Forum for Nuclear Cooperation in Asia (FNCA)
Electron Accelerator Application Project

Summary of the Workshop

Meranti Hotel & Philippine Nuclear Research Institute (PNRI)
the Philippines
8th - 11th February 2016

1) Outline of Workshop

i) Date	8th - 11th February 2016
ii) Venue	Meranti Hotel, Quezon Philippine Nuclear Research Institute (PNRI), Quezon
iii) Host Organisation	Philippine Nuclear Research Institute (PNRI), the Philippines and Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT)
iv) Participants	Eighteen (18) participants from eight (8) FNCA member countries: Bangladesh, Indonesia, Japan, Kazakhstan, Malaysia, Mongolia the Philippines and Thailand
v) Programme	**Annex 1**

2) Workshop Programme

Opening Session (8 February)

The workshop was attended by experts on applications of electron accelerator and radiation processing of natural polymers from the FNCA participating countries namely Bangladesh, Indonesia, Japan, Kazakhstan, Malaysia, Mongolia, the Philippines and Thailand. The list of participants of the workshop is attached in **Annex 2**.

Dr Dela Rosa, Ms Aoki and Dr Namba, each gave a welcoming speech and hoped for a fruitful discussion during the workshop. The participants then briefly introduced themselves.

Session 1: Overview of FNCA

Dr Namba reported on the progress of FNCA projects during JFY2015. In addition to the major decisions made during the last Ministerial Level Meeting held in December 2015, the highlights and achievements of on-going FNCA projects, especially of radiation utilization projects including Electron Accelerator Application Project were enumerated.

Dr Masao Tamada, Director General of Takasaki Advanced Radiation Research Institute, Japan Atomic Energy Agency (JAEA) presented history, achievement and challenges of the project. Electron accelerator application project in FNCA has two major research subjects, one on plant growth promoter (PGP) and the other on super water absorbent (SWA). High quality PGP is produced by radiation-induced degradation of natural polysaccharides such as chitosan and carrageenan. These environmentally friendly PGP products showed significant enhancement of yield on various crops like rice & chili in field tests. Synergetic effect of PGP and biofertilizer was observed in preliminary experiments. In the phase 5, from 2015FY to 2017FY, the project intends to commercialize PGP in all participating countries by addressing the challenges and obstacles for its technology transfer. New applications of degraded polysaccharides or new research will be considered after PGP commercialization. A new guideline for end users of PGP is planned to be uploaded on FNCA home page with the addition of new data. Promising collaboration between PGP project with other FNCA projects, such as biofertilizer and mutation breeding, will be arranged. SWA prepared by crosslinking of natural polysaccharides or grafting of hydrophilic monomer onto natural polysaccharides is applicable as soil conditioner, especially to maintain the water content of soil in arid areas. Mixing of SWA with sandy soil enhanced the germination percentage of various crop seeds. Field test of SWA showed decreased in watering frequency in sandy soil. SWA performance and cost effectiveness will be evaluated in arid soil condition to estimate the possibility of commercialization in participating countries. Simultaneously, new applications for SWA after commercialization as soil conditioner will be explored.

At the first session's discussion, Dr Darmawan Darwis from National Nuclear Energy Agency (BATAN), Indonesia, recommended that application of PGP to a specific plant should be evaluated to get the suitable concentration with maximum yield, due to different plant and soil conditions. It was agreed that suitable concentration for selected plant will be included in the FNCA Guideline for PGP.

Session 2: Country Report on Challenges in Commercialization of Plant Growth Promoter (PGP)

Four (4) FNCA member countries, namely Bangladesh, Kazakhstan, Mongolia and the Philippines, have on-going activities towards commercialization of PGP. The summaries of the reports are attached as **Annex 4 Part A, A-1**.

Each member country is facing different types of problems or obstacles during research and development as well as in commercialization. Bangladesh is still in research and plot trial, whereas Philippine is already in pre-commercialization stage. Kazakhstan and Mongolia are facing problems on the source of raw materials to produce oligochitosan PGP and very short planting period, only 3-4 months during summer to do trial field which could affect collection of enough data to optimize application of PGP. Both member countries were advised to conduct studies based on the established protocol of application and to choose the right crop before trial test. They can request for cooperation from the agricultural ministry in their country and for suggestions on suitable crop and small plot trial. Indonesia already offered the use of PGP developed by their Institute to Kazakstan for field trial.

In conclusion, each member country demonstrated a common beneficial effect of PGP that there is a significant increase in the yield of chosen crop.

Session 3: Obstacles in Commercialization of PGP

In Session 3, Dr Salma Sultana from Bangladesh Atomic Energy Commission (BAEC) made a lead speech by wrapping up previous two sessions. She summarized the various obstacles faced by each member country as follows:

Kazakhstan and Mongolia

1. No available raw material source or supplier of chitosan in the country to prepare oligochitosan
2. In one year, there are only few months to conduct planting/testing that is from June to September (temperature ranging 15 to 27^{o}C)
3. Limited facilities to irradiate chitosan, human resources, and financial/budget to start experiment (Mongolia)

Bangladesh

1. Difficult to make collaboration with agriculture institute
2. There are commercialized PGP from other source as competitor

The Philippines

1. PNRI needs to meet the demand of more than 600,000 L of oligocarrageenan PGP for the multi-location field tests
2. PNRI can only produce 6,720L/month and there is a need for new production method using the Electron Beam facility (2.5 MeV, 100kW)
3. Technical problems in bulk preparation of KC due to high viscosity and formation aggregates or lumps when poured directly into water.

After the discussion, some suggestions were laid down to overcome the obstacles for commercialization of radiation-processed chitosan or carrageenan as PGP and plant elicitor:

<u>Kazakhstan and Mongolia</u>

1. Use the oligochitosan PGP product developed by member states (Indonesia or Malaysia) for a specific plant in green house scale.
2. Determine potential and specific crop to be used for the test.
3. For future activities, chitosan can be purchased from China or Russia.

<u>Bangladesh</u>

1. Collaboration with biofertilizer group is needed in order to get better results and able to compete with other commercialized PGP.

<u>The Philippines</u>

1. Change in production process from gamma irradiation to electron beam irradiation.
2. Some activities should be done such as evaluate the dose distribution, setting dose to get the same results as gamma irradiation, alternative procedure for dissolution of carrageenan.

Session 4: Country Report on New Research and Follow-up of Commercialized PGP

Three (3) FNCA member countries, namely Japan, Malaysia and Thailand, have already achieved commercialization of PGP, while Indonesia is in the semi-commercial stage. The summaries of the reports are attached as **Annex 4 Part A, A-2**.

Questions related to application for patent and product permission were raised. In Indonesian case, registration of PGP is required and the name of product should not be the same as the original material. Registration is not needed for PGP in Thailand. For processing of PGP, Japan has noted that irradiation with 1% of hydrogen peroxide solution will enhance degradation of chitosan based on computer simulation. In Thailand and Malaysian case, 2% and 30% of ethanol, respectively, were added after irradiation of PGP solution in order to prolong shelf-life.

Session 5: Commercialization of PGP, and Tasks/Challenges and Current Situation of New Research (9 February)

In this session, Dr Darwis took a lead speech about the commercialization of PGP, tasks, challenges and the current situation of new research. He summarized the commercialization stages of PGP in member countries, including the market prices and specifications. He also expressed the big gap in the activities of member countries citing that Mongolia and Kazakhstan are still in R&D stage while others have achieved field test and commercialization. Countries in advanced stage have a role in supporting Mongolia and Kazakhstan to speed up their activities. One recommendation is to use PGP produced by Indonesia and follow FNCA Guideline for their identified plant. It was recommended for Mongolia to obtain oligochitosan from the Vietnam group.

During the discussion, it was acknowledged that the new semi-batch process of PGP production using EB in the Philippines is a promising method for mass production. Other member countries mentioned that solid state irradiation of chitosan for large scale production seems to be a more practical method in terms of handling and transportation to end users.

Session 6: Country Report on Hydrogel Super Water Absorbent (SWA)

Six (6) FNCA member countries, namely Bangladesh, Indonesia, Kazakhstan, Malaysia. Mongolia and the Philippines, presented their on-going activities to achieve commercialization of SWA. The summaries of the reports are attached as **Annex 4 Part B, B-1**.

Session 7: Country Report on SWA and Future Possibilities and Needs Analysis

Two (2) FNCA member countries that have already achieved commercialization of SWA, namely Japan and Thailand presented their country reports. The summaries of the reports are attached as **Annex 4 Part B, B-2**.

Session 8: Challenges in Commercialization of SWA in Next 3 Years

The lead speech from the Philippines presented that each country has its own formulation of superwater absorbent, mainly composed of a natural polymer (carboxymethyl cellulose, sago, starch, kappa-carrageenan seaweed) grafted or crosslinked with acrylic acid. Among members aiming for commercialization, only Indonesia has advanced to field testing of SWA. Results on shallots showed increased productivity and reduced irrigation or watering frequency. The study also revealed better productivity if SWA is combined PGP treatment. Bangladesh conducted semi-field tests on tomato and eggplants and showed higher yield of both crops and lower watering frequency. For Kazakhstan and Malaysia, concrete plans to conduct field testing were targeted for this year. The Philippines, aside from continuous R&D activities, will submit a proposal to Department of Agriculture for funding in order to implement the planned semi-field and field activities. In the case of Mongolia, the material to be studied for SWA is wheat husk/straw with acrylic acid.

For countries that have commercialized SWA, Japan briefly talked about the commercialized CMC SWA, manufactured by Nissin High voltage, and its applications. Then a new application of superwater absorbent as radiation dosimeter/indicator for radiotheraphy based on hydroxypropyl cellulose was presented. Thailand presented the pilot scale production of SWA in TINT, with a capacity of 200 kg/day. A memorandum of understanding (MOU) between TINT and Thai Agriculture Cooperative will be signed on the use of SWA to solve drought crisis in the country. Challenges in the commercialization of SWA were discussed, which included scaling up of the production process, especially the drying and grinding of SWA, since much of the cost come from these processes. Other concerns were funding and strong support from Agriculture Ministry. Countries were encouraged to conduct promotional activities of radiation technology for creating agriculture products like SWA, since these activities will help increase the interest of farmers as well as potential takers of the technology.

Session 9: Guidelines on Chitosan PGP Application for Rice, Chilli and Other Crops

In this session, the draft version of PGP guideline was discussed for comments and suggestions of the member countries. Terminologies were collected to give general explanation of PGP in order not to mislead the understanding of readers. Contents were rearranged for better comprehension. In Q& A portion, frequently asked questions by the end users, especially farmers, were listed with corresponding answers. After reflecting the comments of the participating countries, this guideline will be finalized and uploaded to the home page of FNCA by the end of March, 2016.

Session 10: Coordination of the FNCA Project with RCA/IAEA Project on Radiation Processing (11 February)

Dr Marina Talib from Malaysian Nuclear Agency (Nuclear Malaysia) reported on the recent RCA activities. It was reported that RAS 1014 was properly implemented and by and large the objectives were achieved. Under the project about 50 advanced radiation grafted materials were developed in various categories namely (1) adsorbents (2) ion exchange membranes (3) catalysts (4) bioactive carriers (5) tissue scaffold (6) pervaporator membranes and (7) active packaging. FNCA project could collaborate with Myanmar, Sri Lanka and Thailand because some of their research activities are on super water absorbent for agricultural application. It was also reported that there are different stages of up-scaling of developed products among member countries. More than 100 participants were trained during RTC's in the last three years. The RAS project will be extended to the end of 2016 and member of FNCA could get benefit from the training courses and the established radiation grafting protocol.

Session 11: Planning for 5th Phase (2015-2017) and Future Plan

Current status and planning of PGP and SWA projects were summarized for application and commercialization in the 5th phase. Research and development of the projects were conducted in each member states. Malaysia has commercialized oligochitosan named as “GoGrow”. Philippines semi-commercialized oligocarrageenan named as “Carra-Vita” and distributed it freely to end-users. The member states confirmed to cooperate and exchange information to promote field test and commercialization. Thailand commercialized SWA as soil conditioner with the product name of “TINT SWA”. Member states are facing the common problems of funding shortage to conduct field tests and launch the applied research. See attached **Annex 5**.

Session 12: Summary

The Workshop summary was adopted with some modifications by the participants.

Closing Session

The workshop was officially closed by Dr Dela Rosa and Dr Namba.

Open Seminar: “Applications of Radiation Technology to Support Sustainable Development” (10 February)

The Open Seminar titled “Applications of Radiation Technology to Support Sustainable Development” was held in Philippines Nuclear Research Institute (PNRI) on 10th February. The seminar was attended by around 50 participants from research institutes and universities in agricultural and industrial fields in the country.

First, Dr Alumanda Dela Rosa, Director of PNRI gave a welcoming speech and explained about structure and achievements of FNCA. Next, Ms Moe Aoki, Researcher of Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) and Dr Hideki Namba, FNCA Advisor of Japan also gave an opening speech and expressed deep gratitude to PNRI for holding the Open Seminar and hoped the participants enjoy the seminar. Four (4) presentations were delivered by scientists from Philippines (2), Japan (1) and Thailand (1). The summary of the Open Seminar is attached as **Annex 3**.

Technical Visit

The participants visited the Philippine Nuclear Research Institute (PNRI) Gamma and Electron Beam Irradiation Facilities. Ms. Haydee Solomon, Officer-in-charge of the facility, gave an orientation about the Gamma Semi-Commercial and Mutlipurpose Facility and enumerated the materials being processed in that facility. Next stop was the Electron Beam Irradiation Facility, which was only launched last December 2014. The facility which has EB accelerator of 2.5 MeV and 100 kW power is currently utilized for R&D activities on radiation processing of different polymeric materials. A video presentation was shown to the participants regarding the operation of the EB facility and potential products that can be processed. The production of carrageenan, from preparing of solution to dispensing to the liquid handling system, was also demonstrated. Lastly, the participants went to the Radioisotopes Laboratory and learned about the different activities being done in the laboratory.

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Conclusion and Recommendations

- PGP and SWA as products in electron accelerator application project can give the economical benefit to participating countries in terms of yield increment of crops and vegetables.
- FNCA meeting is an information exchange meeting supported by MEXT, which has played the significant role of promotion for commercialization of PGP and SWA although funding for research and field test for plant growth and productivity in participating countries is the driving force for the data acquisition for applications of PGP and SWA.
- Recommendation of coordinators' meeting held in March 2015 was informed to each project leader. The recommendation is to commercialize PGP in all participant countries in phase 5 (2015 – 2017). Participating countries discussed the effective strategies for the commercialization of PGP.
- To clarify the obstacles and problems for commercialization stage of SWA, participating countries discussed the implementation plan for phase 5.
- Collaborative works with agriculture sector such as agricultural institute and FNCA projects of biofertilizer and mutation breeding are strongly recommended to promote the commercialization of PGP and SWA.

Outcomes and planning are listed in the following table. (Pp12-23)

[PGP]

<u>Noteworthy achievements</u>

- Process development of PGP synthesis for field test was reported by Thailand. The capacity of production of oligochitosan PGP in batch irradiation of gamma ray is 50,000L/month.
- Philippines produced carrageenan PGP in semi-commercial scale. Initial production was in Gamma irradiation Facility. Test production is being conducted at the Electron Beam Facility to meet the 600,000 liters needed for multi-location testing, with a total test area of 37,000 hectares.

<u>Recommendation to the countries of ongoing commercialization</u>

- Bangladesh will start the collaborative work with biofertilizer group to increase yield of crops.
- Installation of irradiation facility in Mongolia is recommended for the radiation-induced degradation treatment of chitosan with government financial support.

- Short planting period (June - September) in Kazakhstan and Mongolia needs growth acceleration to mature stage of plants. In this viewpoint, the adequate plant will be selected by pot tests. Chitosan will be bought from China for Kazakhstan.

Conclusion of countries commercializing PGP

- PGP prepared by the irradiation facility in the research institutes has been supplied to end-users by suppliers.
- Collaborative work with biofertilizer project has proceeded in Indonesia and Japan.
- Malaysia has applied PGP to the new variety rice obtained by mutation breeding.
- Japan can estimate the optimum condition of dose and material properties for chitosan degradation by the simulation program. Request of participanting countries will be accepted.

Guideline on PGP application

- Contents of the guideline draft was reconsidered by the viewpoint of end-users. Q&As were listed to respond to expected inquiries from end-users. The guideline will be finalized by end of March 2016 and will be uploaded to FNCA home page.

[SWA]

Noteworthy achievements

- Production plant of SWA was established in Gamma Irradiation Facility in Thailand with the capacity of 200 kg/day.
- New application of SWA as dosimeter/indicator for cancer therapy was investigated using HPC hydrogel by Japan.

Conclusion and Recommendation

- Cost effectiveness should be evaluated to promote the commercialization of SWA.
- Drying and grinding contribute to the costly process for SWA production. In commercial scale, production method should be developed to realize the cost effectiveness of radiation processing technology.
- Capacity building of SWA preparation by radiation processing is necessary to launch the applied research in Mongolia.