IAEA
International Atomic Energy Agency

Interoffice Memorandum

To:	D. Hahn, DIR-NENP	**From:**	I. Khamis, NPTDS
Through:		**Clearance:**	S. Monti, SH-NPTDS
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Subject: Meeting Report of the Technical Working Group on Nuclear Desalination (TWG-ND)

Place of Meeting:	IAEA Headquarters, Vienna
Date of Meeting:	17-19 May 2016
PTAEO Code:	1000155.2016.04.RBF-MP1-2016.613222-NHR-TRV-Non Staff Cons.NENP-Nuclear Power Technology Development Section
Scientific Secretary:	Mr Ibrahim Khamis
Chairperson:	Mr Ron Faibish, USA

1. Participants

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2. Background

The International Nuclear Desalination Advisory Group (INDAG) was established by the IAEA in 1996. INDAG played an active role in the past years, contributed to promotion and stimulation of nuclear desalination activities, and provided a forum for Member States to exchange information on the technological developments, operations, and demonstration of integrated nuclear desalination systems. To enhance its functions, the IAEA has reformed INDAG into a Technical Working Group on Nuclear Desalination (TWG-ND) in 2008. This meeting was the fifth meeting of the TWG-ND. The meeting was held in 17-19 May 2016 at the VIC, Vienna, and attended by 13 members. Mr I. Khamis acted as the Scientific Secretary and Mr R. Faibish of USA served as the Chairperson.

3. Objectives of the meeting

The purpose of the meeting was to:

- Review previous activities undertaken by the IAEA Secretariat and Member States in the fields of nuclear desalination and integrated water resources management (IWRM) at nuclear facilities;
- Provide advice and guidance on future IAEA activities relating to nuclear desalination and IWRM;
- Conduct a preliminary objective discussion on the future of nuclear desalination that would include a consideration of obstacles to the future deployment of nuclear desalination operations and examination of the concept of ‘energy parks’
- Identify a road map for important topics in the field of nuclear desalination such as value chains and localization of nuclear desalination;
- Provide a forum for sharing information and knowledge on developments in national and international programs in the areas of nuclear desalination and IWRM; and
- Identify preparatory actions by Member States for implementing nuclear desalination demonstration projects and IWRM at nuclear facilities.

4. Agenda

see Annex 1 attached.

5. Summary of the work done and results achieved

Mr. D. Hahn (DIR-NENP) opened the meeting with welcoming remarks. He emphasised that the use of nuclear reactors for seawater desalination has already been demonstrated in several countries with operational experience of about 250 reactor-years. Nuclear desalination has been demonstrated in 6 Member States (China, India, Japan, Kazakhstan, Pakistan, and USA) coupled to 16 nuclear power reactors. Several other countries have also expressed interest in nuclear desalination. The experience and information exchange play a crucial rule in expanding nuclear desalination in such interested Member States. Yet, the deployment of large scale nuclear power plant for desalination or cogeneration of power and potable water may face several challenges such as: optimization of the plant design for cogeneration purposes; enhancing safety of coupling; establishing joint infrastructure; training of human resources for both disciplines (nuclear power industry and desalination); and assessing the financial capital and public acceptance. He also emphasised to the members of the TWG-ND that the IAEA activities on nuclear desalination are enriched and guided with your advices and recommendations on technology assessment and integrated water resources management (IWRM) at nuclear facilities. Better vision on the future of nuclear desalination is supported by your discussion that would include a consideration of potential solutions for obstacles to the future deployment of nuclear desalination operations and examination of the concept of 'energy parks'. This goal is augmented by identification of a road map for important topics in the field of nuclear desalination such as value chains and localization of nuclear desalination. At the end of his remarks, he expressed his gratitude to all participants and wished them to have a very successful meeting.

Mr. R. Faibish (Chairperson) He delivered an opening remarks welcoming the new members of the TWG-ND and highlighting future activities related to nuclear desalination. He briefly summarized the status of the SMRs and high temperature reactors and how it might be reflected in the support of nuclear desalination. He also emphasised that such reactors can be quite attractive not only to nuclear desalination but also to other cogeneration applications of non-electric applications, such as industrial heat and hydrogen production.

Mr. I. Khamis (IAEA Scientific Secretary) introduced the new members to the TWG-ND, and gave an introductory talk on the Terms of Reference of the TWG-ND, its scope, functions, chairmanship, methods of work and deliverables as related to the IAEA Programme on nuclear seawater desalination. Then, he presented a summary of the IAEA activities (those already implemented as well as those foreseen in the future) on the following topics: Coordinated Research Program (CRP), Technical Cooperation (TC), forums for information exchange, publications on nuclear desalination, updates on Desalination Economic Evaluation Programme DEEP, DE-TOP, and the nuclear desalination toolkit, and Budget & Planning (B&P).

As per the request of the TWG-ND members, Mr. Khamis made additional presentation highlighting other activities on non-electric applications of nuclear power.

The members of the TWG-ND expressed their satisfaction with the IAEA's conducted activities on non-electric applications and on nuclear desalination specifically, as well as the workplan on nuclear desalination and the successful upgrade and updates of IAEA tools. They enriched the meeting with providing their recommendations as presented in the report.

In the following, the input of participating Member States is presented:

Algeria (Mr. Belkaid) In response to the water scarcity which was experienced by the country over the past four decades, national authorities have implemented a seawater desalination program for taking in charge the increasing water demand expressed mainly by the population. This program derives for the global strategy on conventional and unconventional resources. This extensive desalination program is based on natural gas as an energy source. Due to the strong demand on natural gas seen in recent

years, another program based on renewable energies is set up recently in order to diversify energy sources. Nuclear power is expected in this new program related to the diversification of energy sources. To this end, feasibility studies were carried out on the seawater desalination by means of nuclear power. These studies demonstrated that nuclear desalination is an option to consider in the near future. In this communication, it has reviewed briefly the climatic characteristics of Algeria. It is also presented the global strategy developed for conventional and unconventional resources and key indicators related respectively to: water, energy and desalination. A brief description of the program of activities initiated for the short term in the field of nuclear desalination is presented.

Argentina (Ms. Conti) The technical group that work in Argentina on ND and IWRM since 2011, has made a permanent effort to fulfill the request of the IAEA: has hired and trained personnel, continues and establishes new links with the local nuclear community, and set up new technical areas. All that in accordance to what was concluded along the TWG meetings. For this meeting Argentina presented results related to ND and IWRM. ND activities are focused on the following areas: 1) Techno-economical coupling of a MED and hybrid MED+RO system to CAREM-25. Results show that MED coupled to SMR is technically feasible with the production of water and electricity in cogeneration and with only a small reduction of thermodynamic efficiency (4000-4300 m3/day with 80,000 population of electricity), 2) MED+RO system coupled to SMR is under analysis but preliminary results show that the configuration is flexible enough to obtain either potable, industrial and reactor quality water. In spite of RO to RO+MED production costs ratio, flexibility would be the main advantage of the latter, 3) Hybrid configuration is at the stage of conceptual to basic engineering (i.e.: intermediate loop, pretreatment water for RO and MED), 4) At the CRP-LTND: a MED+RO coupling to SMR in order to be used as an auxiliary system for safety has been proposed and it is under analysis while in normal operation can provide water to Primary and Secondary Circuit, 5) For testing and training in MED+RO modes, an experimental rig is under construction. The rig has been dimensioned as 1:1 scale for a 10 MWth Water Cooled Reactor. IWRM activities were related to technical support to argentine NPPs in the frame of CNEA-NASA contracts and into the 2nd cycle operation of Embalse NPP (CANDU-6 ©) and for the construction of the 4th NPP in the country (up to now a CANDU-6 ©). Different strategies of reduction of water consumption and withdrawal have been: 1) power increase and reduction in cooling water flow rate following seasonal temperature of the cold source, 2) Optimization and update of the Service Water System, 3) Implementation of film forming amines (FFAs) dosing in the BoP (FFAs hydrophobic film on the metal surface reduces corrosion products transport to SGs allowing a reduction in Blowdown water flow rate (BD) in normal operation and/or time to reach chemical specifications in start-up), 4) Recycling of SGs-BD, the not implementation of Condensate polishing in BoP and the technology for Demi Water Plant are under analysis for the 4th NPP located near the river shore (Parana is one of the largest rivers in South America if it is considered as a cold source).

Belgium (Mr Ejjeh) With access to drinking water already a major challenge for as much as one quarter of the world's population, and further forecasts predicting that by 2030, 47% of the global population will face water scarcity, The Global Clean Water Desalination Alliance – H_20 minus CO_2 is one of the few climate initiatives dealing with the water-energy nexus and climate change. As the quest for finding solutions to combat climate change in view of the impacts of global warming on water resources increases, nuclear desalination can offer significant potential to substitute fossil fuel as a source of energy for desalination. The integrated hybrid MED-RO design can make use of warmer seawater discharged from NPP or reject sections final condenser of MED to reduce energy consumption, reduce size of seawater intake and outfall. To minimize energy consumption and reduce power losses of NPP it is recommended to use straight MED with the lowest extractions steam pressure available using straight MED, rather than MED-TVC. In general, there is very important need to educate both parties the NPP and desalination islands about technology implication, operational and maintenance requirements of both. At the same time, continuous public relations campaign is needed to assure the public of safety, explain benefits and reliability of Nuclear Desalination.

Belgium (Mr Snoeck) Because Belgium can rely on many abundant sources of fresh water, no implementation of desalination unit is foreseen in the country. However, TRACTEBEL, as subsidiary of the ENGIE Group, has been investigating for years the possible couplings between all types of power plants (thermal, nuclear, renewable) and existing desalination techniques (MSF, MED, RO) for the projects carried out in arid regions, such as the Middle-East. In this respect, attention is also paid to large and mid-sized NPPs to assess the feasibility of nuclear desalination and the impact on the performances of the generating unit.

Canada (Mr. Dincer) presented on the status of nuclear desalination in Canada to address the use of nuclear waste/process heat or electricity or heat and electricity for desalination applications. An introduction on some country specific information was provided. He discussed the nuclear power generation status in Canada and more specifically for Ontario, provided some facts about current nuclear industry and power generation dynamics, and future plans for the power generation sector. Also, a review of both world and Canadian water resources status and their utilization along with the challenges and opportunities and Canadian water and sanitation sector and Canadian desalination technologies developed for the market were presented. Furthermore, on dwelling historically on nuclear desalination projects, developments and applications, he presented that CANDESAL Water Systems, a Canadian company, was formed to develop the concept of nuclear desalination, combining CANDU reactors with DESALination. Their design couples an RO desalination plant with a CANDU reactor. The coupling of RO and CANDU-6 which was an advanced concept for the design and operation of RO seawater desalination systems was first presented by CANDESAL in 1993 (IAEA-TECDOC-1444). Their works also focused on the development and optimization of an innovative approach to the coupling of RO desalination systems to nuclear power plants and to the experimental demonstration of the key concepts underlying that coupling approach. A coupling scheme was developed that made use of waste heat from the reactor (discharged primarily through the condenser cooling system in water-cooled reactors) to preheat the RO system feedwater above ambient seawater temperature. Three case studies, including RO with CANDU 6 reactor, RO and SFR reactor and RO and GT-MHR are presented as carried out by Mr. Dincer's research group. These studies contain energy and exergy analyses and energy and exergy efficiency assessments under various state properties and operating conditions. Finally, a discussion on the challenges of desalination sector, advantages of using NPPs for desalination and suggestions to promote nuclear desalination as well as actions to take in this regard were conducted during this meeting.

China (Ms. Guo) More than 10 nuclear power plants are in building in China. The nuclear desalination should be promoted. But until now only a RO desalination plant was built in Hongyanhe Nuclear plant. We should have more influence on nuclear power plant authorities. We find the MED system is more efficiency than RO system in north China, where the temperature of seawater is lower. Now we have finished the evaporator design for a MED system used in platform with Nuclear Power Plant.

India (Mr. Adak) presented an overview of the seawater desalination programmes already undertaken in nuclear complexes in Department of Atomic Energy Establishments. He described that after long term successful operation of Indian Nuclear Desalination Demonstration Plants (NDDPs) namely 30 m^3/ Day LTE desalination plant coupled to CIRUS nuclear research reactor and 6300 m3/day MSF+RO hybrid seawater Nuclear Desalination Demonstration Plant (NDDP) coupled to 220 MWe MAPS PHWR nuclear reactor enough data have been generated. These plants have proven the Indian capability to build Nuclear Desalination plants, which have proven the long term feasibility of production of fresh water from seawater utilizing heat (nuclear steam) and sharing other common utilities from nuclear reactors. Also mentioned about 2560 m^3/day each unit of MVC MED (3 operating +1 stand by) desalination plants coupled to (1000 MWe VVER (PWR type) reactor at Kudankulam, India) utilizing electricity from the reactor. Also presented the details of operating models of Multi Effect Humidification & Dehumidification (MEHD) set up at Trombay that could utilize waste heat from nuclear power plant to generate fresh water from seawater. Described the planned and intermediate coupling configuration of two nuclear desalination plants coupled to 300 MWe BWR type called Advanced Heavy Water Reactor (AHWR). Details of coupling with AHWR of LTE plant of capacity 250 m^3/day utilizing waste heat of MHT purification circuit and 3 x 800 m^3/day

MED TVC seawater desalination plants utilizing HP steam. Briefed about the progress of continuing CRP on application of "Advanced Low Temperature Desalination Systems to Support NPPs and Non-electric Applications". Described other developmental work on 240 m^3/day MED TVC plant which is commissioned recently at Trombay to generate simulated data to connect with future nuclear power plant. Future set up of 5 MLD MED+RO desal plant at OSCOM Odisha site was also presented. Also concluded that India is continuously supporting and sharing the experience of nuclear desalination activities under Agency's Technical Cooperation Program along with their member states and will continue to promote nuclear desalination through symposium/ coordinated research programs/ workshops at various National & International forums.

Kazakhstan (Mr. Muralev) Plans of State Corporation Rosatom (Russian Federation) on combining Nuclear Power and Desalination Technologies for constructed worldwide Nuclear Power Plants inspired a renewed interest to experience of Kazakhstan in 20-years operation the largest in the world Industrial Desalination Plant integrated with Fast Breeder Nuclear Reactor BN-350. In the stage of intensive discussions there are plans for cooperation of Kazakhstan and Russian experts for development and testing new ideas and approaches for application of Nuclear Desalination as for NPP Integrated Water Management as for supply with fresh water the population and industry in areas of NPP location.

Pakistan (Mr. Ahsan) Karachi Nuclear Power Plant, KANUPP has gone through experience of integrating NPP with desalination system, MED type, Low temperature, Low pressure using extraction steam of turbine cycle, operating safely since 2009. In the TWG meeting, a brief introduction of nuclear program of the country, Cogeneration plant, coupling scheme, and other activities related to ND were discussed. Pakistan is contributing through its experiences with IAEA in various Technical Meetings and Coordinated Research Program (CRPs) and sharing the valuable experiences gained in the field of design, manufacturing, installation and commissioning of the ND Plant. Successful operation of KANUPP NDDP project may be used as evidence regarding technical viability for coupling desalination with Nuclear Power Plant safely in future projects. Feasibility of coupling for deploying Nuclear Desalination Plant for upcoming Karachi coastal projects (2×1100 MWe each ,PWR) has also been discussed.

Saudi Arabia (Mr. Al-Arifi) There is a tremendous demand for fresh water worldwide due to an increase in population, exponential industrial growth and also drastic climate changes. These factors globally lead to great challenges to many countries. In the Kingdom of Saudi Arabia the water demand is expected to increase from 6.5 Mm^3 per day to more than 9Mm^3 per day by 2030. To fulfil the demand of water more and more countries are becoming dependent intensively on seawater desalination. Desalination in kingdom of Saudi Arabia became strategic choice nowadays. Today Kingdom of Saudi Arabia tops in the production of desalinated water which is about 16.5% of world production. The conducted presentation showed the growth of desalination industry sector in the last sixty years in the world and in KSA over the last thirty six years. The desalination technology used nowadays was presented. The challenges faced the water sector in KSA were covered with highlighting some facts and figures about the government organization responsible for seawater desalination in KSA "Saline water conversion corporation (SWCC)". The future seawater desalination projects (2016-2030) with desalination technologies were also discussed. The presentation also covered the SWCC strategy of diversify fuel portfolio especially for the option of utilizing alternative energy (solar and nuclear energy) for seawater desalination and the plans for that.

Sweden (Mr Persson) IAEA Secretariat and Member States have worked for several years in the fields of nuclear desalination and integrated water resources management (IWRM) at nuclear facilities. Basically, the activities undertaken by the Secretariat and the Technical Working Group for Nuclear Desalination have offered a basis of advice and guidance concerning nuclear desalination and IWRM. Fundamental for the integration of water management into society is the overall goal to offer a sustainable water use. That is to meet the needs of the present generation without compromising the needs of future generations. (The Bruntland Report, 1987). Once desalinated water is introduced as an additional source of freshwater supplied to the society, the improved water balance should be guarded

and used for optimal safety and security. A thorough plan for water reuse should also be considered as an additional measure to decrease water scarcity. The basic need needs to be defined since it can vary widely from region to region, village to village, person to person. Central for modern open water management systems are that all levels have a say in the allocation and use of the resource, in a continuous process where information and knowledge (both indigenous and scientific) are shared openly and honestly. This cannot be managed without understanding the needs of the stakeholders and the possibilities and limitations of the available water resource. Hence, a dialogue between individuals and large institutions must be established in order to be able to formulate appropriate strategies which can be communicated and implemented.

USA (Mr. Faibish) There has been a clear and consistent growing interest in advanced nuclear reactors of the Gen-IV type in the past several years in the U.S. (and indeed across the world). This is in addition to the continuous U.S. government support for the design and licensing of advanced Gen-III+ light water small modular reactors (SMRs). The interest in advanced reactors stems from their versatility in applications and attractiveness when it comes to their unique fuel cycles. These reactors (6 main types as identified in the most recent report from the Gen-IV International Forum's (GIF) from 2014) offer a range of temperature operating conditions (including very high temperatures), enhanced passive safety features, and load-following capabilities, among other features. These Gen-IV type reactors also come in a range of sizes – from single to 100s of MWs – so they can be tailored to specific needs (e.g. desalination and other cogeneration applications, such as industrial heat, hydrogen production, etc.). These could include remote locations/off-grid where very small reactors might be preferred. Such encouraging developments could vote well for the future of freshwater production using nuclear power. The two key challenges to deployment of advanced reactors are obtaining the required licensing and demonstrate that their economics and path to commercialization are viable, if not competitive with existing technology options.

6. Conclusions

- The TWG-ND agrees that nuclear desalination activities present an important and impactful opportunity for nuclear power applications in the future, especially as new nuclear reactors come on line.
- Advanced (Gen-IV) type reactors may provide unique features and operating parameters for electricity generation (e.g., higher temperatures and thermodynamic efficiencies) which could also enable greater deployment of coupled desalination operations.
- Nuclear desalination represents an important option for augmenting water resources and mitigating the adverse effects of climate change.
- The TWG-ND recognizes the importance of the intermediate thermal coupling loops (e.g., designs and efficiencies) between the nuclear power plant and the desalination systems. Coupling of the desalination plant (e.g., thermal, mechanical separation, or hybrid operations) can be considered either with extracted heat directly from the power cycle or rejected heat.
- The members of the TWG-ND agree to proactively engage the IAEA and specifically on nuclear desalination with ideas and concepts for future implementation by the Agency.

7. Recommendations

The TWG-ND recommends the IAEA to:

- Examine the techno-economics and opportunities for non-electrical applications with emphasis on nuclear desalination using micro- and small- modular reactors.
- Consider surveying the current reactor installations around the world for existing, or potential for, desalination operations, and comparing the performance of future possible advanced reactor concepts to that of existing reactors when it comes to non-electrical applications, and specifically nuclear desalination.
- Explore closer and collaborative ties with other relevant international organizations in the fields of desalination, power production and nuclear energy

- Promote the advantages of nuclear desalination and the coupling for cogeneration applications for clean nuclear power options as climate change mitigation and carbon free energy and water production.
- Assess the importance of licensing issues and related gaps relevant to the coupling of nuclear and water production systems and explore interlinks between comprehensive integrated water resources management and nuclear desalination practices.
- Consider the creation of information exchange platform for sharing nuclear desalination and/or desalination and/or nuclear energy experiences, and encourage MSs with nuclear desalination experiences to share their updated information with the IAEA on latest development with the specific operations and encourage the IAEA to reach out to these MSs, the TWG-ND acknowledges the recent and continuous attempts by the IAEA to solicit such information.
- Consider updating the IAEA nuclear desalination information booklet with the latest relevant information, with encouraging MSs to share their experience with using IAEA-generated analysis and information tools, such as DEEP, DE-TOP, ND Toolkit in order to identify potential errors and needed updates to codes and general improvements.

Annex.1: Agenda of IAEA's Meeting of the Technical Working Group on Nuclear Desalination (TWG-ND)

17-19 May 2016, Room: M0E79, VIC, Vienna

DAY 1: Tuesday, 17 May 2016		
09:30	Welcoming and Opening Remarks	Mr. D. Hahn, DIR-NENP & Mr. I. Khamis, IAEA
09:45	Opening Remarks by the TWG-ND Chairperson	Mr. R. Faibish, USA
10:00	Roles and Responsibilities of TWG-ND & Goals of this Meeting	Mr. I. Khamis, IAEA
	IAEA Project on Nuclear Desalination	
10:45	***Coffee Break***	
11:00	The Future of Non-electric Applications of Nuclear Energy	Mr. I. Khamis, IAEA
11:30	**Brainstorming Session I**: The Future of nuclear desalination: The Role of hybrid & low temperature desalination technologies & potential use of waste heat recovery?	All participants
12:30	***Lunch Break***	
14:00	Brief on National Program & Identification of Important Topics in The Field of Nuclear Desalination	Mr. G. Ejjeh, Belgium
14:20		Ms. M. Conti, Argentina
14:40		Mr. Y. Muralev, Kazakhstan
15:00	***Coffee Break***	
15:30	Brief on National Program & Identification of Important Topics in The Field of Nuclear Desalination	Mr. A. Khan, Pakistan
16:00	**Brainstorming Session II**:Technical consideration for nuclear desalination: Standing alone or cogeneration? Coupling Issues?	All participants
17:30	***Wrap up of Day 1***	
18:00	***Dinner Reception (Venue is to be announced)***	
DAY 2: Wednesday, 18 May 2016		
09:00	Brief on National Program & Identification of Important Topics in The Field of Nuclear Desalination	Mr. A. Adak, India
09:30		Mr. A. Al-Arifi, KSA
10:00		Mr. I. Dincer, Canada
10:30	***Coffee Break***	
11:00	Advances in SMR Designs & Technologies, and their Applicability for Non-Electric Applications	Mr. H. Subki, IAEA
11:30	**Brainstorming Session III:** Role of small modular reactors for nuclear desalination?	All participants
12:45	***Lunch Break***	
14:00	Brief on National Program & Identification of Important Topics in The Field of Nuclear Desalination	Mr. R. Faibish, USA
14:20		Mr. K. Persson, Sweden
14:40		Ms. Y. Guo, China
15:00	***Coffee Break***	
15:20	Brief on National Program & Identification of Important Topics in The Field of Nuclear Desalination	Mr. J. Snoeck, Belgium
15:40		Mr. A. Belkaid, Algeria
16:30	***Wrap up of Day 2***	
DAY 3: Thursday, 19 May 2016		
09:00	• Conclusions & Recommendations • Identification of important topics to SAGNE	All participants
10:30	Summary of the Meeting by Chairperson	Mr. R. Faibish, USA
11:00	***Coffee Break***	
11:15	Finalizing the meeting report	All participants
12:30	***Closing Remarks***	