Report of Study Group on Radionuclide Science in the North Pacific Ocean

Introduction

The PICES Study Group on *Radionuclide Science in the North Pacific Ocean* (SG-RS) convened a workshop on "*Radionuclide Science and Environmental Quality of Radiation in the North Pacific*" from March 14–15, 2013, in Xiamen, China, under the chairmanship of PICES Science Board (SB) Chairman Dr. Sinjae Yoo, PICES MEQ (Marine Environmental Quality Committee) Chairman, Mr. Chuanlin Huo, and SG-RS Chairman Dr. Yusheng Zhang. The workshop was jointly sponsored by PICES and the State Oceanic Administration (SOA) of China, and organized by the Third Institute of Oceanography, SOA. Twenty participants attended the workshop including 8 SG-RS members from 5 PICES member countries: Canada, China, Japan, Korea and the United States (*SG-RS Endnote 1*). The member from Russia was unable to attend. Besides Dr. Yoo and Mr. Huo, the IAEA/RCA leading country coordinator (LCC), Dr. Ronald Szymczak, was invited to attend the workshop.

The workshop had multiple objectives (*SG-RS Endnote 2*), including to present the research status on marine environmental quality of radiation in each PICES member country, to exchange views on how to develop a scientific focus within PICES on understanding the quantities and distributions of radionuclides in the North Pacific, and to refine the terms of reference and Action Plan for the proposed PICES Working Group on *Assessment of Marine Environmental Quality of Radiation around the North Pacific* (WG-AMR).

SG-RS Chairman, Dr. Zhang, introduced China's proposals to establish the SG-RS in PICES and to hold a PICES workshop in Xiamen. He pointed out that the widespread application of nuclear science and technology and a recent nuclear power plant accident had led to increasing amounts of radionuclides released into the North Pacific. In addition, the long half-life radionuclides could potentially endanger the marine ecosystem, including human health through food chain exposures. Consequently, it is important to monitor the radiation exposure level and assess the effects of radioactive substances on marine ecosystems in the North Pacific waters. Therefore, China proposed to establish a WG-AMR to exchange technologies and share experiences on the monitoring of radioactive contaminants in North Pacific waters, to assess the radiation effects and radiological risks in these waters and to promote the public understanding of radiation effects. The outcome from this workshop is intended to provide a sound foundation for the future establishment of WG-AMR.

AGENDA ITEM 2
Status of research on marine environmental quality of radiation

Presentations were made by participating members and by the invited representative from IAEA (International Atomic Energy Agency) LCC. Key points of their presentations are listed below.

IAEA LCC

Dr. Ronald Szymczak presented the research status on environmental quality of radiation and quality/risk assessment around the North Pacific: A post-Fukushima analysis project under the auspices of the IAEA. He highlighted that:

- In the North Pacific there is a legacy of 'background' radioactivity from nuclear testing in the 1950s and 1960s and from ocean dumping activities before 1972.
- The 2011 Fukushima Dai-ichi nuclear power plant accident was the largest accidental release of radioactivity to the marine environment (in the North Pacific).
- North Pacific Ocean currents will transport the plume eastwards from Fukushima but dilution/dispersion will soon reduce the radioactivity concentrations.
- Food web transfer may result in future elevated radionuclide levels in certain species.

- Local/site-specific studies are needed to develop regionally appropriate ecological risk analyses and response plans for possible future events.
- Naturally-occurring polonium-210 may be a significant radionuclide of concern to North Pacific ecosystems.
- Apart from localized coastal impacts in Japan, the 2011 accident poses no significant radiological threat to marine ecosystems in the North Pacific region.

Canada

Dr. John Smith carried out the monitoring and analysis of radioactivity in the eastern North Pacific and Arctic Oceans and reported that:

- 137Cesium (^{137}Cs) levels in the upper 1000 m measured in June 2011 along Line-P at stations P4 and P26, located 100 and 1500 km, respectively, off the Canadian west coast, were consistent with background levels throughout the North Pacific from atmospheric nuclear weapons tests in the 1950s and 1960s.
- 134Cesium (^{134}Cs) from Fukushima was detectable in the upper 50 m at station P26 in June 2012, but not at station P4. Inferred levels of ^{137}Cs from Fukushima, based on ^{134}Cs concentrations, were about 0.3 Bq/m^3.
- The timing of the arrival of Fukushima ^{137}Cs at station P26 precedes model predictions for oceanic transport, so a significant inventory of ^{137}Cs must have been deposited from the atmosphere and then transported by advection to station P26.
- Atmospheric transport of Fukushima ^{137}Cs into the Arctic Ocean may also have occurred. Samples collected in the Arctic in September 2012 are being evaluated.

China

During the past 2 years, China has undertaken four cruises to measure environmental radioactivity in the North Pacific. Concentrations of a wide range of radionuclides, including ^{137}Cs, ^{134}Cs, ^{90}Sr, ^{110m}Ag, ^{60}Co, *etc*. in surface seawater and biota were measured. The radiological risk for the marine ecosystem was assessed as well. The results showed that radioactivity of surface seawater decreased during the past 2 years, but the signal for radioactivity releases from the Fukushima accident was still detectable. Moreover, the concentration of some radionuclides in marine biota, especially ^{110m}Ag in squids, had increased. This is a subject that should get more attention in future research. Finally, more inter-laboratory comparisons of proficiency-testing activities and international cooperation on marine radioactivity monitoring were proposed.

Japan

The accident at TEPCO's Fukushima Dai-ichi Nuclear Power Station (1FNPP) released a large amount of anthropogenic radionuclides into the environment. More than 80% of the radionuclides was either blown offshore or discharged directly into the ocean from waters used to cool the reactors. It was reported that significant concentrations of anthropogenic gamma-emitting radionuclides, such as ^{131}I, ^{134}Cs, ^{137}Cs, ^{129m}Te, ^{110m}Ag, ^{95}Nb, and ^{125}Sb were detected from seabed sediments located at the eastern end of Honshu, the main island of Japan. Since most of the radionuclides have short half-lives, their activity soon declined to below detection limits. Therefore, the two isotopes of radiocesium, ^{134}Cs and ^{137}Cs, have been monitored from a viewpoint of radiological dose assessment. However, the concentrations of radiocesium in seawater had been diluted and rapidly decreased.

Korea

Researchers took samples of seawater, suspended particulate matter, bottom sediment, and biota (zooplankton, fish, shellfish and macro algae) in the sea and analyzed the key radionuclides (^{134}Cs, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239+240}$Pu, ^{210}Po, ^{210}Pb and others) in their onshore laboratory. Korea does not have national radiation quality standards for seawater, marine sediment and marine biological organisms. However, there is a radiation threshold for food to be sold in the market that is 375 Bq of total ^{134}Cs and ^{137}Cs per kg of food in wet weight. Current programs for the monitoring and assessing of marine environmental radiation quality in the North Pacific included field sampling programs in the Yellow Sea, East China Sea, East/Japan Sea, Northwest

Pacific, and laboratory programs including experiments on the uptake and release of radionuclides by marine biota in aquaria.

United States

On the large ocean scale, radionuclides with large atmospheric fallout terms (^{137}Cs, ^{90}Sr, ^{3}H, ^{14}C) are found to be mostly concentrated in the well-mixed surface layer of the ocean (0 m to ~1000 m). With the combination of upwelling, downwelling and turbulence introduced at the coastal margins of the North Pacific, and the mixing action of the currents that form the North Pacific Gyre, these radionuclides are found at higher concentrations towards the center of the gyre than at the margins for any given depth. There is a small westward trend in the peak concentrations at lower and lower depths. Plutonium and americium are more heterogeneously distributed in the North Pacific. Peak activities are usually found near the bottom of the euphotic zone, then dissolve back into solution as organic particulate matter sinks. A few locations exhibit a small secondary peak activity concentration near the bottom of the ocean. ^{210}Pb shows a similar pattern, but with the peak concentrations near the bottom of the ocean approaching the concentrations seen at the peak of the euphotic zone due in large part to ^{222}Rn emissions from the ocean bottom. ^{210}Po appears heterogeneously distributed; there are few measurements below the surface in the data presented here. All other radionuclides lacked sufficient data to discuss their distribution across the Pacific for a given period of time.

Discussion

Following the presentations and discussion, the workshop participants agreed that knowledge gaps do exist with respect to effective radiological risk analysis in the ecosystems of the North Pacific and that the proposed WG-AMR would contribute to a better understanding of the quantities and distributions of radionuclides in the North Pacific and their impact on ecosystem health.

AGENDA ITEM 3

Proposal for a Working Group on *Assessment of Marine Environmental Quality of Radiation around the North Pacific*

The terms of reference for the proposed WG-AMR were developed in consideration of their relevance to the second PICES integrative science program, FUTURE (**F**orecasting and **U**nderstanding **T**rends, **U**ncertainty and **R**esponses of North Pacific Marine **E**cosystems), and the Action Plan of MEQ, the parent committee.

FUTURE

FUTURE was inaugurated in 2009. This new science program is expected to generate a wealth of information and understanding about how ecosystems respond to changes during its life span of 10 years. Currently active expert groups that contribute to FUTURE include four Sections, five Working Groups and two Study Groups. The program is organized around three key questions that were developed by PICES scientists and adopted by the Organization as declarations of priorities for FUTURE research activities:

1. What determines an ecosystem's intrinsic resilience and vulnerability to natural and anthropogenic forcing?
2. How do ecosystems respond to natural and anthropogenic forcing, and how might they change in the future?
3. How do human activities affect coastal ecosystems and how are societies affected by changes in these ecosystems?

MEQ Action Plan

The MEQ mission is to:

- Promote and coordinate interdisciplinary scientific research on marine environmental quality;
- Improve understanding of the ecological effects of marine pollution on valued resources with emphasis on the sources and fates of environmental contaminants (including radionuclides), harmful algal blooms, marine aquaculture, and non-indigenous species;
- Increase societal awareness about human uses and influences on North Pacific marine and coastal ecosystems.

Radionuclides are listed among the proposed focus areas of MEQ. What does MEQ suggest to be done on marine environmental quality of radiation? It was suggested that the work plan for WG-AMR include: inter-calibration of NIT (Nuclear Isotopic Techniques); exchange of assessment methods of marine environmental quality of radiation; assessment of the current marine environmental quality of radiation of the North Pacific; and collaboration on databases of MEQR (marine environmental quality of radiation) experts.

Canada

The following terms of reference for the proposed WG-AMR was suggested by Dr. John Smith:

1. To review the past and ongoing studies on radioactivity (natural and artificial) in the Pacific Ocean including both pre and post-Fukushima information; consider linkages with and downstream effects in the Arctic Ocean.
2. To summarize and review the current understanding of radioactivity levels in North Pacific environmental phases (sediments, seawater, biota, atmosphere) providing supporting and supplementary radionuclide data and reference materials.
3. To evaluate sources of significant radiological doses to environmental organisms and humans; compare the magnitudes of exposure from artificial and natural sources of radionuclides.
4. Marine ecosystems are impacted by multiple stressors (temperature, ocean acidification, hypoxia/ eutrophication, *etc*.) which can affect ecosystem function, structure and dynamics in complex ways; do changing patterns of radioactivity constitute an additional stressor that should be included in ecosystem models for the North Pacific?
5. To develop conceptual frameworks and low-order process-based models for the cycling of radionuclides through the North Pacific environmental compartments, which can be used by health physicists to predict radiological doses and by ecosystem scientists to explore hypotheses linking ecosystem dynamics to variability in the natural and anthropogenic radiation environments.
6. To promote international collaboration among PICES member countries for exchanging available information on environmental radioactivity and encourage joint research surveys/research among PICES member countries.
7. To publish a final report summarizing the results, including recommendations to policy makers with regard to radiological threats posed by radioactivity levels in the Pacific Ocean to human health and the environment.

China

The following terms of reference were proposed by China (Jianhua He):

1. To discuss and implement inter-calibration of radioactive isotopic techniques in PICES member countries, such as ^{137}Cs, ^{134}Cs, ^{110m}Ag, ^{90}Sr, ^{238}U and ^{226}Ra;
2. To recommend the representative organism species in the North Pacific waters;
3. To recommend the environmental quality standards of radionuclides in seawater, marine sediment and the reference organisms;
4. To exchange and select the assessment methods of MEQR (marine environmental quality of radiation) in PICES member countries;
5. To assess the current marine environmental quality of radiation of the North Pacific waters;
6. To compile a list of existing databases of MEQR experts of the North Pacific for academic exchange;
7. To promote collaboration of PICES member countries.

The suggested WG-AMR work plan was as follows:

<u>*Year 1*</u>

- Select the concerned radionuclides and representative organisms for assessing the effects of radiation on the ecosystems in the North Pacific;
- Encourage concerned laboratories in PICES member country to perform inter-calibration of key radionuclides;
- Compile a list of existing databases of MEQR experts of the North Pacific for academic exchange.

<u>*Year 2*</u>

- Collect radioactivity for seawater, marine sediments and marine organisms;

- Implement an inter-calibration of radioactive isotopic techniques, compile a report, and then select the top three methods as the references for future work;
- Select and exchange assessment methods for marine environmental quality of radiation and distribute them to PICES member countries as the recommended procedures.

Year 3

- Undertake the assessment of marine environmental quality of radiation in the North Pacific based on the available data and the recommended methods;
- Compile a report of MEQR of the North Pacific;
- Promote public awareness and understanding of potential radiation effects.

Korea

A preliminary work plan was proposed (Suk Hyun Kim) as follows:

2013–2014

- Compile the published marine artificial radionuclides data for the entire the PICES maritime area;
- Hold a scientific conference to invite key scientists to present their findings (level, transport pathways, interaction with fisheries resources and human health);
- Collect national and international regulations on the protection of the marine environment and human health from radioactive substances from all PICES member countries;
- Collect information on the discharge of radioactivity from nuclear installations located at the coast or are discharged into the PICES marine environment.

2015–2016

- Synthesize the levels of key marine radionuclides (^{90}Sr, ^{134}Cs, ^{137}Cs, $^{239+240}$Pu, ^{210}Po, ^{210}Pb) for the main marine environmental compartments (sea water, suspended particulate matter, bottom sediment, phytoplankton, zooplankton, fish, macroalgae, *etc.*) in the PICES maritime area;
- Summarize the interaction of biota in the PICES maritime area with key radionuclides;
- Synthesize the current and potential sources discharging radionuclides to the PICES maritime area.

Japan

Japan (Takami Morita) responded to the terms of reference proposed by China by noting that they can detect only ^{134}Cs, ^{137}Cs and ^{90}Sr and used the AMP (ammonium phosphomolybdate) method for radioactive Cs. Regarding inter-calibration, he agreed with the technique in PICES member countries. As to the assessment methods of marine environmental quality of radiation, they compared the quality of radiation before the Fukushima accident. For the reference organism species in the North Pacific waters, he pointed out that the organism species from ICRP Publication 108: *Environmental Protection: the Concept and Use of Reference Animals and Plants are flatfish, crab and algae*. For the assessment of current marine environmental quality of radiation of the North Pacific waters, he mentioned that many articles had already been published. Moreover, he suggested that maybe IAEA has a database for compiling a list of existing databases of MEQR experts.

United States

Published radionuclide data gaps and research needs were reviewed (Kathryn A. Higley). An introduction to radioecology research efforts at Oregon State University was provided. Suggested research on radionuclides in the North Pacific should emphasize the following:

- developing transparent tools for radiological / radioecological assessment,
- filling hidden data gaps,
- generating scientifically robust radionuclide transfer factors,
- developing a dynamic model,
- collecting more species data.

IAEA LCC

In relation to the terms of reference for the proposed WG-AMR, Dr. Ronald Szymczak pointed out that there is a need in the Asia/North Pacific region to:

- update and manage a regional marine radioactivity database which includes natural (*e.g.*, 210-polonium) as well as artificial radionuclides;
- define/establish local representative/reference organisms for the different marine ecosystems;
- establish biological transfer factors to enable locally relevant dose assessment. Further studies on food web analysis, trophic-transfer modeling and radiation dose-effect experiments should also be considered.

Partnerships with other international groups and initiatives are also required. A recommended end-product for WG-AMR would be an Interactive Radiological Risk Map for the North Pacific – one which the public could use and understand.

Based on these recommendations, the workshop participants developed the WG-AMR terms of reference and Work Plan (included in *SG-RS Endnote 3* and *SG-RS Endnote 4*, respectively) for consideration by Science Board.

AGENDA ITEM 4
Proposed WG-AMR membership

Although some potential WG-AMR members had been recommended initially during the workshop, some member country participants suggested that it would be better to discuss the proposed working group members with their national PICES delegates. Thus, it was agreed to develop a list of proposed WG-AMR members in two weeks after the workshop, which led to the list of WG-AMR members proposed in *SG-RS Endnote 5*.

AGENDA ITEM 5
Feedback to MEQ

Suggestions were made for MEQ's Action Plan for the next 5 years.

Canada

Goal 1. Understand the impacts of the natural and anthropogenic radiation fields on the functioning of marine ecosystems

Action 1.1 Address the need for improved data and information on natural and anthropogenic radioactivity levels in the North Pacific.

Action 1.2 Address the need for improved modeling of radionuclide cycling within different components of marine ecosystems; identify a suite of indicators or variables that will facilitate the monitoring of ecosystem status.

Goal 2. Understand and quantify the impacts of human discharges of radioactivity on human and ecosystem health

Action 2.1 Evaluate and extend knowledge in PICES of the radiological dose models appropriate for human health in coastal based populations in the North Pacific.

Action 2.2 Evaluate and extend knowledge in PICES of the radiological dose models appropriate for ecosystem health in the North Pacific.

China

Goal 2. Understand the effects of multiple stressors on coastal and marine ecosystems of the North Pacific Ocean

Action 2.5 To assess the relevant effects of radionuclides in coastal and marine ecosystems, promote public awareness and understanding of potential radiation effects.

Task 2.5.2 To assess radiological impacts to marine organisms from natural and anthropogenic releases of radionuclides into the marine environment.

Goal 3. Provide scientific advice for the wise use of the North Pacific Ocean

Task 3.1.3 To identify and compile the representative organism species in the North Pacific ecosystems for the biota radioactive quality assessment.

Goal 4. Promote communication and collaboration among scientists within PICES and other organizations, scientific programs, and stakeholders that are relevant to the PICES strategic mission and goals

Task 4.2.1 To encourage inter-calibration of radio-analytical techniques among PICES member countries with collaboration with IAEA and other organizations to improve the detection methods.

Goal 5. Provide an effective infrastructure to support PICES programs

Task 5.1.1 To establish Working Groups on Marine Environmental Quality of Radiation in the North Pacific Ocean.

Goal 6. Develop the comprehensive capacities of PICES

Task 6.1.5 To compile a list of existing databases of MEQR experts of the North Pacific for academic exchange.

Final suggestions for the MEQ Action Plan for the next 5 years are presented in *SG-RS Endnote 6*.

Working Group Approval

At its 2013 inter-sessional meeting (May 20-21, 2013, St. Petersburg, Russia), Science Board unanimously endorsed the proposal from the Study Group on *Radionuclide Science in the North Pacific Ocean* (SG-RS) to establish a new Working Group on *Assessment of Marine Environmental Quality of Radiation around the North Pacific* (WG-AMR), under direction of MEQ. Science Board also arranged for comments from relevant expert groups on the draft terms of reference suggested by SG-RS and requested revisions by July 31. The final terms of reference approved by Science Board are included in *SG-RS Endnote 7*. Immediately thereafter, the Executive Secretary sent a request to PICES member countries asking for their endorsement of WG-AMR and its terms of reference, and for their appointments of national members to this Group. By August 14, 2013, all member countries had indicated their approval and nominated their members. Co-chairmanship of WG-AMR will be a subject for the first meeting of the group at PICES-2013.

SG-RS Endnote 1

SG-RS workshop participants

Members and invited experts

Kathryn A. Higley (USA)
Gi-Hoon Hong (Korea)
Chuanlin Huo (China, MEQ Chairman, invited)
Suk Hyun Kim (Korea)
Hongzhi Li (China)
Takami Morita (Japan)
John N. Smith (Canada)
Ronald Szymczak (Australia, IAEA LCC, invited)
Sinjae Yoo (Science Board Chairman, invited)
Wen Yu (China)
Yusheng Zhang (China, SG-RS Chairman)

Local participants

Jian Chen (China)
Jinqiu Du (China)
Jianhua He (China)
Dongmei Tang (China)
Senming Tang (China)
Tao Yu (China)
Xianquan Xiang (China)
Haifeng Zhang (China)
Peng Zhou (China)

SG-RS Endnote 2

SG-RS workshop agenda

1. Opening remarks;
2. Status of research on marine environmental quality of radiation in each PICES member country and exchange of views on the idea of developing a scientific focus within PICES on understanding the quantities and distributions of radionuclides in the North Pacific;
3. Discussion and refinement of the terms of reference and the work plan for the proposed Working Group on *Assessment of Marine Environmental Quality of Radiation around the North Pacific* (WG-AMR);
4. WG-AMR membership;
5. Discussion and suggestions for the Action Plan of the Marine Environmental Quality Committee (MEQ) for the next 5 years.

SG-RS Endnote 3

Proposed WG-AMR Terms of Reference

Marine ecosystems are impacted by multiple stressors (temperature, ocean acidification, hypoxia/ eutrophication, *etc.*) which can affect ecosystem function, structure and dynamics in complex ways. An emerging question is: do changing patterns of radioactivity constitute an additional stressor to the ecosystem in the North Pacific? This question can be addressed by conceptual frameworks and low-order, process-based models that simulate the cycling of radionuclides through North Pacific environmental compartments. These results can be used by health physicists to predict radiological doses and by ecosystem scientists to explore hypotheses linking ecosystem dynamics to variability in the natural and anthropogenic radiation environments.

Terms of Reference

1. To compare and analyze radiological doses to North Pacific marine organisms from natural and anthropogenic radionuclides in a post-Fukushima world.
2. To examine the utility of applying natural and artificial (from Fukushima and other sources) radionuclides as tracers of circulation, ecological transfers and biogeochemical cycling in North Pacific (and downstream, *e.g.*, Arctic) environments undergoing modification by climate change.
3. To determine the state of the science with respect to the assessment and mitigation of radiological impacts to marine organisms from natural and anthropogenic releases of radionuclides into the marine environment.
4. To contribute to FUTURE by producing status reports for items 1–3, management related guidelines and/or technical manuals.

5. To foster collaboration with other expert groups to achieve the goals of items 1–3.
6. To identify priority research requirements for knowledge gaps identified in items 1–3, the planned expansion of nuclear facilities and other emerging issues in the PICES region.
7. To promote collaboration among PICES member countries and international organizations in the exchange of information on environmental radioactivity and encourage joint surveys/research among PICES member countries.

SG-RS Endnote 4

Proposed WG-AMR Work Plan (2014-2016)

TOR 1: Compare and analyze radiological doses to North Pacific marine organisms from natural and anthropogenic radionuclides in a post-Fukushima world)

1.1 To review and summarize past and ongoing studies on the distribution of radioactivity (natural and artificial) in the environmental phases (sediments, seawater, biota, atmosphere);

1.2 To identify, select and compile databases for the representative organisms and their characteristics in North Pacific ecosystems for the biota quality assessment;

1.3 To evaluate radiological doses via collaborations with other entities using models of radionuclide dose, transport and fate;

1.4 To identify information gaps and compare the magnitudes of exposure from artificial and natural radionuclides sources.

TOR 2: Examine the utility of applying natural and artificial (Fukushima and other sources) radionuclides as tracers of circulation, ecological transfers, biogeochemical cycling and consequences of climate change in the North Pacific.)

2.1 To determine how this information illuminates the underlying mechanisms;

2.2 To update the current understanding of the application of radionuclides as tracers for climate change modeling and study;

2.3 To identify the ecological pathways and associated transfer rates for natural and artificial radionuclides;

2.4 To identify the significant biogeochemical cycling processes in the North Pacific environmental phases.

TOR 3: Determine the state of the science relative to the assessment and mitigation of radiological impacts to marine organisms from natural and anthropogenic releases of radionuclides into the marine environment.)

3.1 To review existing information for regionally important/representative species (identified in 1.2 above) on the uptake and depuration of radionuclides under acute and chronic exposure conditions;

3.2 To assess the adequacy of this information for making decisions with regard to existing radiological emergency management guidelines for marine ecosystems.

TOR 4: Contribute to FUTURE by producing status reports for item 1–3, management related guidelines and/or technical manuals.

4.1 To contribute to FUTURE by producing status reports for items 1–3, management related guidelines and/or technical manuals.

TOR 5: Foster collaboration with other expert groups to achieve the item 1–3 goals.

5.1 To interact and collaborate with WG27, 28, 29 or S-CCME, *etc.*;

5.2 To convene joint topic sessions with other expert groups as appropriate.

(For TOR 6: Identify priority research requirements for knowledge gaps identified in items 1–3, the planned expansion of nuclear facilities and other emerging issues in the PICES region.)

TOR 6: To identify priority research requirements for knowledge gaps identified in items 1-3, the planned expansion of nuclear facilities and other emerging issues in the PICES region.

6.1 To produce annual status reports and a summary analysis following completion of the project after 3 years.

TOR 7: Promote collaboration among PICES member countries and international organizations for exchanging available information on environmental radioactivity and encourage joint surveys/research among PICES member countries.)

7.1 To compile an MEQR expert pool;

7.2 To establish relationships with international organizations for academic exchanges and other related issues;

7.3 To encourage the inter-calibration of radio-analytical techniques among PICES member countries via collaborations with IAEA or other organizations in order to verify the quality of national radio-analytical methodologies.

General Actions

To provide and/or publish a final report summarizing the results, including recommendations to policy makers with regard to radiological threats posed by radioactivity levels in the Pacific Ocean to human health and the marine environment. Materials for an informational (brochure-like) outreach product will be prepared for broad dissemination to the public.

SG-RS Endnote 5

Proposed WG-AMR members

John N. Smith (Canada)
Hongzhi Li (China, P.R.)
Wen Yu (China, P.R.)
Yusheng Zhang (China, P.R.)
Takami Morita (Japan)
Tsuneo Ono (Japan)
Tomowo Watanabe (Japan)
Gi-Hoon Hong (Korea, R.)
Suk Hyun Kim (Korea, R.)
*Vladimir Goriachev (Russia)
Kathryn A. Higley (USA)

* To be further confirmed.

SG-RS Endnote 6

Suggestions for the MEQ Action Plan for the next 5 years

Goal 2. Understand the effects of multiple stressors on coastal and marine ecosystems of the North Pacific Ocean

Action 2.5 Understand the quantities and distributions of radioactive contaminants, and assess the relevant effects of radionuclides in coastal and marine ecosystems.

Task 1 Convene a science review session and summarize past and ongoing studies on the distribution of radionuclides (natural and artificial) in the environment phases (sediments, seawater, biota, atmosphere).

Task 2 Determine the state of the science related to assessment and mitigation of radiological impacts to marine organisms from natural and anthropogenic releases of radionuclides into the marine environment.

Task 3 Evaluate radiological doses in collaborating with other entities using models of radionuclide dose transport and fate.

Goal 3. Provide scientific advice for the wise use of the North Pacific Ocean

Action 3.1 Provide widely concerned and controlled contaminants list as a primary reference for the conservation of coastal and marine ecosystems of the North Pacific Ocean

Task 1 Identify and compile database of the representative organism species in the different North Pacific ecosystems for the biota radioactive quality assessment.

Task 2 Identify priority research requirements for knowledge gaps, the planned expansion of nuclear facilities and other emerging issues in PICES region.

Goal 4. Promote communication and collaboration among scientists within PICES and other organizations, scientific programs, and stakeholders that are relevant to the PICES strategic mission and goals

Action 4.2 Promote collaboration among PICES member countries and international organizations in the exchange of information on environmental radioactivity and encourage joint surveys/research among PICES member countries.

Task 1 Encourage the inter-calibration of radio-analytical techniques among PICES member countries including collaborations with IAEA or other organizations in order to verify the quality of national radio-analytical methodologies.

Goal 5. Provide an effective infrastructure to support PICES programs

Action 5.1 Form one new study group and new working groups on marine aquaculture and marine contaminants in the North Pacific Ocean.

Task 1 Establish Working Group on Assessment of Marine Environmental Quality of Radiation in the North Pacific.

Goal 6. Develop the comprehensive capacities of PICES

Task 1 Examine the utility of applying natural and artificial (from Fukushima and other sources) radionuclides as tracers of circulation, ecological transfers and biogeochemical cycling in North Pacific (and downstream, e.g. Arctic) environments undergoing modification by climate change.

Goal 7. Make the scientific products of PICES accessible

Task 1 Provide/publish a final report summarizing the results, including recommendations to policy makers with regard to radiological threats posed by radioactivity levels in the Pacific Ocean to human health and the marine environment.

SG-RS Endnote 7

Approved WG-AMR Terms of Reference

Marine ecosystems are impacted by multiple stressors (temperature, ocean acidification, hypoxia/ eutrophication, *etc*.) which can affect ecosystem function, structure and dynamics in complex ways. An emerging question is: do changing patterns of radioactivity constitute an additional stressor to the ecosystem in the North Pacific? This question can be addressed by conceptual frameworks and low-order, process-based models that simulate the cycling of radionuclides through North Pacific environmental compartments. These results can be used by health physicists to predict radiological doses and by ecosystem scientists to explore hypotheses linking ecosystem dynamics to variability in the natural and anthropogenic radiation environments.

Terms of Reference

1. Determine and compare radiological doses to North Pacific marine organisms, where data are available, from natural and anthropogenic radionuclides using existing data bases, newly acquired post-Fukushima monitoring results, and state of the art dosimetric approaches;
2. Examine the utility of applying natural and artificial (Fukushima and other sources) radionuclides as tracers of circulation, ecological transfers, biogeochemical cycling and consequences of climate change in the North Pacific, including the downstream interconnectivity, with establishing link to POC or WG 29, *etc*.;

3. Determine the state of the science relative to assessment and mitigation of radiological impacts to marine organisms from natural and anthropogenic releases of radionuclides into the North Pacific marine environment, including a summary of peer reviewed literature and an overview of major sources and types of radiological releases into the marine environment;
4. Foster collaboration with other expert groups, especially physical oceanographers and climate modellers, to achieve the item 1–3 goals;
5. Identify priority research requirements for knowledge gap identified in item 1–3, the impacts on marine environment from the planned expansion of nuclear facilities, other emerging nuclear issues and other sources of radionuclides in the PICES region;
6. Promote collaboration in oceanographic studies using radio-tracer distribution and exchanging available information on environmental radioactivity, and encourage joint surveys/research among PICES member countries and international organizations;
7. Contribute to FUTURE by producing report on whether radioactive pollution is an additional stressor to marine ecosystem in North Pacific Ocean.