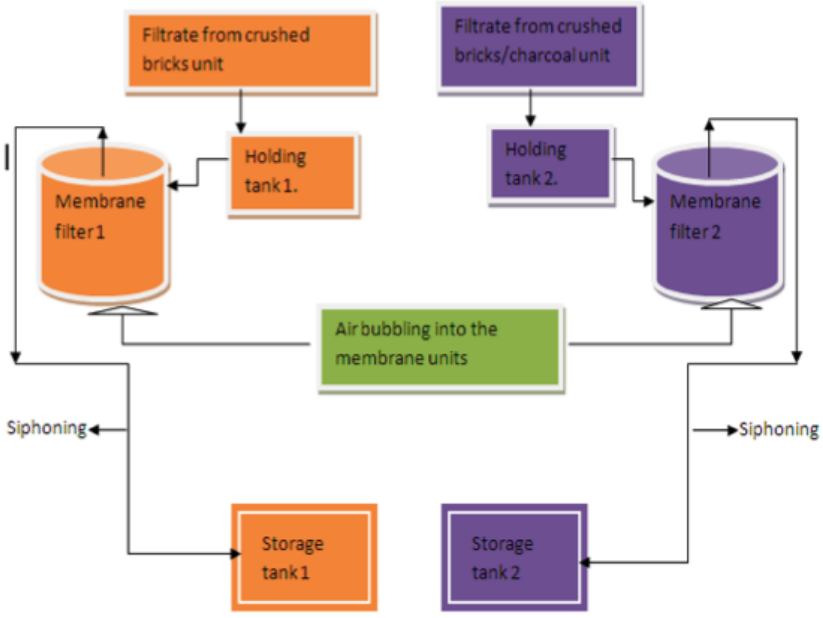



Figure 17. Schematic diagram of the membrane filtration system in the experiment in Moi University.

Hollow fiber MF membrane

The hollow fiber MF (micro filtration) membrane

The nominal pore size is 0.2µm

The inner diameter is 1.1mm and the outer diameter is 2.2mm

The effective length is 18cm. Surface area is 12.43cm$^2$.

Figure 18. Photograph of the membrane filtration system in the experiment in Moi University.

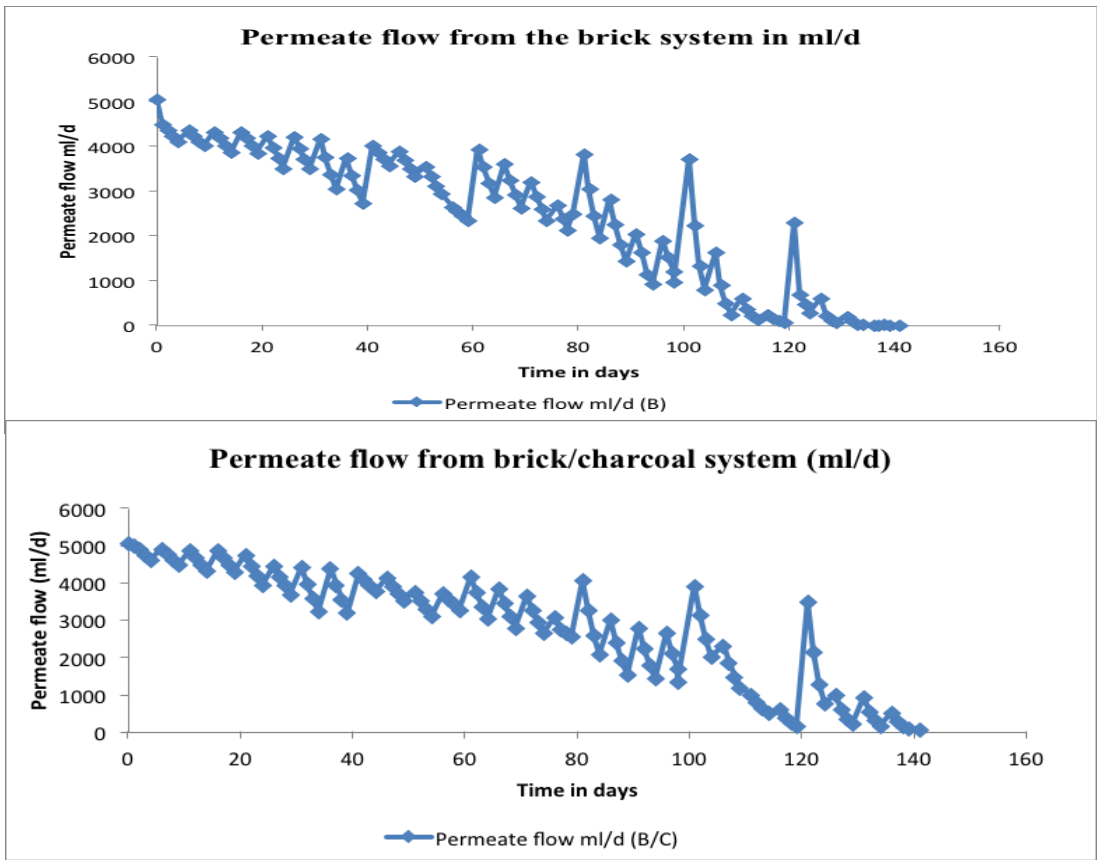



Figure 19. The change of the flux of the filtration system for the effluent from the system (B) and that from the system (B+C).

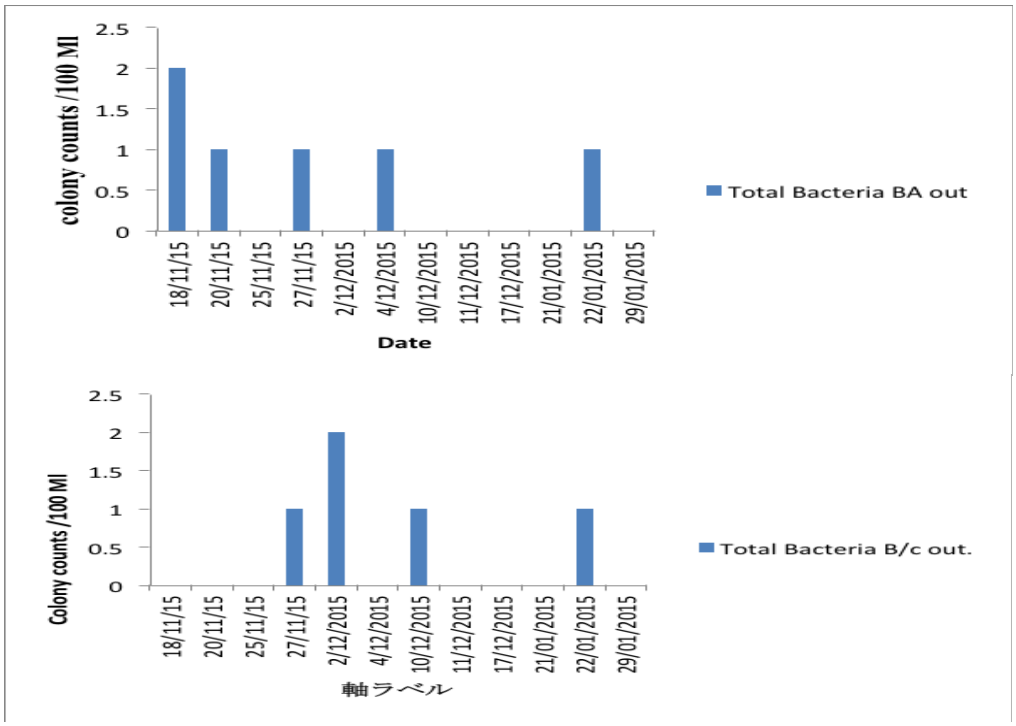



Figure 20. The change of the total bacteria (CFU) in the effluent water from the membrane filtration system.

The membrane treatment remove small colloidal particles including bacteria. The turbidity was observed to reduce by approximately 95 % in average and total suspended solids reduction of 99.9% in average. Performance slightly turned to be poor after four months of operation but no value was recorded in excess of 10 NTU.

From Figure 19, it was observed that fouling was less severe and we had almost constant permeate flux after normal backwash of ten minutes however, under same operating conditions, there was decreased permeate flux of membrane filtration set up when using filtrate from bricks-alone pre-treatment unit. Permeate flux declined sharply for both the membrane filtration units with increased scale formation on the membrane surface, and this was directly traced to days that experienced longer hours of power black outs, hence there was absence of bubbling. This observation outlays the importance of bubbling on micro-membrane filtration.

It was observed that fouling escalated for both the membrane filtration units after a hundred days of operation. There occurred steep fluctuation of permeate flux after every backwash as well as chemical cleaning. This was attributed to an increased organic loading and total suspended solids resulting from the pre-treatment units at specific observed times. For that purpose the pre-treatment unit with bricks as filter media reached its optimal performance almost two weeks earlier that the other pre-treatment unit containing bricks and charcoal as media support. From Figures 19 the erratic change in pre-treatment caused rapid flux fluctuations for both the membrane filtration units even after every backwash and chemical cleaning. Therefore, influent loading stability plays a very important role on the fouling rate.

Figure 20 shows the changes of the number of general bacteria in effluent water of the both systems. The general bacteria measured by the agar plate of R2A media which is a standard media to count the general bacteria in tap water. Normally the guideline value is less than 100 CFU (Colony formation unit)/mL as safe water. Apparently the filtrated water is sufficiently safe. This membrane can't pass through a bacterial cell of 1μm in diameter due to the nominal pore size of 0.22μm. Several colonies on the plate may be from the contamination in the sample water collection, because it was not performed under the axenic condition. Therefore membrane filtration remove the risk of pathogenic bacteria. However, it is not effective to remove pathogenic virus particles considering with the pore size of the membrane.

**Practical on-site recycle system in a secondary school**

One of the goal of the development of the on-site water recycle system is to install the water recycle system in a school which is far from the water resource. However, we should examine the preliminary experiment in a school to extract the several problems before the realistic installation to school. In this purpose, the choice of the school that best suited the waste water treatment unit for re-use was done after visiting various schools that showed potential. Cheplaskei secondary school (Figure 21) was chosen as it didn't have tap water, was handling a bigger population of students and had a closer proximity to a tarmac road.

The work started in February 2016 with the delivery of the building materials and erection of the fence. The work was then followed by the erection of the tank stand structure and the welding of the tray holding frame work. Finally, the crushing of the bricks and charcoal was then done.

The installed system was the same as shown in Figure 14. However the electric pump was never used. The raw grey water from kitchen was pumped up to the raw water storage tank at the top by a foot pump. Then water flowed down to the anaerobic pre-treatment chamber containing charcoal gravels and the slanted chamber system by gravity. The two support media for the slanted treatment chamber were then characterized for required particle sizes and mixed in the ratio of 1:3 (charcoal to brick basis). One slanted chamber system was filled with this mixed media (B+C), and the other slanted chamber system was filled with the brick only media (B).

Work of the grey water treatment begun on Tuesday 24th May 2016. The first sample was collected on Wednesday 25th May 2016 and was analyzed for water quality parameters (BOD5, COD, NH4, NO2, NO3 and PO4). The system is currently running under our stewardship and that of an appointed support personnel.


Figure 21. Cheplaskei secondary school

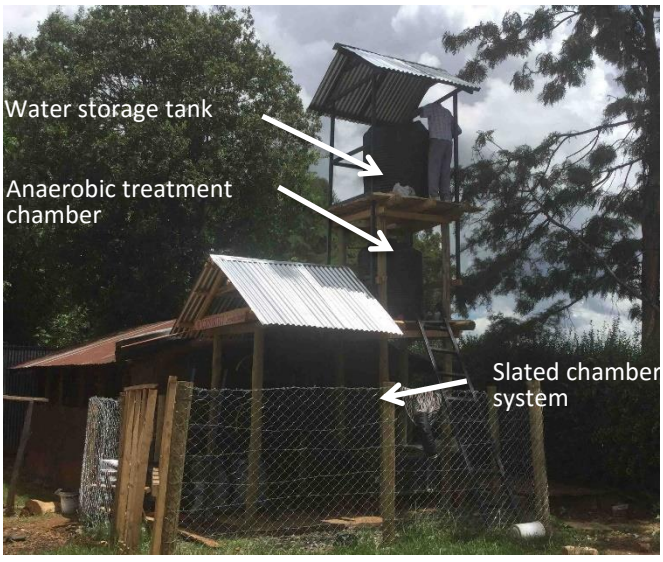



Figure 22. The on-site water recycle system in Cheplaskei secondary school

Figure 23 The slanted chamber system in Cheplaskei secondary school

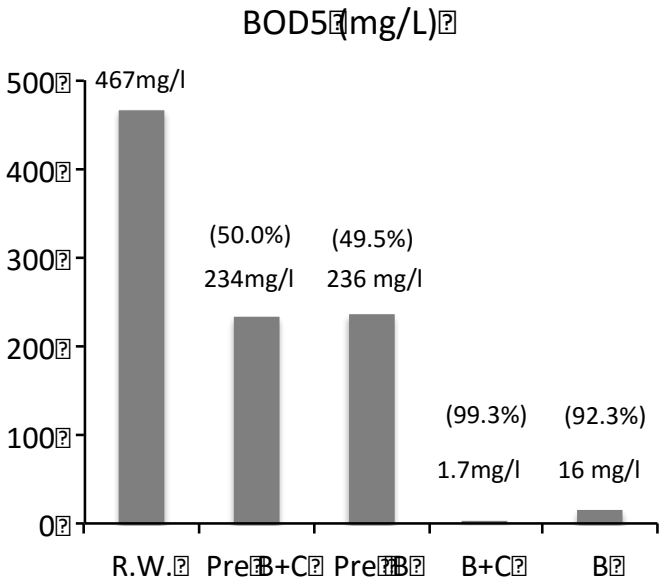



Figure 24. Average BOD5 of the raw water (R.W.), pre-treatment water by anaerobic chamber for the mixed media (Pre B+C) and for brick media (Pre B), and the final treated water from the slanted chamber system filled with the mixed media (B+C) and the brick media (B). Each number above each bar shows the BOD value, then each number in the bracket shows the removal for each treatment.

Table 2. Average water quality in the final treated water of each slanted chamber system

| | $BOD_5$ (mg/L) | COD (mg/L) | $NO_3$(mg/L) | $NO_2$ (mg/L) | $NH_4$ (mg/L) | $PO_4$ (mg/L) |
|---|---|---|---|---|---|---|
| B+C | 1.7 | 7 | 5.15 | 0.056 | 0.49 | 0.28 |
| B | 16 | 9 | 24.65 | 0.627 | 0.71 | 0.26 |

Figure 24 shows the average BOD values for the 8 weeks from the start-up of the system. The mixed media with brick and charcoal (B+C) apparently showed the better performance in the removal of BOD (organic matter) than that by the system with brick media (B) as well as the result

of the experiment in Moi University. The mixed media system also showed better water quality in the effluent as shown in Table 2. Ammonia concentration in the treated water of the system (B+C) is lower than that of the system (B). It means nitrification activity of the system (B+C) is higher than that of the system (B). However, nitrite and nitrate in the treated water of the system (B+C) was also lower than that in the system (B). This fact indicates that the denitrification activity in the system (B+C) was higher than that in the system (B). It was thought that charcoal media might provide a good habitat for the microorganism to decompose organic matter and for nitrification bacteria in aerobic condition. On the other hand, denitrification can be caused in anaerobic condition with the existence of organic matter as electron donor. The mixed media system might provide the heterogeneous filed of aerobic or anaerobic condition in the slanted chamber system. Thus, ammonia can change to nitrite and nitrate when it is passing through the media with aerobic part. Then small particulate organic matter gradually change to soluble organic matter at the same time. When the water containing nitrate pass thorough the anaerobic part, nitrate microbiologically changed to nitrogen gas by denitrification activity using the soluble organic matter. In the slanted chamber system, such alternative reactions of nitrification and denitrification might be repeatedly carried out at the aerobic part and the anaerobic part in the heterogeneous filed in the mixed media system.

In this system in the secondary school, we don't install membrane filtration system after the slanted chamber system to remove bacteria. Therefore, it is better to evaluate the number of general bacteria in the treated water even though the treated recycle water doesn't use for drinking water.

It is important to evaluate the safe of the recycle water sufficiently before spreading the developed on-site water recycle system to schools or domestic houses in dry area, because the pollutants in water might concentrate in the recycle process.

**Study 3. Development of a measurement tool of water quality monitoring using mobile phone (smart phone) for Aqua Health Network**

***Background***

In the project, we developed Bio-fence system and the on-site water recycle system which supply safe and clean water for riparian around Nyanza Gulf of Lake Victoria and inhabitants in the basin. The both systems are functioning well according to our studies. However we have to consider that the on-site water recycle system or Bio-fence is normally operated by not the specialist but the general inhabitants in the realistic case. This operation and management problem is a common problem for such decentralized water treatment systems. One solution is that a semi-specialist sometimes visits there to check the water quality of the treated water and the equipment. Then if the water quality is not sufficient or they find the some troubles, they can report it to a specialist.

Community health extension workers (CHEWs) have contributed various health services in developing countries. It has rolled out the community health strategy as a way of improving health care at the household level. The safe water problem is the related important topic for health problem. Thus CHEWs is a candidate to check the system and water quality. Of course, even if CHEWs can be trained well to conduct the monitoring work, they need several tools. In our purpose CHEWs have to be monitor the water quality of Nyanza Gulf, the inside of the bio-fence

water quality and the recycle water in each school. The ready to use water quality analysis kit can be applied to monitor the water quality by CHEWs. Each colored well or tube can be evaluated by human eye basically. However, nowadays, a digital camera of a mobile phone reads the color quantitatively, then it can calculate the concentration by the computer chip in the mobile phone. A digital camera of a mobile phone is equally matched to analytical equipment and it has an equal capability to a computer in information (image) processing. And then, we can use the mobile phone network in all area of Kenya. We can immediately communicate or share the information on the water quality and its risk with each other. We named this system as Aqua Health Network System. Figure 25 shows the concept of Aqua Health Network System.

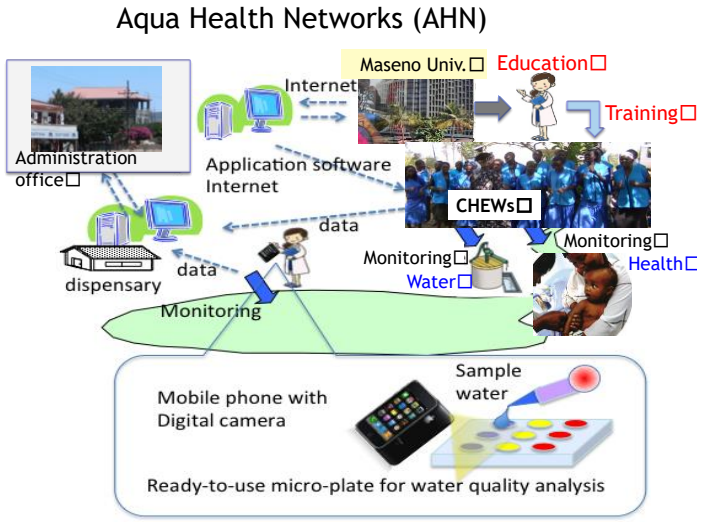



Figure 25. Concept of Aqua Health Network

MyApplication.java › class MyApplication

```
package com.example.slab.helloworld;

import android.app.Application;
import android.graphics.Bitmap;
import android.graphics.Color;
import android.util.Log;

/**
 * Created by SLAB on 2016/05/24.
 */
public class MyApplication extends Application {
    private final String TAG = "APPLICATION";
    private Bitmap obj;
    private int[] analyzedColors = new int[3*6];

    @Override
    public void onCreate() {
        //Application作成時
        Log.v(TAG,"--- onCreate() in ---");
    }

    @Override
    public void onTerminate() {
        //Application終了時
        Log.v(TAG,"--- onTerminate() in ---");
    }

    public void setObj(Bitmap bmp){
        obj = bmp;
    }
```

Figure 26. A part of JAVA source code of the application software for Android smartphones

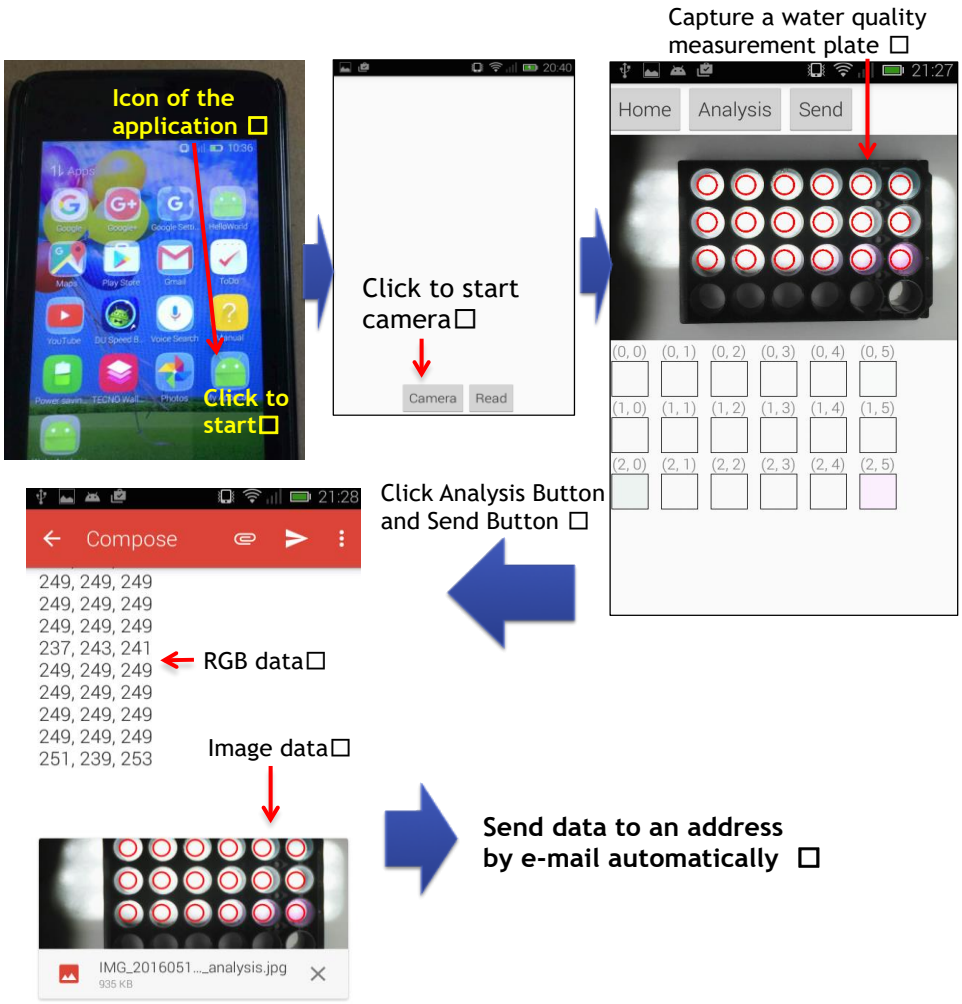



Figure 27. Snap shots of the application software and the workflow of the analysis

**Results**

The development of the system using mobile phone (Android smart phone) has been conducted in Nagasaki University. We have been developing the application software to measure a color image of a plate or a tube of "Ready to use kit" for water quality measurement which shows a specific color depending on the concentration of pollutants in water. In this study, we use "PACKTEST (KYORISTU Chemical Check Lab Corp.)" which is a ready-to-use kit made in Japan. But we can purchase it in Kenya. Then several android base smart phones were purchased in Kisumu to develop the software. Figure 26 shows a part of source code for the smartphone (The language is JAVA). Figure 27 shows a snap shot of the application software and the work flow of the analysis.

We can use the RGB data to determine the concentration of several chemicals in water. In this development, we try to measure ammonia, nitrite and nitrate in water, because these are important indicator of the biological water treatment process. Moreover, if we detect the high concentration of ammonia and nitrite in well water, it may indicate the contamination from a borehole of latrine. Therefore the well may be contaminated with fecal coliform, and the well water has a risk to spread several water bone diseases such as cholera. Figure 28 shows the example of the nitrite analysis from RGB data. In this case, we use PACKTEST for nitrite. This is a small tube in which a reagent

powder is packed. We suck sample water into the tube, and then it shows the pink color depending on the concentration of the nitrite after several minutes. This workflow can be performed in the smartphone application automatically, because the current smartphone is a sort of small high performance computer.

Color image of PAKCTEST for Nitrite measurement

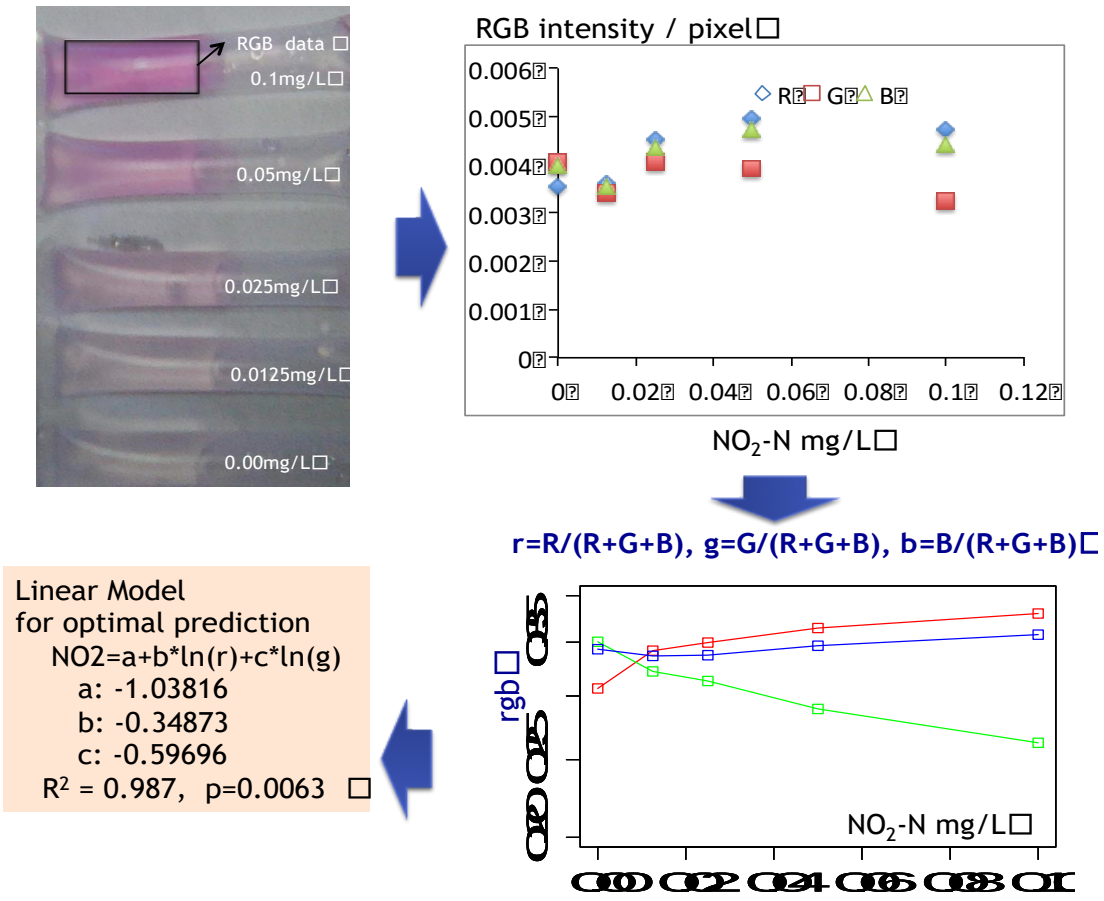



Figure 28. An example of the work flow of nitrite analysis using RGB data

In the next step, we will develop the application to measure chlorophyll concentration (green color) in lake water which is the indicator of the eutrophication. It can directly reflect the phytoplankton or cyanobacteria biomass. Therefore, we can use it for the operation and management of Bio-fence. Now we are using several sophisticated and expensive equipment to monitor the performance of Bio-fence for the study purpose. However, it is impossible for BMU to use the expensive specialized equipment. Therefore the smartphone application is so useful to check quantitatively removal of chlorophyll, because the removal efficiency correlates to removal of cyanotoxin microcystin according to the previous study. Figure 29 shows the application of the smartphone system which we are developing in LAVICORD.

It is an important task is to establish the education (training) system for semi-specialist as shown in Figure 20. In LAVICORD, we can't touch this important task. Therefore we have to continue this issue in a next project after LAVICORD.

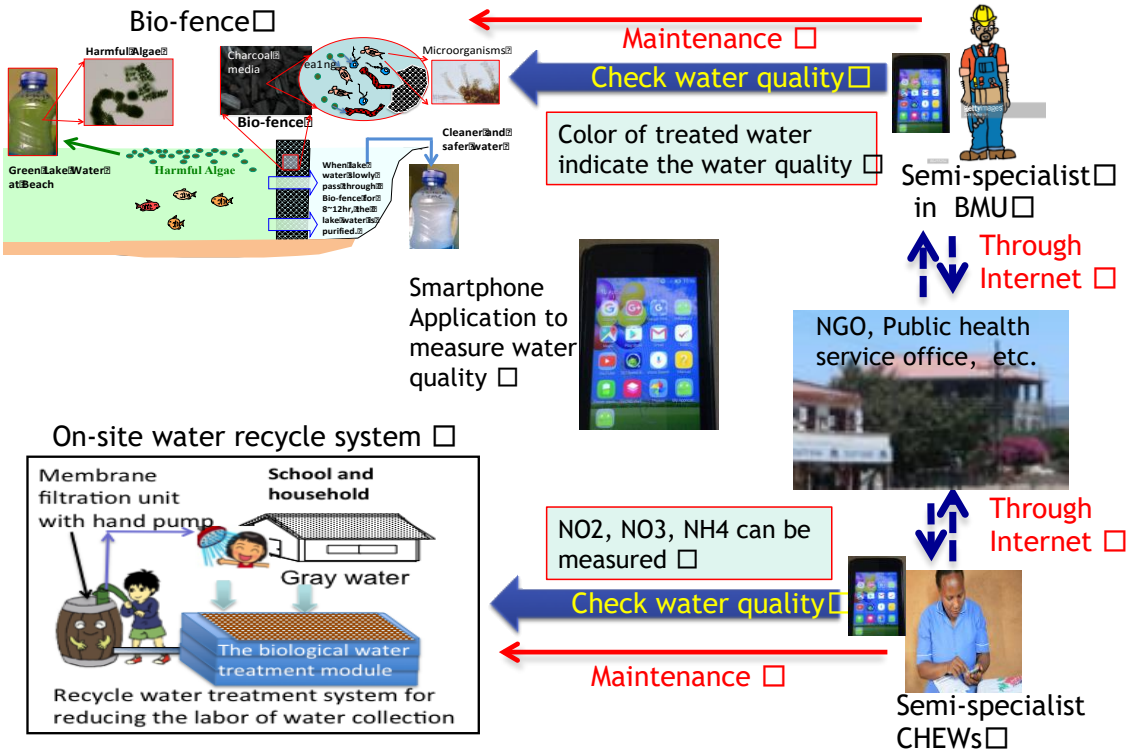



Figure 29. Effective use of the smartphone system to measure water quality

***Conclusion***

We conclude the three topics in component 2 as follows:

◆ **Bio-fence**

- ✓ We installed the fixed type Bio-fence at Ogal Beach BMU.
- ✓ This Bio-fence showed 97% removal of cyanobacteria in the experiment.
- ✓ Microcystin concentration in treated water by Bio-fence was less than 1μg/L of the guideline value of drinking water by WHO.
- ✓ We are going to install three Bio-fences which doesn't use electricity.
- ✓ These can supply $6m^3$ of treated water a day for BMU.
- ✓ The purpose of the treated water is mainly for general purpose water such as washing water of kitchen ware and hand etc..
- ✓ In case of use of the treated water as drinking water, we recommend boiling or chlorination of water strongly as post treatment after Bio-fence.
- ✓ We evaluate heavy metal and arsenic in the treated water using AAS (Atomic Absorption Spectrometer) to ensure the safe of water.

◆ **On-site water recycle system**

- ✓ We examined on-site water recycle system composed of anaerobic chamber and the slanted chamber system to treat gray water discharged from cafeteria of Moi University.
- ✓ The slanted chamber system filled with the bed media mixed with crashed bricks and corncob charcoal gravels showed high performance of removal of BOD (organic matter). BOD value in the effluent was 2mg/L in average.
- ✓ Membrane filtration for the effluent water of the slanted chamber system was examined using a hollow fiber microfiltration (MF).

- ✓ Membrane filtration removed bacteria from the treated water almost perfectly.
- ✓ We installed the on-site water recycle system in a secondary school to evaluate the performance and extract the problem on the operation in realistic use.
- ✓ The purpose of the treated water is mainly for general purpose water such as washing water of kitchen ware and hand etc..
- ✓ We evaluate heavy metal and arsenic in the treated water to ensure the safe of water.

◆ **Development of a measurement tool of water quality monitoring using mobile phone (smartphone)**

- ✓ We developed the application software of Android base smartphone to measure water quality parameter and share (send) the data thorough internet.
- ✓ The application software capture the color image of a plate or a tube of Ready-to-use kit for water quality measurement. Here, we use PACKTEST made in Japan which can be purchased in Kenya.
- ✓ We measured nitrite concentration using RGB data captured by smartphone camera. Moreover the application measures nitrate and ammonia and chlorophyll.
- ✓ The developed smartphone system will apply the management of Bio-fence and the on-site water recycle system by semi-specialist.
- ✓ We have to establish a training course for semi-specialist for the management of such water purification system or monitoring of safe of water as well as health monitoring.

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Chunyan Liu, Xueying Bi, Hajin Cho, Dong Xia, Norio Iwami, Kazuya Shimizu, Niwoot Whangchai, Redel Gutierrez, Chayaporn Teercharernwong and Tomoaki Itayama, Experimental Analysis on a Bio-Fence System for Removing Toxic Cyanobacteria, International Conference on Interdisciplinary Research and Development in ASEAN Universities , ChiangMai, Thailand (2013,8)

**On-site Water Reuse System**

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# COMPONENT 3

| | |
|---|---|
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## SUMMARY

Capture fisheries and aquaculture produced approximately 124,000 metric tons of fish that corresponded to 13,858,682,000 KSh from Lake Victoria in 2013 (Ministry of Agriculture, Livestock and Fisheries, 2015). Thus, fisheries activities in the Lake region are important source of revenue for Kenya. In addition, the Lake also provides food and employment to the riparian community. However, intense fishing and other human activities have been impacting fisheries and aquatic environment of the lake. The introduction of a predator, Nile perch *Lates niloticus* has substantially changed the lake ecosystem, which also leads to the increase of stronger predator, fishermen, who sought after this highly valued fish. Moreover, the number of riparian community around the Lake substantially increased, thus, wastes from their daily activities added to eutrophication and pollution of the lake environment. The degradation of the lake environment affected fish resources, with fishermen escalating their fishing efforts to catch more fish from decreasing resources. This clear negative chain reaction in the fisheries in Lake Victoria, we witness today.

The Fisheries Sciences component of LAVICORD project (also called Component 3) which consists of scientists from Maseno University, Nagasaki University and Kenya Marine and Fisheries Research Institute (KMFRI) conducted studies and presented new concepts of fisheries that are based on sciences, to encourage riparian community to change this negative chain reaction to positive. With this objective, component 3 was divided into 3 groups (capture fisheries, aquaculture and post-harvesting), each group tackled following research topics:

***Capture fisheries***

1. Research to understand the basic biology/ecology of Nile perch, Nile tilapia and omena
2. Tracking fish and fishermen behavior in Lake Victoria to understand change in fishing grounds
3. Development of the trap-net fishing gear for Lake Victoria as a tool for sustainable fishing.

***Aquaculture***

1. Development of cage aquaculture technology for Nile perch to determine the potential of Nile perch to be the next aquaculture species after Nile tilapia and catfish
2. Development of culture technology for endangered endemic species in captivity with primary aim of producing larvae for stock enhancement and culture

3. Introduction of aquaponics system for harmonizing aquaculture and environment and increase food production.

### *3.3 Post-harvesting*

1. Development of Kenyan style fish paste products for value addition of lake fish
2. Development of gelatin extracted from discarding fish scale

**Study 1. Biological characteristics of omena**

Some biological characteristics of omena *Rastrineobola argentea* such as length-weight relationship, condition factor, Gonadal Somatic Index (GSI), sex ratio, size at first maturity, feeding and food selection were studied.

The main activities for this research started in January 2015. 24 hour-sampling of omena was conducted at the sites below for the specified dates. Wichlum: 21/01/2015-22/01/2015; Ngegu: 12/02/2015-13/02/2015; Dunga: 27/02/2015-28/02/2015. Fishing was done at 3h interval in which omena and zooplankton samples for each haul were preserved in 5% formalin (Fig. 1). Depth and water quality parameters (DO, Temp, Conductivity, turbidity and pH) were recorded. The aim of this sampling was to investigate on the food and feeding habit of omena as well as determining the effect of water quality parameters and depth on catch.

Fig. 1. Picture of zooplankton sampling (left) and at night (right)

Analysis was carried out at LAVICORD Lab for the period of 29/01/2015-26/03/2015, including dissecting of the omena samples; microscopic identification of the prey types in the stomach; weighing the stomach contents.

Our results showed that *R. argentea* feeds exclusively of zooplankton during the day and more on insects (larvae/pupae) at night (Fig. 2). This study also showed that when *R. argentea* is feeding on zooplankton it is able to actively select copepods (Cyclopoida and Calanoida), while incorporating very little of cladocerans and rotifers in its diet (Fig. 3).

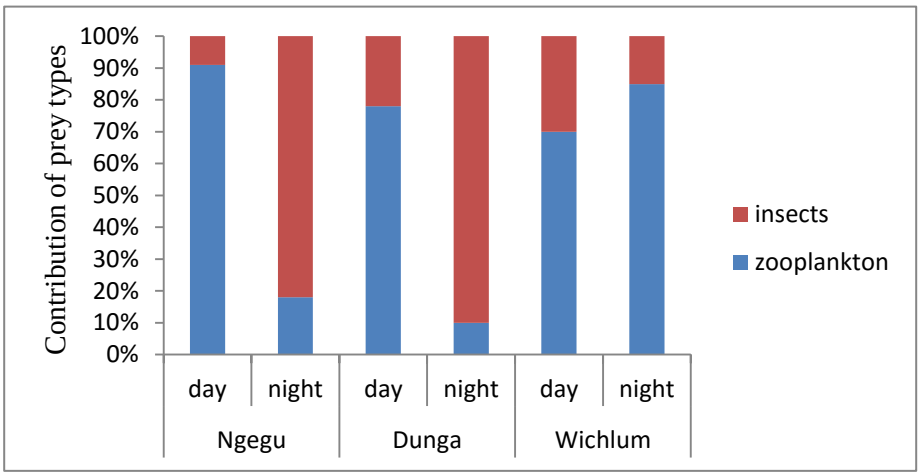



Fig. 2. Contribution of the prey types in the diet of *R. argentea* during day and night

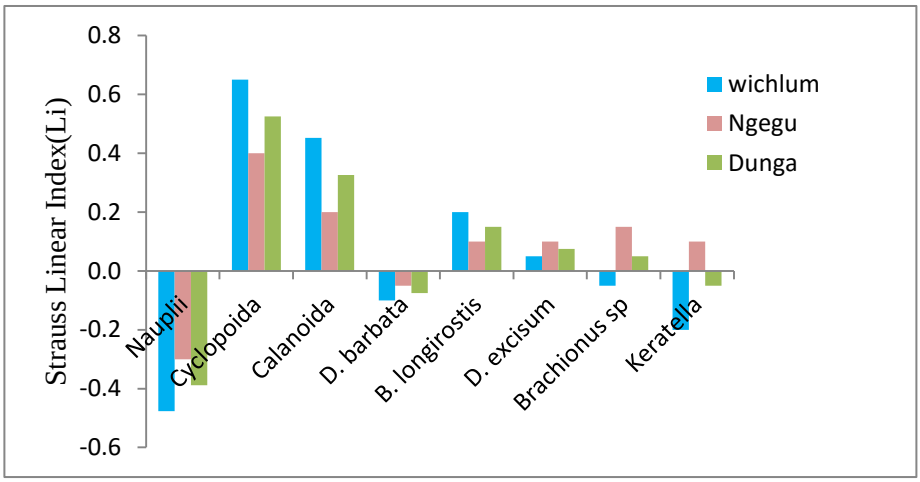



Fig. 3. Selectivity of zooplankton species by *R. argentea* in Lake Victoria, Kenya. (B= *Bosmina longirostis*, M= *Diaphanasoma excisum*, D= *Daphnia barbata*)

The principal component analysis at 51.93% variance showed that *R. argentea* catch has a positive correlation with Dissolved Oxygen, pH and depth, whereas turbidity, temperature and conductivity revealed a negative correlation with catch (Fig 4).

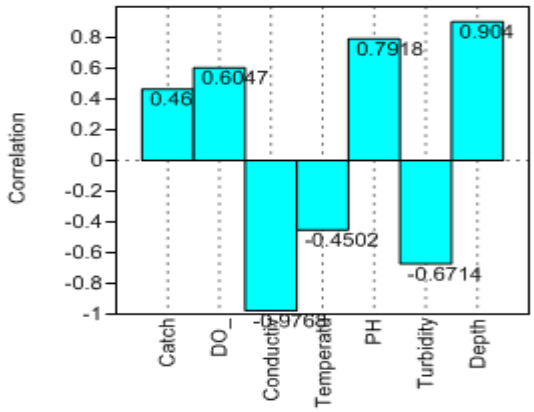



Fig.4. Principal Component Analysis of Catch, depth and water parameters

**Study 2. Visual acuity of Omena**

We conducted fish sampling in the nighttime in June 2015 at Dunga and Wichlum. Fishing was done at 2 hours interval in which omena samples for each haul were preserved in 10% formalin. The aim of this sampling was to investigate visual acuity and light adaptation of omena. Histological analysis were done at Nagasaki Laboratory from 13 to 27 June 2015. We obtained transverse section of retina of omena (Fig. 5).

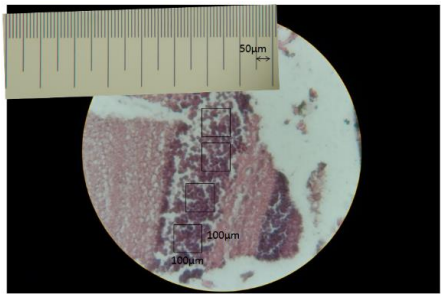



Fig. 5. Cone cells in the retina of omena

We counted numbers of cone cells per 0.01 $mm^2$ in the transverse section of retina of sampled omena. Then visual acuity of sampled omena was estimated according to following equation proposed by *Miller et al*. (1993).

$$\sin\alpha = \frac{0.0435}{dr}$$

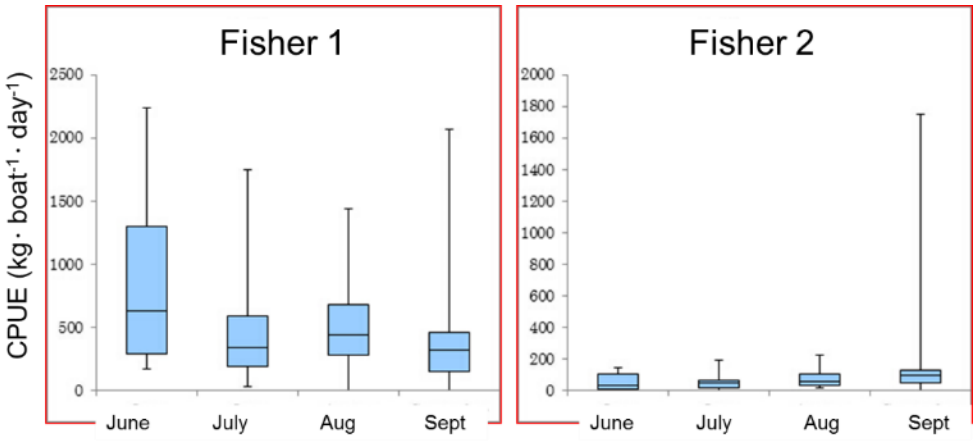
($\alpha$; acuity, d; cone density per 100 um, r; radius of lens)

Average number of cone cells was 32.6 cells/0.01 mm2, so acuity was obtained as 0.019 and visual acuity of sampled omena was calculated as; Visual acuity $= \left(\alpha \times \frac{180}{\pi} \times 60\right)^{-1}$ =**0.015**

This value suggested that visual ability of omena seemed bad comparing to other fresh water fish, but also it was considered we need to improve analysis techniques because some procedures in the analysis seemed not adequate.

**Study 3. Fishing efforts monitoring**

Fishing efforts monitoring for Omena fishing, gillnetting, longlining and handlining at 4 Beach Management Units (BMUs) was carried out from June 2014 to May 2015. Catch data at each BMU was collected every week.



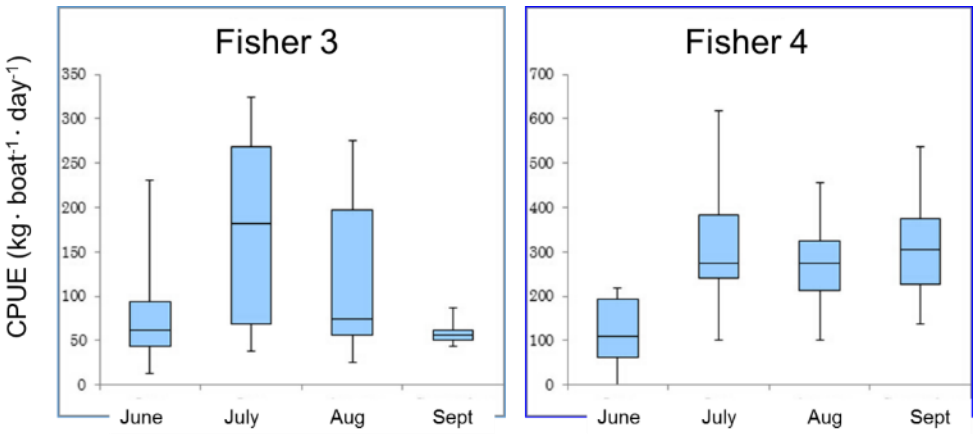



Fig. 6. Box and whisker plots of CPUE (kg·boat$^{-1}$day$^{-1}$) of Omena fishermen in Honge BMU (Fisher 1 and 2) and Wichlum BMU (Fisher 3 and 4)

Change in CPUE of omena fishery (Catch Per Unit Effort, kg·boat$^{-1}$day$^{-1}$) in Honge and Wichlum during June to September 2014 was calculated from the logbook records which we have requested to fishermen in LAVICORD project, as shown in Fig. 6. Fishermen who used motorized fishing boats (Fisher 1 and 4) showed higher CPEU when compared with fishermen using paddle boats (Fisher 2 and 3). Thus difference in fishing boat gave a strong influence on the fishing performance in omena fishery. Stratification such as motorized and puddled boats may be necessary to standardize the fishing efforts.

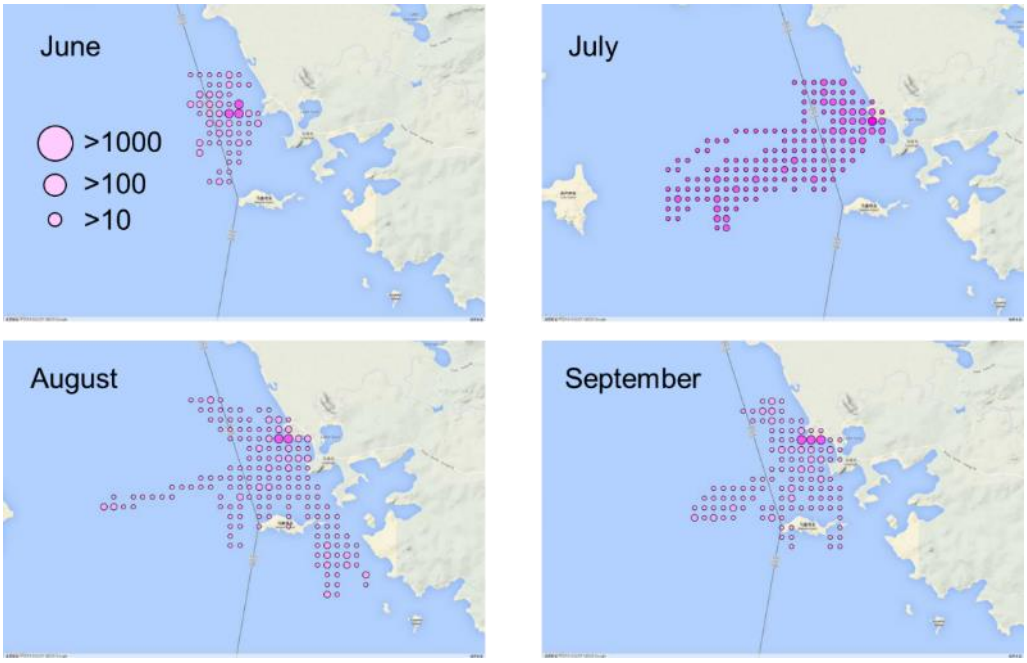



Fig. 7. Time series change of Omena fishing ground in Honge BMU during June to Sept 2014

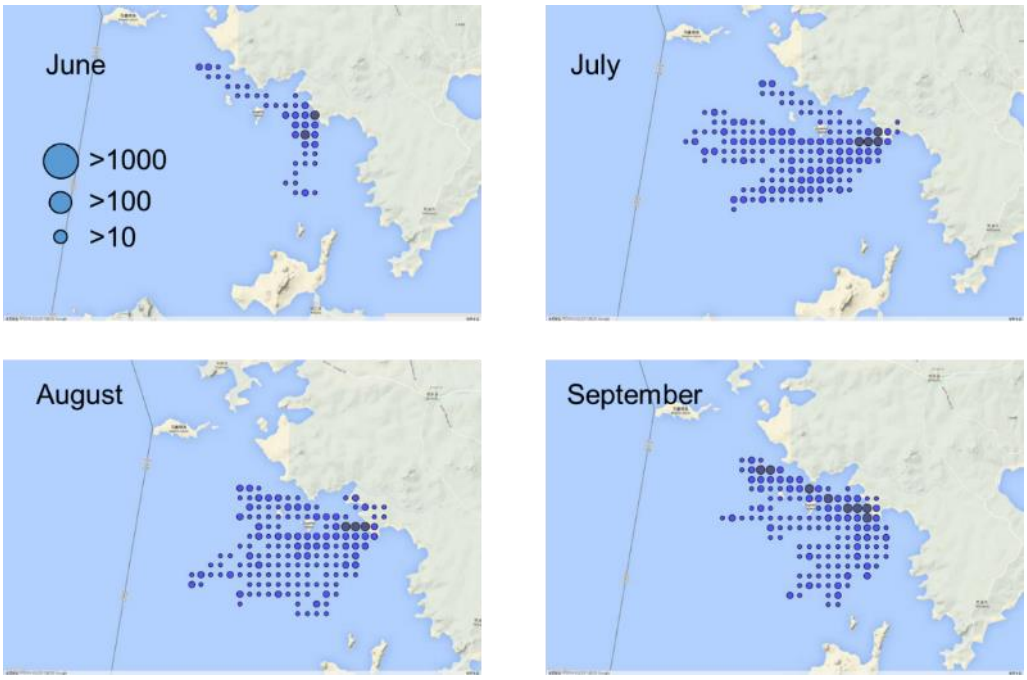



Fig. 8. Time series change of Omena fishing ground in Wichlum BMU during June to September 2014

Change in fishing ground during June to September 2014 was also analyzed by using GPS-logger data which was recovered from 4 omena fishermen every week. Spatial distribution of fishing ground was identified from the logbook records and GPS data was plotted over electric maps by using open source Q-GIS software (Figs. 7 and 8). In Honge BMU, main fishing ground was close to the coast in June, but after that, fishing boats tended to operate in offshore water in July, then also spread along the coast line in August and September. This tendency of spatio-temporal distribution of fishing boats were similar in the Wichlum BMU.

Fishing efforts of gillnets and longline were also estimated as shown in Table 1.

**Study 4. Biotelemetry research to track Nile perch**

We set ten receivers that detect the presence of released fish (pingers) within 500 meters in the Lake in Kendu Bay, Homa Bay, Luanda K'Otieno and Kunya (Figs.9 and 10). We released 11 Nile perch ranging 23 – 51 cm of total lengths from the beach near Kendu Bay on 28 September 2015. Small, but state of the art pingers that emit acoustic signals were implanted in abdominal cavities of 10 fish out of 11 (Figs. 11).

We confirmed that most released fish stayed released area only for a few days and moved to other areas. However fish were not able to move far away. Five fish out of 11 were captured by local fisheries within 10 days after released and then another fish was captured one and half month later, which means more than 50 % of fish were recaptured within 45 days (Table 2).

Table 1. Fishing efforts, catch and CPUEs by fishing sectors of BMUs

| Gillnet fishery Nile perch | Honge | | Wichlum | | GUL KAMIN OUGO |
|---|---|---|---|---|---|
| | June | July | June | July | July |
| n (boat·day) | 42 | 52 | 47 | 55 | 9 |
| total number (ind.) | 151 | 229 | 167 | 278 | 11 |
| average (ind/boat·day) | 3.60 | 4.40 | 3.55 | 5.05 | 1.22 |
| sd (ind/boat·day) | 2.93 | 5.37 | 2.64 | 5.26 | 0.44 |
| median (ind/boat·day) | 2.5 | 2 | 3 | 4 | 1 |
| total weight (kg) | 91.35 | 138.75 | 345.2 | 556.5 | 6.7 |
| average (kg/boat·day) | 2.34 | 2.78 | 7.34 | 10.31 | 1.12 |
| sd (kg/boat·day) | 1.50 | 3.83 | 5.52 | 10.42 | 0.20 |
| median (kg/boat·day) | 0.5 | 0.75 | 6 | 7 | 1 |
| | Honge | | Wichlum | | GUL KAMIN OUGO |
| Nile tilapia | June | July | June | July | July |
| n (boat·day) | 67 | 91 | | | 37 |
| total number (indiv.) | 411 | 435 | - | - | 114 |
| average (indiv/boat·day) | 6.13 | 4.78 | - | - | 3.08 |
| sd (indiv/boat·day) | 4.40 | 5.04 | - | - | 1.32 |
| median (indiv/boat·day) | 5 | 4 | - | - | 3 |
| total weight (kg) | 258.5 | 275.25 | - | - | 43.7 |
| average (kg/boat·day) | 3.92 | 3.06 | - | - | 2.08 |
| sd (kg/boat·day) | 3.05 | 3.46 | - | - | 0.96 |
| median (kg/boat·day) | 3 | 2 | - | - | 2 |

| Longline fishery Nile perch | Honge | | Wichlum | |
|---|---|---|---|---|
| | June | July | June | July |
| n (boat·day) | 5 | 10 | 35 | 53 |
| total number (ind.) | 12 | 131 | 153 | 251 |
| average (ind/boat·day) | 2.40 | 13.10 | 4.37 | 4.74 |
| sd (ind/boat·day) | 2.07 | 7.89 | 3.55 | 4.24 |
| median (ind/boat·day) | 2 | 12 | 4 | 3 |
| total weight (kg) | 61 | 105 | 413 | 488.5 |
| average (kg/boat·day) | 12.20 | 10.50 | 11.80 | 9.22 |
| sd (kg/boat·day) | 9.78 | 6.28 | 13.04 | 9.36 |
| median (kg/boat·day) | 11 | 9.5 | 6 | 7 |


Fig. 9. Position of acoustic receivers

Fig. 10. Acoustic receivers set in the Lake

Fig.11. Surgery operation for implanting a pinger into a Nile perch

Table 2. Details of released and recaptured Nile perch

| Fish ID | TL (cm) | WW (g) | Sex | re-capture d date | Time re-capture | Re-capture fishing gear | Fishing ground | Landing site | Size when re-capture (TL, cm) |
|---|---|---|---|---|---|---|---|---|---|
| #1 | 35.2 | - | M | 29 Sept. | 2:00 | Seine | Jewlet | Chuowe | |
| #2 | 39.0 | 676 | F | 30 Sept. | - | Longline | - | Doho | |
| #3 | 35.5 | 622 | M | 2 Oct. | 4:00 | Seine | Chuowe | Rambira | |
| #4 | 22.8 * | - | ? | 3 Oct. | 8:00 | Gillnet | Nduru | | 25.5 |
| #5 | 46.0 | 1284 | M | 6 Oct. | 3:00 | Seine | Rakwaro | Chuowe | |
| #6 | 36.7 | - | F | 12 Nov. | 10:00 | Longline | Achuodho | Seka | 41 |
| #7 | 51.0 | 1538 | M | | | | | | |
| #8 | 42.5 | 914 | M | | | | | | |
| #9 | 39.0 | 716 | M | | | | | | |
| #10 | 31.8 | - | ? | | | | | | |
| #11 | 31.0 | - | ? | | | | | | |

*acoustic pinger was not implanted due to its size.

This is the first report of Nile perch behavior in Lake Victoria and an astonishing fact implying such a large amount of fishing pressure/effort was allocated. Because these recapture rate and duration is higher and shorter than any other studies conducted in relatively large hydrosphere like Lake Victoria.

**Study 5. Trap-net experiment**

We developed the trap net gear for Lake Victoria (Mase-NU trap, Fig. 12) and tested at Wichlum BMU between 11 and 16 April 2016.

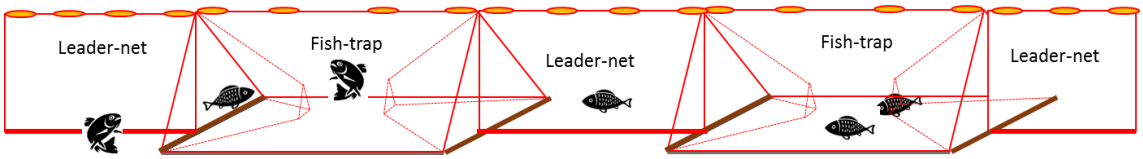



Fig. 12. Design of the trap net fishing gear for Lake Victoria tested at Wichlum BMU

We hired four crews daily during the trial experimental period (11th-16th 2016). The boat used measured 33 feet long, 6 feet wide and 1.9 feet depth. Shooting was done parallel to the wind and wave directions toward the offshore direction, while hauling was done in the opposite direction. The net was set at different areas including shallow and deep waters, thus covering the fishing ground between Saga Island and Wichlum beach. Setting and hauling of the net by the four fishers could take at most 20 minutes.We could check the gear twice; in the morning hours from around 7 am and late evening from around 6 pm. Thereafter we set the net at night and checked the next day. A total of two fish were caught as shown in the Table 3.

Table 3. Summary of trap-net experiment

| Date | Haul time | Set time | Haul time | Set time | SL cm | TL cm | Wt (g) | Sex | |
|---|---|---|---|---|---|---|---|---|---|
| 11/04/2016 | - | 10:00 | 18:00 | 19:00 | - | - | - | - | |
| 12/04/2016 | 06:00 | 07:00 | 17:00 | 18:00 | 16.5 | 19.5 | 73 | Immature | Fig.22 |
| 13/04/2016 | 07:00 | 08:00 | 17:00 | Repair | - | - | - | - | |
| 14/04/2016 | 07:00 | 08:00 | 16:00 | 17:00 | 52.0 | 59.0 | 2380 | Male- 3 | Fig. 23 |
| 15/04/2016 | 07:00 | 08:00 | 17:00 | 18:00 | - | - | - | - | |
| 16/04/2016 | 09:00 | - | - | - | - | - | - | - | |

On 13th around the evening hours while hauling, we observed the trap torn on the side. We attributed this to the bigger Nile perch that was trapped inside and managed to escape (Fig.13).

After the experimental period, the following suggestions were made:

- To increase the length of the leader net to about 200 m on both sides. This was based on the fact that it is too short in comparison to the gill nets used at the BMU. A suggested by the fishermen in liaison with the BMU chairperson.
- To reduce the mesh-size of the trap to about 1/2 inch so as not to catch juvenile fish a suggestion by the fisheries department at Bondo
- To increase the height or depth of the trap to about 8 m a suggestion by fishermen. In my understanding what the fishermen meant here was the distance between the bottom of the trap and the floats which for our design was about 2 m.

General comments from the fishermen

- The fishermen are so positive on the trap net and have the idea that it may be efficient with time
- The trap net should be set at the river mouth
- The trap net should be set only at night
- The setting should be done in the mid water not at the bottom
- That the experimentation period was too short
- The light green rope used to make the net is visible to the fish in water and thus will always avoid entrance
- To use some wire in the triangular opening to keep the entrance in position


Fig. 13. Pictures of the second fish caught and the entrance into the trap was torn

We developed a new design of the gear incorporating suggestions from fishers and Fisheries Department. The height of gear was designed to be about twice of previous gear (1.75 m to 3.3 m). The length of the leader-net was also increased to 40 m. Webbing of smaller mesh sizes are used to avoid fish entanglement at the trap-net. Field experiment to compare catches between improved gear and previous gear (Fig. 14) was done at Wichlum BMU during July and August 2016. Results are in analysis.

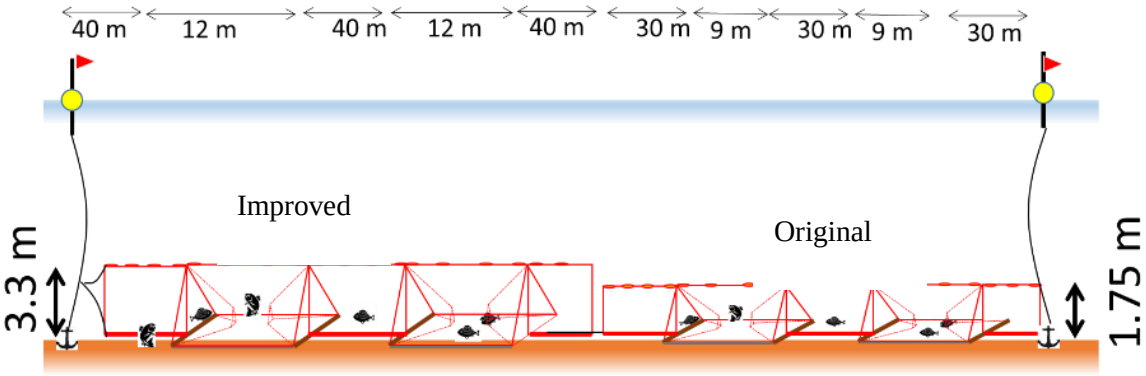



Fig. 14. Schematic diagram of comparative experiment of Mase-NU trap

**Publication**

1. Length-weight relationship, Condition factor, Sex ratio, Gonadal Somatic Index and Size at Maturity of Omena, Rastrineobola argentea (Pellegrin, 1904) in Lake Victoria, Kenya, Yongo, E.,Manyala, J.O.,Njiru, J.M., Outa, N.O., Kito and K. Matsushita,Y., International Journal of Advanced Research, 4(6), 1740-1746(2016), DOI URL **:** http://dx.doi.org/10.21474/IJAR01/619

2. Diet of Silver Cyprinid, *Rastrineobola argentea* in Lake Victoria, Kenya, E. Yongo, J.O. Manyala, K. Kito, Y. Matsushita, N.O. Outa and J.M. Njiru, International Journal of Advanced Research, 5(5), 22-29(2016), DOI URL: http://dx.doi.org/10.21474/IJAR01/113

## Component 3-2. Aquaculture

### Study 6. Studies on the biology and culture of Nile perch *Lates niloticus*

Nile perch, *Lates niloticus* is one of the most important fishes in Lake Victoria contributing to over 90% of Kenya's fish export. We conducted a series of experiments to explore the possibility of culturing Nile perch in captivity. First, we conducted biological survey on their feeding behavior of Nile perch caught within the Winam Gulf. Results showed that Nile perch feeding ontogenetic shifts from zooplanktivore to macrocrustacea and to piscivorous as it grows (Table 1).

Table 1. Contribution of each food item in the overall diet of *Lates niloticus* caught from Winam Gulf

| Length class (cm) | Nile perch | *Caradina ilotica* | Haplochromines | Other fish | Unidentified fish |
|---|---|---|---|---|---|
| 1-5 | 8 | 61 | 8 | 9 | 13 |
| 6-10 | 18 | 39 | 20 | 6 | 17 |
| 11-15 | 18 | 49 | 9 | 6 | 19 |
| 16-20 | 18 | 49 | 9 | 6 | 19 |
| 21-35 | 64 | 11 | 15 | 5 | 5 |

Freshwater shrimp, *Caridina nilotica* comprising 61.1% in the diet of juveniles (1-5 cm total length) and reduced to 11% in fish 21 cm and longer. Cannibalism was observed even in juvenile stage (5 cm total length) and highest when fish reached 21 cm. Haplochromines, omena (*Rastrineiobola argentea*) and other identified fish comprised 25-37% of the food in Nile perch. These showed that Nile perch is a fish.

Secondly, we conducted transport experiments of fingerlings. Fingerlings were caught in the Winam Gulf early in the morning, packed in oxygenated plastic bags and loaded into an air-conditioned car. Transport was done for 4 hours (from Kendu Bay to KMFRI, Kegati station). Results showed that fish 8-15 cm in total length at a density of 40-100g/L is the optimal size and density in transporting Nile perch (Table 2).

Table 2: Mortality and survival of L. *niloticus* fingerlings after 4 hours transport and after 5 days

| Fish size (cm) | Packing density (g/litre) | % Mortality during transportation | % Mortality after 5 days | % Survival after 5 days |
|---|---|---|---|---|
| 2 – 4 | 40 | 63.3±15 | 8.3±10 | 28 |
| | 80 | 70.0±21 | 3.3±3 | 27 |
| | 100 | 57.3±34 | 4.0±5 | 30 |
| 5 -7 | 40 | 15.0±5 | 0.0±0 | 74 |
| | 80 | 11.1±10 | 0.0±0 | 88 |
| | 100 | 24.2±14 | 7.0±4 | 64 |
| 8 – 15 | 40 | 0.0±0 | 0.0±0 | 100 |
| | 80 | 6.7 | 5.0±7 | 88 |
| | 100 | 2.7±2 | 3.0±4 | 94 |

Thirdly, we conducted culture experiments in pond and cage. Fishpond culture experiment was conducted in Jewlet Farm (Kendu Bay), while cage experiment was conducted in Mageta Island (Figure 1). Fingerlings were sourced from the wild and transported as described above. Stocking of fish in fishpond and cage was done on the month (May 2015). In the fishpond, Nile perch were co-cultured with Nile tilapia broodstocks, with the purpose of the use of tilapia offspring as food for Nile perch. In the cage, a solar lamp was installed on the top of the cage which is on during the night, with the purpose of attracting other fish especially omena to enter the cage. These small fish will serve as food for Nile perch. When Nile perch are approximately 100g, dead small fish (mostly comprised of haplochromines) were supplied in the cage every other day at approximately 20% of the total fish biomass. The culture experiment was carried for 6 months (May – November, 2015). In the cage, culture experiment was extended up to one year.

Results showed that wild-caught fingerlings can be stocked either in cage or pond to reach table-size in 6 months (Figure 2). Fish cultured in cage, reached more than 2.5 kg after one year of culture (Figure 3).

Figure 1. Fishpond in Jewlet farm (Kendu Bay) and fish cage in Mageta Island were culure experiments were conducted

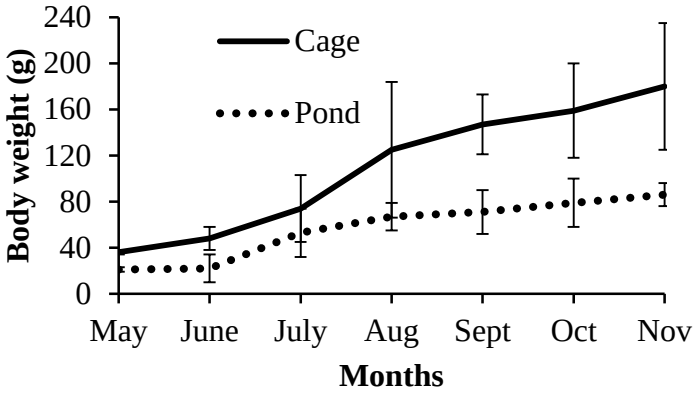



Figure 2. Growth rate of Nile perch *Lates niloticus* in cage and fishpond.

Figure 3. Nile perch after one year of culture in cage

**Study 7. Studies on the culture potential of endangered fishes (*Barbus altianalis* and *Labeo victorianus*) of Lake Victoria**

African carps *Barbus altianalis* and *Labeo victorianus* are considered as endangered species of Lake Victoria. We conducted series of studies to explore the culture potentials of these species with the aim of enhancing the wild stocks and also explore their culture potentials. Broodstocks of *L. victorianus* and *B. altianalis* were collected from the wild by electro fishing, and transported to the laboratory at Kegati Station, Kenya Marine and Fisheries Research Institute (KMFRI). For *L. victorianus*, mature females (body weight = 97.41 – 720.11g) induced by hormone Ovaprim successfully spawn 11-12 hours after injection and pairing with mature males. Fecundity of females was 68,189 ± 2,397 (46,702-86,712); fecundity was highly correlated with the size of the fish ($R^2 = 0.96$). Only males re-spawn in captivity, while females spawned once. Produced fingerlings accepted both artificial diet and natural zooplankton, with the fastest growth rate when fed Japanese-produced artificial diet (Product of Hayashikane Sangyo Co., Ltd, Japan) containing high protein (ANOVA; $P < 0.05$; Table 3). Also, both broodstocks from the wild and fingerlings produced in the hatchery were resistant to transport stress. We concluded that *L. victorianus* has high culture potential since it can be induced to spawn in captivity, readily accept commercial diet, resistant to transport

stress and the produced fingerlings have high survival rate. In case of *B. altianalis*, none of the brood-stocks collected from the wild spawned in captivity, in spite some of the fish we collected are matured (males produced whitish milt and females with round oocytes). Further studies are necessary in order to determine factors influencing the spawning of *B. altianalis* in captivity.

Table 3. Growth and survival of *L. victorianus* larvae fed on different diets. Data are mean ± standard deviations (n=3). Means with the same letter in the row are not significantly different (P<0.05).

| Parameter | Japanese formulated diet | KMFRI formulated diet | Natural zooplankton |
|---|---|---|---|
| Initial length (cm) | 0.43±0.01[a] | 0.44±0.03[a] | 0.44±0.02[a] |
| Final length (cm) | 3.16±0.05[a] | 2.96±0.01[a] | 2.10±0.07[b] |
| Initial weight (mg) | 4.0±0.2[a] | 3.9±0.3[a] | 4.0±0.7[a] |
| Final weight (mg) | 341.1±60.0[a] | 254.0±42.2[b] | 119.0±20.0[c] |
| Weight gain (mg) | 336.0[a] | 247.1[b] | 106.0[c] |
| Survival (%) | 49.3±0.8[a] | 46.1±0.8[a] | 51.6±0.6 [a] |

**Study 8. Use of locally available materials in tilapia feed formulation**

One of the major handicaps in enhancing fish farming in the Lake Victoria region is the non-availability of quality feeds as well as the high cost in producing it. Sunflower and cotton seed cakes have been used as plant protein sources in formulating tilapia diet in Kenya. However both are not locally available. Thus, we explore the use of soybean and other locally available beans, as substitutes to sunflower and/or cotton seed cake. The feeds were formulated manually at Maseno University (Figure 4) The proximate composition of our diet and local commercial diet is shown in Table 4. Diets were tested with tilapia *Oreochromis niloticus*. Diet containing soybean have the fastest growth rate, followed by those fed commercial diet, and those containing local bean (Figure 5). It is therefore evident that our local beans will perform equally well or better in comparison to commercially available feeds, hence the need for further explorations into local the sources.

Table 4. Proximate composition of test diets.

| | Soybean diet | Local bean mean | Commercial diet |
|---|---|---|---|
| Crude protein | 28.5 | 21.9 | 23.2 |
| Crude fat | 8.6 | 6.8 | 3.05 |
| Ash content | 12.50 | 12.90 | 18.3 |
| Crude fiber | 10.25 | 10.0 | 6.9 |
| Carbohydrate | 40.15 | 48.4 | 48.55 |

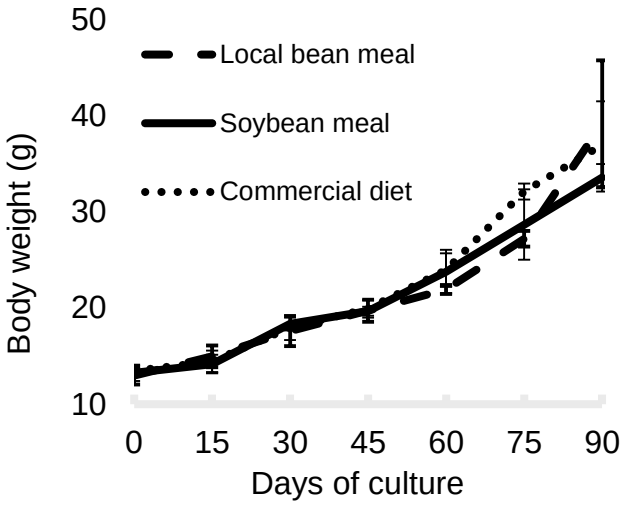



Figure 5. Growth of Nile tilapia *Oreochromis niloticus* fed diets containing different protein sources

Figure 4. Tilapia feed were made manually

**Study 9. Development of aquaponics system in Kenya**

Aquaponics has been practiced in many regions in the world, especially in areas where water and land are scarce. We developed an aquaponics system appropriate to Kenya topography. Two concrete ponds (total area = 56 $m^2$) were stocked with 400 tilapia broodstocks. Waste water from fish tank was channeled to a greenhouse built on top of concrete pond (total area = 30 m). Local vegetables including spinach, manago, cucumber, lettuce,tomato, succhini, and eggplant grew well in the system (Figure 6).

Figure 6. The aquaponics system and some plants growing inside the greenhouse

**Publication:**

Elijah M. Kembenya, Helen S. Marcial, Nicholas O. Outa, Yoshitaka Sakakura, Atsushi Hagiwara (2016). Captive Breeding of Threatened African Carp, *Labeo victorianus*, of Lake Victoria. Journal of World Aquaculture Society.

# Component 3-3. Post-harvest

## Study 10. Fish paste processing

The value of fish in nutrition is well recognized, since it supplies good protein, unsaturated fatty acid contained oils and minerals with a relatively low caloric content. Fish processing in Kenya varies to a greater extent with fish species and size of the fish. Mainly, Omena (*Rastrineobola argentea*) Nile perch (*Lates niloticus*), Tilapia (*Oreochromis niloticus*), are found in Lake Victoria. To develop the fish processing technology in Kenya, there exist a need for further fish processing operation to improve the value as well as shell life of fish products.

The basic gel-forming abilities were investigated on fish flesh of Nile perch and Nile tilapia that caught in Lake Victoria from September 2014 to February 2016. The gel-forming ability on each species shown in Fig. 1 suggested that both fish flesh are acceptable for the materials of the fish past production, such as fried fish paste or broiled fish paste. In general, gel-forming abilities on freshwater fish meats are lower than those of marine fish meats that used for the fish paste processing. However, we found that both Nile perch and Nile tilapia living in Lake Victoria have relatively good gel-forming ability, exceptionally.

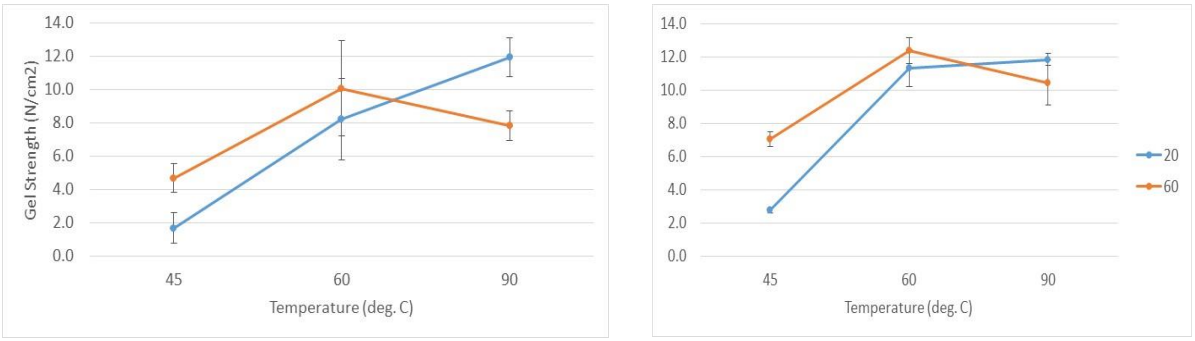



Fig. 1: Gel strength of salt-ground fish paste of Nile Perch (left) and Nile Tilapia (right) after 20/60 minutes heating at different temperatures in December 2015

The seasonal changing of heat-set gel-forming ability of Nile tilapia and Nile perch surimi were studied continuously, the result shows that it is possible to use 2 species as fish paste material in any seasons. Also, new items of fish paste for Kenya people are developing.

We established a fish processing system at the LAVICORD laboratory, shown in the Fig.2, in order to modify Japanese traditional recipes into the one which would be favorable to Kenyans. In general, Japanese fish processing technique is very unique. It had developed to earn the elastic chewiness (Japanese call it “Ashi”), and makes its processing system also unique and too expensive to set up. However, we successfully established a small-scale processing system for fried fish paste and other products by combining three cooking appliances available in the general market in Kenya and a home-use vacuum sealer.

Fig. 2: Micro processing system for fish paste processing (from left, vacuum sealer, deep fryer, food processor, mincer)

The cost of all expenses was approximately 50,000 Kenyan shillings. The scale of the production is estimated 500g of product per hour. The operation of this system is possible by one person. Since it can be started with relatively small investment of fund and resources, this system was named “Micro fish-paste-processing system”. Additionally, at the LAVICORD laboratory, a refrigerator is set up for stocking raw fish and products. And also, we slightly modified the combination of our processing unit to elevate the production ability. One food processor and a deep fryer were added to the original production line for speed-up the rate-limiting steps by our production process. As the result, it was possible to increase the production rate in 1 kg/hr by this improvement.

Many recipes were tested to produce different type of fish cakes (fish paste) by using our processing system, and needs to be tasted and evaluated by many Kenyans. We continued to make fish paste recipes for modifying Japanese traditional recipes into the Kenya recipes which would be favorable to Kenyans. A few recipes was selected to produce two different type of fish cakes such as fried-fish paste and broiled-fish paste by using our processing system and an electric oven at the LAVICORD laboratory, and needed to be tasted and evaluated by Kenyans.

Fried fish-paste
(right side; Nile Perch colored in red by pigment, left side; Nile Tilapia on natural color)

Fried fish-past wrapped with bread, ”Samaki toast”

Fish-sausage including beef-fat

Grilled fish-paste, “Samaki sticks”

Samaki croquette

Fig. 3: Fried-fish paste and grilled-fish paste products made from fish in Lake Victoria

For the purpose of closely fitting to the national preference of Kenya people and/or for the purpose of elevating the shelf stability of the product itself, we tested to make new recipes of fish-paste items. Then it was succeeded to expand items shown in Fig. 3. “Samaki toast” is the item which is added the value as the fast-food by combining with bread, as well as is an item which reduced the total cost of a product. “Samaki sticks” is the item with Kenyan favorite texture, and also it has the longer shelf life than a fried fish-paste without cold storage. For the preparation of Samaki sticks, we need an oven with the basic micro fish-paste-processing system to bake fish paste, additionally.

To adjust the Kenya people favorite taste, we selected and built up three kinds of recipes for fish paste, shown in next procedures. Basic step of fish paste processing was carried out under the same scheme, however, a few steps shown by picked up numbers were differed.

**Processing step of fish paste products:**

*Filleting ➔2) Mincing ➔3) Grinding with salt ➔4) Mixing with additives ➔ 5) Shaping ➔6) Heating ➔7) Cooling➔8 )Packaging*

- **Fried fish paste;** *4)egg white, sugar, (vegetable), 6)deep-frying*
- **Samaki toast;** *4)egg white, sugar ,5)wrapping with bread ,6)frying*
- **Samaki sticks;** *4)egg white, butter, milk, 6)broiling*

The nutrient composition analysis of those fish-paste were performed. The summary of results shown in the Table 1. We selected the corn oil for the deep-frying. “Fried fish paste” contained about 20% of protein, in the case of “Samaki toast”, the level was 10~14%, and “Samaki sticks” contained 35~46% of protein. The results suggest that protein contents of both fried fish-pastes of Nile tilapia and Nile perch were almost equal to beef meat’ one, however the lipid contents of those fish pastes were clearly lower than that of beef meat. Also, those fish

paste were rich in Calcium and Iron. However, oil contents of them were very low, expect "Samaki toast". Therefore, the consumption of those fish pastes is not only valuable for protein malnutrition of children and old people, but also able to reduce the risk of lifestyle-related disease of adults even if people over consumed them, unlike red meat with saturated fatty acid.

Table 1. Nutritional Composition of Fish Paste Products

| | Nile perch | | | | Nile tilapia | | | |
|---|---|---|---|---|---|---|---|---|
| Composition | Fried fish past | Samaki toast | Samaki croquette | Samaki stick | Fried fish pate | Samaki toast | Samaki croquette | Samaki stick |
| Moisture (%) | 65.34 | 39.39 | 64.44 | 50.56 | 67.05 | 42.84 | 66.4 | 38.3 |
| Crude protein (%) | 20.57 | 14.2 | 16.3 | 35.1 | 20.33 | 10.78 | 12.2 | 46.3 |
| Oil (%) | 0.3 | 23.02 | 5.62 | 2.25 | 0.45 | 25.9 | 5.65 | 7.4 |
| Crude ash (%) | 3.05 | 1.9 | 2.31 | 3.55 | 3.18 | 2.4 | 2.35 | 5.64 |
| Crude fiber (%) | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 2.03 | 0.04 | 0.87 |
| Calcium (mg/kg) | – | 535.66 | 416.26 | 325.94 | – | 487.67 | 451.4 | 567.37 |
| Iron (mg/kg) | – | 21.85 | 24.49 | 21.02 | – | 34.76 | 24.32 | 33.41 |

The production costs of "fried-fish paste", "Samaki toast" and "Samaki sticks" were 72, 34 and 158Ksh per 100g of products, respectively. Those values were calculated when the raw fish price was 300 ksh/kg and the cost of other additional ingredient were retail price at a supermarket in Kisumu.

We should mention that we produced two kinds of fried-fish paste from Nile tilapia and Nile perch and vacuum packed them, then, we brought them from LAVICORD in Kisumu into "The Japanese festival 2014" held in Nairobi and sold them to guests. Our products gained popularity among guests, so 75 packs of fried-fish paste were sold out within one hour. So, we had sent Samaki toast and Samaki sticks for "The Japanese festival 2015". Those products also gained popularity among Kenyan guests.

In 2016, our research activity was presented for the general public in Tokyo, Japan at the event which held on 9$^{th}$ -13$^{th}$ of May by the Japanese Ministry of Agriculture, Forestry and Fisheries. This state has been published on the Japanese magazine, "Kamaboko Tsu-sin".

As an accomplishment of this activity, dissemination activities of those fish-pastes processing are expected to training to restaurant's chefs for serving them at their restaurants, and to developing for "one village one product program (OVOP)" in Nyanza area. The booklet of recipes of Kenya people favorite fish paste (title; FISH PASTE PROCESSING FOR MICRO-SCALE PRODUCTION) was published in July 2016 from LAVICORD, and has been distributed in Kenya.

**Study 11. Gelatin extraction from fish scale as a by-product**

The gel formable fish gelatin which used the processing waste of fish from Lake Victoria as materials were prepared. We found the fish scale of Nile perch was good material to extract the good quality gelatin that have excellent gel-formable ability on the comparison with mammal gelatins for a home cooking which sold on a city market. The pre-treatment of scale by two step washings in acid- and alkaline-solution was essential to obtain the high-gelable (HG) gelatin at a higher yield, also, it was needed to carry the short time extraction at 80℃ shown in Fig.4. However, in the case of Nile tilapia scale, it was difficult to prepare the HG type gelatin by the same procedure.

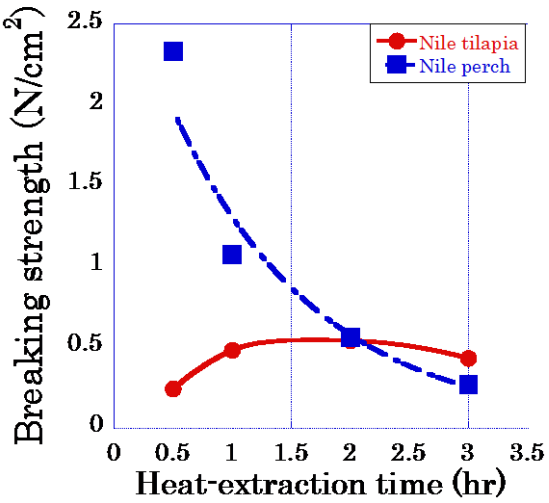



Figure 4: Changing the gel strength of 80℃-extracted gelatin obtained from Nile perch and Nile tilapia scales

The procedure of fish gelatin preparation from scale of Nile tilapia was modified. As the result, we found that the short time ultrasonic irradiation was very effective to extract the excellent gel-formable gelatin from Nile tilapia scale. The pre-treatment of the scale by two step washings in acid- and alkaline-solution elevate the gel strength of Nile tilapia gelatin up to 5 times higher, already, and the ultrasonic irradiation during the heat-extraction could elevate the gelatin gel strength, additionally, up to 4 times higher against the level without ultrasonic irradiation as shown in Fig.5. By this arrangement, the gel forming ability of Nile tilapia scale gelatin has become the commercially competitive level with that of Nile perch.

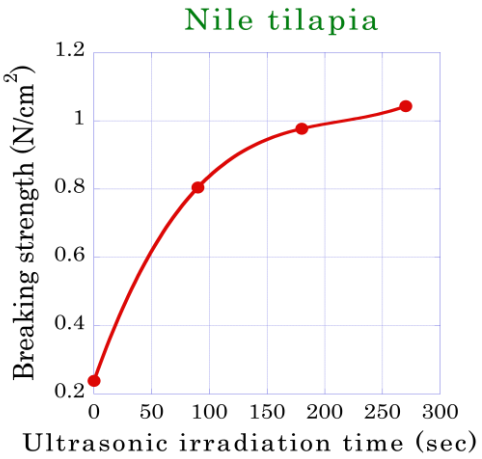



Figure 5: Effect of ultrasonic irradiation during heat-extraction on the gel strength of gelatin obtained from Nile tilapia scales

We found that 180sec of ultrasonic irradiation (50KHz, 100w) during 80℃-extraction was performed to collect the better quality gelatin that have excellent gel-formable ability on the comparison with the ordinal heat extraction method (Fig.6 right). However, the protein yield was not changed by the ultrasonic irradiation (Fig.6 left).

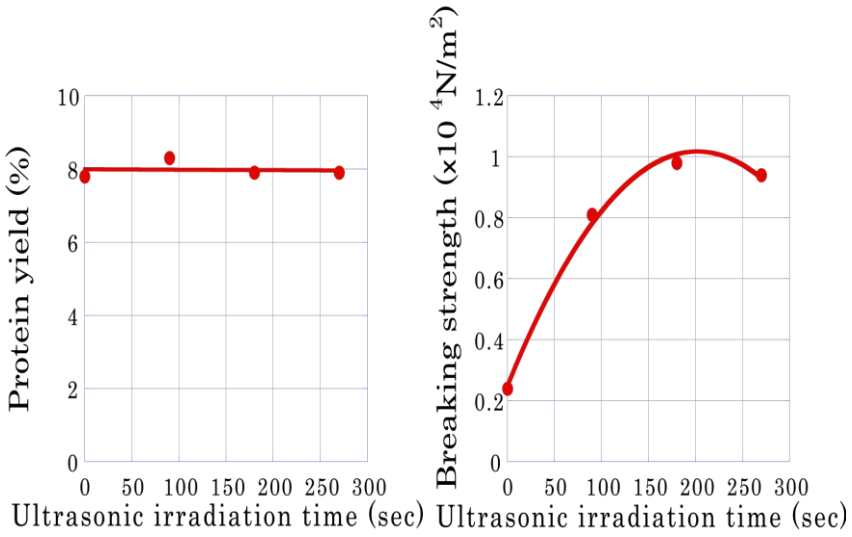



Figure 6: Protein yield and gel strength of 80℃-extracted gelatin using ultrasonic irradiation during extraction step

At that time, the protein composition (Fig. 7) of the obtained gelatin by this new method showed the slightly different pattern from the gelatin obtained by the ordinal method. The content of α1- and β- chains in the extracted gelatin fraction were clearly increased. We already found that those proteins are essential for the cold gel formation of the gelatin. Therefore, this is the reason why the superior gel strength of the gelatin obtained by the newly found method.

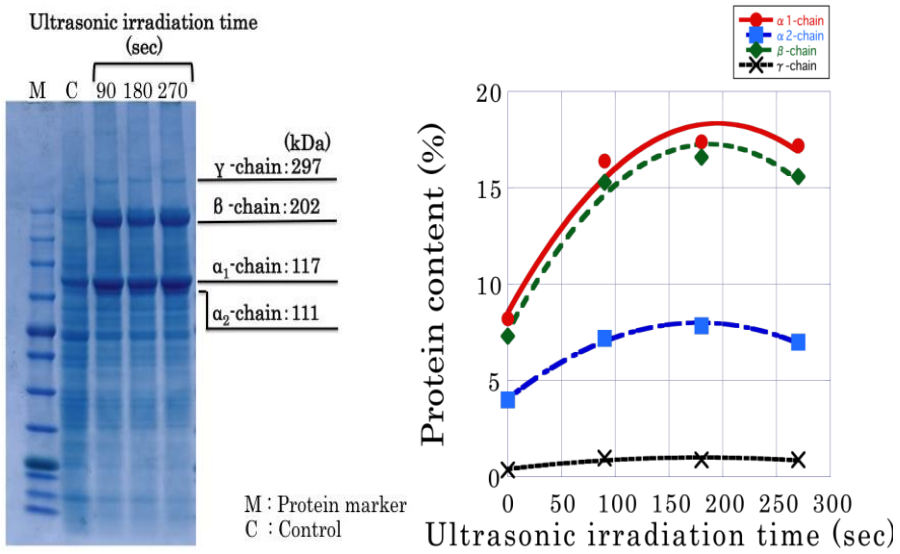



Figure 7: Protein composition of 80℃-extracted gelatin using ultrasonic irradiation during extraction step

After the investigation of the excellent method for obtaining high-gelable (HG) gelatin extracts from fish processing waste scale, the usage of the extraction residues (solid scale) are considered. To investigating of utilization of solid scale residues achieve the zero emission for the environmental loading reduction. The residue of solid scales is prospecting to be contained phosphorus and nitrogen. It may be available as a fertilizer for land plants or an additive of fish feeds. As the result, the chemical composition analysis of solid scales residues are summarized as in Table 8.

Table 8. Chemical composition of gelatin extracted residue of fish scale from Lake Victoria

| Chemicals | Content (ppm) | |
|---|---|---|
| | Nile perch scale | Nile tilapia scale |
| Total Nitrogen | 1,057 | 1,968 |
| Total Phosphorus | 1,372 | 966 |
| Potassium | 792 | 864 |

Total nitrogen in each species were more than 1,000ppm, and total phosphorus were about 1,000ppm, and also potassium was included in both powders of scale residue. Further the analysis showed that Nile perch scale residue powder had a fertilizer ratio (N-P-K) of 30-40-20 while Nile tilapia scale residue powder had a ratio of 50-20-20. Those results showed the possibility of the usage of both residue powders as complete fertilizers for plant cultivation. Nile perch residue powder can be applied in soils which are deficient in phosphate and Nile tilapia scale residue powder can be utilized in soils deficient in nitrogen due to the high each element's content in the residue. By further demonstration, the zero-disposal of fish scale waste can be achieved.

**Study 12. Fish freshness**

To assess fish freshness, we employed a portable device for measurement of impedance, which enable us to conduct non-destructive, quick and on-site assessment of freshness. In general, impedance value correlates with K-value, the traditional index of fish freshness. However, we should confirm relationship between impedance and K-value in each fish species, before using impedance for estimation of K-value. Here, we determined the impedance value and K-value during storage of Tilapia in the laboratory of Nagasaki University.

Figure 8: Measurement of impedance using the portable device

Results: We found negative correlation between impedance and K-value during storage of Tilapia for 6 days. These data will contribute on-site estimation of freshness using the device.

## TASK FORCE COMMITTEE

A task force committee is responsible the technical and scientific aspects of the project. The members are particularly task to plan research activities, review research progress and deliberate and deliberate on problems encountered during the course of the project. The members convene the meeting once every quarter.

| | | | |
|---|---|---|---|
| Chairman : | Prof. C. Ouma | | |
| Secretary : | Prof. W. Otieno | | |
| Members: | Prof. Y. Ichinose | Prof. A. Tada | Prof. T. Itayama |
| | Prof. J. Jondiko | Prof. Y. Matsushita | Dr. C. Kowenje |
| | Prof. E. Waindi | Dr. D. Owiti | |

Task Force Committee Meeting last 8th June 2016

Meetings were held during the following dates:

| No. | Date | Time | Venue |
|---|---|---|---|
| 1 | 4/4/2014 | 9:00 – 13:20 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 2 | 23/6/2014 | 14:20 – 17:30 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 3 | 1/10/2014 | 9:30 – 12:25 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 4 | 14/1/2015 | 12:30 – 15:38 | NUITM Conference Room Nairobi |

| | | | |
|---|---|---|---|
| 5 | 12/5/2015 | 9:12 – 13:00 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 6 | 5/7/2015 | 9:27 – 13:06 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 7 | 25/9/2015 | 9:15 – 12:58 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 8 | 7/1/2016 | 9:22 – 15:38 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 9 | 20/3/2016 | 9:41 – 14:32 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 10 | 8/6/2016 | 9:46 – 13:32 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |

## ADMINISTRATIVE COMMITTEE

An administrative committee was also created to deal with the administrative and financial issues of the project. Specifically, the committee is tasked to plan administrative and financial services, as well as planning of procurement and maintenance of the assets of the project. Members are also tasked to review the financial performance of the project as well as develop a financial strategy for fund management.

Chairman : Prof. Y. Seko

Secretary : Prof. W. Otieno

Members: Ms. Y. Saito, Mr. P. Odhiambo, Mr. R. Onyancha

Administrative committee meeting last 16th March 2016

Members usually convene before the task force meeting. The following are the dates and venue of the meeting:

| No. | Date | Time | Venue |
|---|---|---|---|
| 1 | 2/4/2014 | 8:30 – 12:30 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 2 | 9/6/2014 | 8:30 – 11:00 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 3 | 23/7/2014 | 8:30 – 11:50 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 4 | 16/9/2014 | 8:45 – 10:50 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 5 | 5/1/2015 | 9:15 – 12:30 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 6 | 5/5/2015 | 9:47 – 12:27 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 7 | 30/6/2015 | 8:30 – 12:00 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 8 | 10/9/2015 | 9:05 – 11:20 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 9 | 26/10/2015 | 9:22 – 12:07 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 10 | 8/12/2015 | 8:30 – 12:00 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 11 | 16/3/2016 | 9:25 – 11:54 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 12 | 3/6/2016 | 9:20 – 13:30 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |
| 13 | 5/7/2016 | 8:30 – 12:00 | LAVICORD Office, 3rd Floor Wing A Varsity Plaza, Kisumu |

## MEETINGS/CONFERENCES

Launching ceremony of the project was conducted last 3rd February 2014 at Kisumu Hotel, Kisumu. A total of 154 participated including governors, Professors and staff of both Nagasaki and Maseno University. Also scientist and administrators of Kenya Marine Fisheries Research Institute and Professors and staff of Moi University were also present.


Group picture of the participants during the kick-off meeting

After one-year, LAVICORD hold the first scientific conference in Kisumu Hotel, Kisumu on 11th May 2015. During the conference supervisors, research interns presented the progress of their studies. The result of the conference was published as a booklet "Tracking One Year Progress"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Participants during the 1st scientific conference

A second conference was held last Kisumu Hotel, Kisumu on 7th June 2016. During the conference, each component presented the results of their two-year research. This time, stakeholders including Beach Management Units (BMUs), and other local officials are also present. A total of 45 participants came. The result of the conference was published as a booklet "Providing solutions towards sustainable fish production and provision of clean water from Lake Victoria.

Participants of the 2nd scientific conference

Closing ceremony of the project was held last 22nd July 2016 at Acacia Premier Hotel in Kisumu. A total of 88 guests participated including representative from the Ministry of Environment, Water and Natural Resources and Embassy of Japan as well as governors of different counties, Professors and staff of both Nagasaki and Maseno University. Also scientist and administrators of Kenya Marine Fisheries Research Institute and Professors and staff of Moi University were also present. Each component presented their achievements through oral and poster presentations. A video presentation of the achievement of LAVICORD was shown. A panel discussion of way forward was held in the afternoon session. A day after the conference, an excursion to show our project sites was organized. The result of the symposium is published in "Two years progress report and a symposium on Lake Victoria fisheries, water and ecosystem"


A group photo of participants during the LAVICORD's closing ceremony with Lake Victoria on the background

Professors viewing the posters

Guest visited our Nile perch cage in Mageta

# LAVICORD IN ACTION


*Collaborators have a side trip to equator after visiting Maseno University*

*Collaborators in planning session*

*.....off for water sampling*

*Fishing gear inspection*

*Counting and packing of fish fry*

## LAVICORD IN ACTION

*Our product: samaki roll, samaki stick and samaki ball*

*Fish cake made from tilapia and nile perch and the process on how to make it*


*...we presented our product during Japanese festival in Nairobi*

## LAVICORD IN ACTION

*LAVICORD is particularly interested in the biology, ecology and culture of Nile perch and omena*

## LAVICORD IN ACTION

*.....we brought our visitors and stakeholders to our research sites*

# LAVICORD IN ACTION

our bio-fence produced clean and clear lake water for the people of Ogal beach

## LAVICORD IN ACTION


in addition to fish we also produced organic vegetables in our aquaponics system

Gut content analysis

Our research interns visited fish market and undergo further training in Japan

**LAVICORD and RESTECH STAFF IN KISUMU**

## MEMBERS OF LAVICORD

### Steering Committee

| *Name* | *Affiliation* | *Position in Lavicord* | *Date* |
|---|---|---|---|
| Prof. D. Makawiti | Maseno University | Chair | 2014/2/1 – 2/28/2016 |
| Prof. J. Nyabundi | Maseno University | Chair | 2016/3/1 – 8/31/2016 |
| Prof. J. Jondiko | Maseno University | Member | 2014/2/1 – 3/1/2016 |
| Prof. J. Chacha | Maseno University | Member | 2016/3/1 - 8/31/2016 |
| Prof. Y. Seko | LAVICORD | Member | |
| Ms. Y. Saito | NUITM | Member | |
| Prof. C. Ouma | Maseno University | Member | |
| Prof. W. Oteino | RESTECH | Secretary | |

### Task Force Committee

| *Name* | *Affiliation* | *Position in LAVICORD* | *Date* |
|---|---|---|---|
| Prof. D. Makawiti | Maseno University | Chair | 2014/2/1 – 2/28/2016 |
| Prof. J. Nyabundi | Maseno University | Chair | 2016/3/1 – 8/31/2016 |
| Prof. C. Ouma | Maseno University | Member | |
| Dr. R. Lesiyampre | MOEWNR | Member | 2014/2/1 – 2/28/2016 |
| Prof. Y. Ichinose | Nagasaki University | Member | |
| Prof. A. Tada | Nagasaki University | Member | |
| Prof. T. Itayama | Nagasaki University | Member | |
| Prof. Y. Matsushita | Nagasaki University | Member | |
| Prof. J. Jondiko | Maseno University | Member | |
| Dr. C. Kowenje | Maseno University | Member | |
| Dr. D. Owiti | Maseno University | Member | |
| Prof. Y. Seko | LAVICORD | Observer | |
| Prof. J. Jondiko | Maseno University | Member | 2014/2/1 – 3/1/2016 |
| Prof. J. Chacha | Maseno University | Member | 2016/3/1 – 8/31/2016 |
| Prof. Y. Seko | LAVICORD | Member | |
| Ms. Y. Saito | NUITM | Member | |
| Prof. W. Oteino | RESTECH | Secretary | |

**Administrative Committee**

| *Name* | *Affiliation* | *Position in LAVICORD* | *Date* |
|---|---|---|---|
| Prof. Y. Seko | LAVICORD | Chair/Finance Manager | 2014/2/1 – 10/31/2015 |
| Ms. R. Chesang | Maseno University | Officer | |
| Mr. E. Kitati | Maseno University | Member/Finance Member | 2015/11/1 – 8/31/2016 |
| Mr. P. Odhiambo | Maseno University | Member/Registrar | |
| Ms. Y. Saito | NUITM | Member/HR Manager | |
| Prof. W. Otieno | RESTECH | Secretary/Advisor | |

**Component 1**

| *Name* | *Affiliation* | *Position in LAVICORD* | *Date* |
|---|---|---|---|
| Prof. A. Tada | Nagasaki University | Supervisor | |
| Prof. J. Jondiko | Maseno University | Coordinator | 2014/2/1 – 3/1/2016 |
| Ms. R. Owiga | Maseno University | Deputy Coordinator | |
| Prof. H. Nakata | Nagasaki University | Deputy Supervisor | |
| Dr. A. Morikawa | LAVICORD | Research Coordinator | |
| Mr. S. Omari | LAVICORD | Research Intern | |
| Ms. L. Otoigo | LAVICORD | Research Intern | |
| Ms. G. Shisanya | LAVICORD | Research Intern | |

**Component 2**

| *Name* | *Affiliation* | *Position in LAVICORD* |
|---|---|---|
| Prof. T. Itayama | Nagasaki University | Supervisor |
| Dr. C. Kowenje | Maseno University | Coordinator |
| Dr. S. Sitati | Moi University | Deputy Coordinator |
| Prof. A. Tanabe | Nagasaki University | Deputy Supervisor |
| Prof. Y. Shibata | Nagasaki University | Deputy Supervisor |
| Dr. A. Morikawa | LAVICORD | Research Coordinator |
| Mr. J. Outa | LAVICORD | Research Intern |
| Mr. N. Outa | LAVICORD | Research Intern |
| Mr. E. Mudalungu | LAVICORD | Research Intern |
| Mr. G. Onyango | LAVICORD | Research Intern |

**Component 3**

| *Name* | *Affiliation* | *Position in LAVICORD* |
|---|---|---|
| Prof. Y. Matsushita | Nagasaki University | Supervisor |
| Dr. W. Ojwang | KMFRI | Coordinator |
| Mr. K. Werimo | KMFRI | Coordinator |
| Prof. A. Hagiwara | Nagasaki University | Deputy Supervisor |
| Prof. Y. Sakakura | Nagasaki University | Deputy Supervisor |
| Prof. O. Arakawa | Nagasaki University | Deputy Supervisor |
| Assoc Prof. Ichikawa | Nagasaki University | Deputy Supervisor |
| Dr. H. Marcial | LAVICORD | Research Coordinator |
| Ms. K. Kito | LAVICORD | Research Coordinator |
| Mr. N. Outa | LAVICORD | Research Intern |
| Mr. E. Yongo | LAVICORD | Research Intern |
| Mr. E. Achiro | LAVICORD | Research Intern |
| Ms. E. Odera | LAVICORD | Research Intern |