International Nuclear Desalination Advisory Group

to the International Atomic Energy Agency

INDAG NEWSLETTER

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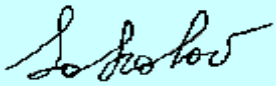
A WORD FROM THE DEPUTY DIRECTOR GENERAL

The nuclear desalination activities in the Member States carried out with the support of the IAEA comprised of establishing nuclear desalination demonstration projects, carrying out techno-economic feasibility studies on the introduction of nuclear power-desalination plants at the specific sites having water scarcity and design and development of small and medium sized reactors for safe and economic production of potable water from seawater. The CRPs on nuclear desalination have provided information on optimum coupling of different reactor types with the commercially established desalination processes. The economic evaluation of nuclear desalination and its competitiveness with conventional desalination has been made by MSs using the Agency's software DEEP.

The Programme Evaluation of the nuclear desalination activities conducted by the External Evaluation Panel has recognised a job well done and supported the continuation of the programme. It recommended to also deal with issues collateral to the nuclear desalination technology that can address concerns of the public to its practical implementation. During the last meeting of INDAG held in July 2004, it reviewed the current and the future activities of the Agency and by the Member States and suggested to include the socio- economic and environmental aspects of nuclear desalination.

I am pleased with the release of the fourth issue of the INDAG Newsletter highlighting the current activities of the Agency and from the Member States.



Y.A. Sokolov
Deputy Director General
Department of Nuclear Energy, IAEA

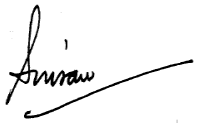
A WORD FROM THE CHAIRMAN

INDAG, so far, has been the only IAEA group to publish its Newsletter regularly before each General Conference Meeting. It is no doubt mainly this motivation for communication with complete transparency, coupled with expert advice, that led the independent panel for the evaluation of IAEA's nuclear desalination activities to highly commend INDAG for its actions.

This time, INDAG brings you some concrete results of the International cooperation activities, strongly supported by INDAG and carried out under the aegis of IAEA's INT/4/134 programme: Thus, the Kalpakkam nuclear desalination complex in India is nearly completed, the Pakistani project for desalination with the Karachi nuclear power plant is now well on the way. At the same time, two technical and economic feasibility studies of nuclear desalination have also been completed. The final report on the feasibility of SMART + MED based integrated desalination system for the Madura island in Indonesia (Collaboration between South Korea and Indonesia) has already been published. That from the French -Tunisian collaboration, known as the TUNDESAL project, would come out as this Newsletter reaches you.

As INDAG has consistently tried to communicate, these two studies have independently concluded that nuclear desalination is indeed a viable option for the future. In the case of TUNDESAL, for example, even though Tunisia has somewhat privileged situation today (limited but indigenous natural gas reserves, use of a fraction of the gas transiting Tunisia, leading to current gas price of about 130$/tep), it was found that as soon as gas prices go beyond 150$/tep, the nuclear options would be economically more attractive than the competing combined cycle based system. The CRP on the economic assessment of site-specific cases, launched after INDAG's recommendation, continues to move forward. It was indeed the revised new models in DEEP that permitted the comprehensive economic evaluation of desalination costs in the two international feasibility studies.

Happy reading!



S. Nisan
Chairman, INDAG

INDAG is an Advisory Body to DDG-NE established in 1997.
The next INDAG meeting is planned for 2006.

Recent Activities in Nuclear Desalination in Member States

ARGENTINA:

Argentina has continued to support the Agency's ongoing programs on nuclear desalination.

In CRP 1 the participating institution, INVAP, completed the foreseen achievement of developing a flexible modelling tool, DESNU spreadsheet, helpful for evaluating nuclear desalination systems from the safety point of view. DESNU produces RETRAN input files for MED, MSF and RO desalination systems, and the BoP of a small NPP. The additional goals set by agreement within the CRP were also achieved, including greater flexibility, review by the participants and a User's Manual. CNEA participates in CRP 2 and considerable progress has been made assessing potential Nuclear Desalination sites both on Regional and National basis, and on the optimal cogeneration plant conceptual specification and economical assessment.

Beyond the activities on the CRPs, there is a relevant effort on developing safety aspects of ND. A well settled practice of technology development within INVAP gave the adequate framework for producing clear advances, first in the practical knowledge and understanding of these aspects and then on specific engineering and project management findings. During the last year, specific expertise on Nuclear Desalination Safety has been shared with colleagues of PAEC, BATAN and KAERI with fruitful technical exchanges.

CANADA:

Over the past year Candesal has evaluated the extension of its advanced RO seawater desalination technology into other applications. Of particular interest has been the application of this technology to the clean-up of salt-contaminated wastewater produced as a result of environmental remediation activities. Environmental remediation of contaminated sites, such as abandoned oil and gas fields, industrial sites,or municipal highway maintenance depots, has become an issue of major concern in Canada, as well as internationally. The remediation of such sites generally results in large volumes of salt-contaminated wastewater that creates a significant disposal problem. RO seawater desalination technology can be applied, with some modification to system flow paths, to reduce the volume of wastewater by factors ranging from 10 to 20. This leaves only 5-10% of the original volume for disposal, with the balance being fresh, clean water that can be safely returned to the environment or reused in an industrial process.

CHINA:

The construction of a nuclear desalination demonstration plant (SNDP) with production capacity of 160.000m3/d in Shandong Peninsula of China was proposed in 2000. Hao-Zin Investment Co. is the owner and the Institute of Nuclear and New Energy Technology, Tsinghua University is the engineering contractor.

The feasibility study started from 2003 March. The SNDP consists of a NHR/200 coupled to a MED process. The NHR-200 as a nuclear heating reactor with 200 MW capacity is designed with a numbers of advanced features, such as integral arrangement, full natural circulation, self-pressurized, in-vessel CR drive, passive safety systems in order to achieve very high safety margins. The coupling desalination process is based on high temperature MED with vertical tube foamy evaporation.

The feasibility study is expected to be completed before end of 2004. After assessment of feasibility study it will be decided whether to build the SNDP. In parallel the experiment on vertical tube foamy evaporation is carried to investigate the operation behaviour and parameters.

EGYPT:

NP PA is carrying a number of integrated activities and studies to keep a state of readiness for efficient execution of NPP when the decision is taken. Also NPPA is working to complete the necessary infrastructure, including site development, preparation of the required studies and documents as well as manpower development.

With the cooperation of the IAEA, technical and economical feasibility study to use NP for electricity generation and potable water production has been completed. Also, the IAEA is supporting the effort to construct a simulator for ND.

An experimental facility is under construction at the site. The objective of this facility: to obtain real data on preheat-RO technology at the site conditions, which will useful for the future activities.

FRANCE:

CEA, Nuclear Energy Directorate (DEN), Cadarache Atomic Centre, is involved in several nuclear desalination studies:

- Own studies under the Future Reactor Systems Division, Project No. SF/13.
- Site-specific study for the La Skhira site in Tunisia under the bilateral agreement between CEA and CNSTN under the aegis of IAEA's INT/4/134 programme: the TUNDESAL Project.
- Development of an MED process simulator for the NPPA (Egypt) under an IAEA TC contract N° EGY/4/046

CEA has recently completed two other important studies:

- Financing of nuclear desalination projects in developing countries: preliminary study of the rate of return of different fossil and nuclear energy based systems.
- Extraction of useful materials from the concentrated brine rejected by the desalination plants.

As part of its own activities, CEA is developing a new code system, called COSMOS for nuclear desalination coupling scheme simulation, interactive modelling and optimisation and cost evaluations. In this context, new analytical models for RO and MED have been developed.

India:

BARC (India) is setting up a 6300 m^3/d combined MSF-RO Nuclear Desalination Demonstration Plant (NDDP) connected to 2 x 170 MWe PHWR units at Kalpakkam.

Considerable progress has been made in the project. SWRO section of NDDP has already been commissioned and operating successfully as per design intent since August 2002. Potable water produced is supplied to nearby areas. MSF is in advanced stage of construction. India is committed to share the NDDP experience with the Member States. It is planned to organise a Technical Meeting on "Integrated Nuclear Desalination Systems" during December 13-16, 2004

in Chennai (India) including site visit to NDDP. BARC (India) has an active programme to study the possible utilization of waste heat from the heavy water research reactor and PHWR by coupling low temperature evaporation (LTE) desalination systems for seawater desalination. A 30 m^3/d LTE desalination plant has been commissioned this year (2004) producing very high quality water from seawater. It is coupled to CIRUS nuclear reactor utilizing a part of its waste heat for seawater desalination. It is planned to integrate a 500 m^3/d nuclear desalination plant with AHWR for seawater desalination. The development work done at BARC (India) has generated capability to design, fabricate, commission and operate small and large size nuclear desalination plants for large scale deployment and providing opportunities for the socio-economic development of water scarcity areas and coastal arid zones. The road map includes establishing large size nuclear desalination plants (100-300 MLD) coupled to nuclear power plants in coastal regions for both power and water security.

ISRAEL:

The revised governmental desalination policy is to install seawater desalting plants up to the accumulative capacity of 315 millions m^3/yr within this decade. In addition, quite a few plants of tens of million cubic meterper year capacity from brackish water are already operating, under construction or will be ordered soon. This policy has been determined in view of the existing national water balance deficit and the growing water demands.

The largest plant, SWRO of 100 MCM/Y nominal capacity, located near Ashkelon on the Mediterranean about 60 km south of Tel-Aviv, is already in the midst of its construction. The pumps and RO membranes are now being installed. The first part [50%] of the plant is expected to supply desalted water in mid 2005; the second half is due by the end of 2005. The promised water price at the plant exit is as low as about 50-53 US cents per cubic meter. The required desalted water quality is extremely high - 20 ppm chlorides and low boron content.

Nuclear desalination, however, seems now more remote than ever for Israel. Nevertheless, data and experience – construction as well as O&M - gathered from the Ashkelon and Hadera projects might most probably contribute a lot of information as well as ground for decision making regarding future large nuclear desalination projects.

JAPAN:

Japan has no national projects, international projects and inter-regional projects at the present time. However, Japan has nuclear desalination facilities, which are co-located inside the nuclear power plants, in order to supply the fresh water, which is being used inside the plant. The capabilities of all desalination facilities is not so high, however, those are being operated without any serious troubles now.

R&D of some innovative nuclear technologies are being conducted under the contract with MEXT and METI. These technologies will be incorporated into the future nuclear power plants.

Two kinds of improved RO system, in which the recovery ratio can be increased from 40 % to 60 % have been developed by Toyobo and Toray. One of system with one stage was installed into the desalination plant (50,000ton/day), which was constructed in Fukuoka. Its construction was finished and the test operation by each unit will be started in the near future. The fresh water will be supplied from the next year (2005). Another new technology related to the intake of seawater was also installed into the Fukuoka desalination plant.

KOREA REP OF:

The objectives of Korean programme are mainly to develop an integrated desalination plant with SMART (System-integrated Modular Advanced Reactor) for a dual-purpose application. The programme is being carried out by the Korea Atomic Energy Research Institute (KAERI) as the leading organization with the support of Government and participation of industries. The concept of the SMART desalination plant aims to supply 40,000 tons of fresh water per day and 90 MW of electricity to an area with approximately hundred thousand population or an industrialized complex.

Since 1997, Government of Korea has been supporting the development of SMART. Both the conceptual design and basic design of SMART with a desalination system were successfully completed in March of 1999 and in March of 2002, respectively. In 2002, Korean government launched construction project of the SMART plant with one-fifth scaled power for comprehensive performance verification. Prelicensing documents were submitted to licensing authority on July 2003. Now, the SMART design verification phase is currently underway to conduct separate effect tests and comprehensive integral tests. A SMART desalination plant currently under construction will be in operation by 2008**.** It is expected that SMART desalination plant can be completely commercialized from 2009.

LIBYA:

Libya has seen the desalination of seawater to be one of the major option to augment national efforts for the supply of potable water and decided to conduct certain activities toward capacity building and cost optimization in this field. Among the activities in this direction are:

1. The establishment of a specialized research center to be responsible for research and development in technologies for water desalination and wastewater treatment. A national program to acquire know-how and transfer of technology in the field of seawater desalination was initiated in collaboration with some European companies.
2. Continuing the site-specific studies to assess economic competitiveness of energy options to be coupled with desalination plants using DEEP and other tools.
3. Establishing cooperation with other countries for feasibility study on nuclear desalination for specific site is being considered so as to promote and deepen the technical and economic investigations for the optimum coupling between energy and desalination systems.

MOROCCO:

Morocco adopted specific law covering all water management aspects, including pricing and environmental issues and creating Basin agencies. In order to address water scarcity in the near term Water Authorities set up and are implementing the 2005-2025 National Water Plan. Nuclear desalinisation is an option among other options. The Government of Morocco strongly believes that existence of effective regulatory infrastructure is a prerequisite for the development of any promotional nuclear activities. Consequently, it is establishing an adequate and sound legal and institutional legislative and regulatory nuclear framework and is committed to become familiar with all existing and available technologies and expertise in nuclear peaceful activities in general and desalination in particular.

RUSSIAN FEDERATION:

The design and licensing activities for the small floating heat and power co-generation plant based on ship propulsion reactor technologies has been finished. Several financing schemes, including using international co-operation channels, are being elaborated for construction of the first station in the North of a European part of Russia. The Nuclear Floating Power Unit (NFPU) equipped with two KLT-40C 150 MWt PWRs, being a part of the station, can be effectively used as energy source for nuclear desalination complex. Russia proposes to implement international nuclear desalination demonstration project based on the above technology and invites interested partners for participation in such a project.

The preliminary design work aimed at the assessment of technical and performance characteristics of nuclear desalination systems has been conducted for prospective Russian medium-sized reactors VVER-640, GT-MHR, BREST-300, and small-sized reactors KLT-40C, RUTA, UNITERM, NIKA, SBBR-75/100.

SAUDI ARABIA:

Saudi Arabia is the largest desalinated water producer in the world, contributing to 30 percent of global production, according to official statistics. Desalinized water currently constitutes Saudi Arabia's chief source for drinking water. The Saudi government transports its desalinated water via a 2,500 kilometer pipeline network, 21 pumping stations, 131 depots and 10 stations for mixing the desalinated water with underground water.

King Abdulaziz City for Science and Technology has financed a research project in nuclear desalination planning for Saudi Arabia. The outcome of the study showed that nuclear desalination is very promising option, however besides economic issues, safety concerns of water contamination is very important issue need to be investigated for coupled nuclear desalination system

TUNISIA:

In 2002, the Tunisian National Centre for Nuclear Sciences and Technologies (CNSTN) and CEA-France signed and under the aegis of IAEA's Interregional Cooperation Programme INT/4/134 launched a nuclear desalination feasibility studies for the La Skhira site in the south of Tunisia, known as the TUNDESAL project. This feasibility study considers the following tasks:

- Pre-dimensioning of the nuclear reactor and desalination processes, compatible with Tunisian electricity needs and required water production capacity at La Skhira site.
- Coupling of the selected nuclear reactor to desalination processes and system optimisation.
- Economic evaluation of the integrated systems elaborated above.
- Safety verification studies of coupled systems.

The first three tasks were completed. The fourth task related to safety and radiological analysis will be finalized in October 2004.

UNITED STATES OF AMERICA:

In the framework of nuclear desalination, the U.S., with the leadership of Argonne National Laboratory (ANL), is actively engaged in assessing the possible contribution of cogeneration of water and power using advanced desalination and power plant combinations for sustainable development. ANL is actively engaged in the IAEA's coordinated research projects (CRP) on site-specific economics and technical feasibility of a possible nuclear desalination facility in the U.S. and in helping upgrading the Agency's relevant software DEEP.

A new project in the U.S. State of Texas co-led by Sandia National Lab and sponsored partly by the U.S. Department of Energy (DOE), will examine the technical, economic and socio-economic feasibility of a nuclear energy/water cogeneration plant along the Texas coast for supplying energy, water and hydrogen for the local petrochemical industry as well as the surrounding population. ANL's Nuclear Engineering Division (NED) has been given a leading role in the technical design and economic assessment of this possible future plant. Other nuclear desalination operations such as at the Diablo Canyon Nuclear Powel Plant and co-located membrane desalination plant will also be reexamined to assess future possible expansion of operations and lessons learned from operations thus far.

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WATER MONITORING AS A SAFETY FEATURE FOR NUCLEAR DESALINATION

Néstor Masriera, Alicia Doval and Mariana di Tada, INVAP, Argentina

The safety aspects of the design of a Nuclear Desalination Plant (NDP) have been analysed in general terms from several points of view, and it is widely accepted that the general safety approach for Nuclear Facilities is valid. Thus the body of existing IAEA standards and guides contains the general requirements that are applicable to these plants.

In a simplified description, the NDP (or the coupling) should be designed with the **safety objective** of ensuring that its inclusion does not result in:

- Any adverse effect on the safety of the Nuclear Power Plant (NPP).
- Any hazards of a different nature or higher probability than those stated or implied in the NPP SAR.

The first objective is readily complied with by virtually any known NDP design, so the relevant issue turns to be the possibility of transferring radioactive material to the product water.

These objectives have to be translated into safety design requirements under the light of defence in depth principle. These general safety design requirements could be:

- The provision of multiple barriers between potentially radioactive material and product water.
- The provision of features preventing the radioactive material from reaching the product-water even in case of any (credible) sequence of failures.

These requirements should be reflected into a conceptual design of a Coupling System, and the approach verified by a standard safety assessment using Postulated Initiating Events (PIEs) covering all aspects of the design, operation and utilisation of the coupling components.

Among several possible engineered safety features for preventing contamination spread, there are several documents in which the monitoring of product water is proposed, but an analysis of the effectiveness of this approach seems to be lacking.

The purpose of this presentation is to draft a coupling system safety assessment as part of the design process, following the "top-down" approach from fundamentals and general requirements, down to specific design requirements, producing a conceptual design of the monitoring system, comprising sensors, sampling sub-system, signal processing, etc. The state of the art of monitoring systems imposes some design constraints to the coupling system design, in terms of hold-up capability and piping interconnection.

This conceptual design gives a better idea of the complexity of the systems implied (process and I&C) in having monitoring of product water as a safety feature. It may also be seen that even using updated technology, the hold-up requirement for batch monitoring cannot be reduced below 60 minutes, which has a massive consequence on the design, due to the storage capability required.

The lower bound of the economical impact of this design solution was assessed at a conceptual level. It may be concluded that for most cases, product water monitoring should be considered strictly as a surveillance task periodical manual operation. If it were taken as the key safety feature for automatically triggering the isolation of the DP, even if technically viable, this monitoring approach may be an economical burden. These conclusions are extremely relevant when drafting general user requirements, in the first stages on NDP projects.

WATER TRANSPORT EVALUATION

M.A. El Sharaky, A.A EL Desouky and N. Mahran, NPPA, Egypt

The objective of the water transport system computer program is to provide the technical and economic evaluation and assessment of the desalted water transport system. For the technical evaluation and assessment, the water transport system was modelled as hydraulic model, built and solved by using the engineering equation solver (EES) software program. Also the economic evaluation and assessment for the water transport system was built and solved by using the EES.

- The technical and economic water transport program was built as an integrated structure which includes simplified modules of the hydraulic and cost parameters.
- The program was operated with sample cases and the output analysis was done and validated with the practical cases.

<u>The program technical capabilities are</u>:

- How to estimate the water transport system pipe length with the different hydraulic parameters, such as the elevation of the pipe from reference level, water flow rate, pumping power, etc

<u>The program economic capabilities are</u>:

- How to calculate total annual cost ($/m^3/km).
- How to estimate the effect of variations of pipe elevation on the total annual cost ($/m^3/km).
- Sensitivity analysis with several factors such as interest rate, energy price, and pipe length.

FINANCIAL ANALYSIS OF NUCLEAR DESALINATION SYSTEMS

N. Benzarty, S.Nisan, CEA, France

In the context of the TUNDESAL project, carried out by France and Tunisia under IAEA interregional collaboration programme INT/4/134, it was decided to make a preliminary financial analysis, regarding the profitability of selected concepts.

The analysis requires the determination of the project Cash Flows, where Cash Flow = Earnings (from sales of the project output) – Initial expenditure (Operation & Maintenance Costs, fuel costs).The profitability of a given project is then judged by applying the financial criteria such as the Net Present Value, (NPV); the Internal Rate of Return (IRR) and the Payback Period (PBP).

$$\mathbf{NPV = \Sigma[Discounted\ cash\ Flows,\ CF_i] - [initial\ expenditure,\ I_0]}$$

$$\mathbf{NPV = [CF_1 / (1+i) + CF_2 / (1+i)^2 + \ldots + CF_n / (1+i)^n + \ldots + CF_T / (1+i)^T] - I_0}$$, which then gives $\mathbf{NPV = \Sigma[CF_t / (1 + i)^t] - I_0}$If **NPV** > 0, the project is considered profitable because: one can recover the capital invested, remunerate the funds on discount rate basis and realise benefits for the project sponsors. If **NPV** is <0, the project is not profitable.**IRR** is the discount rate at which net present value (NPV) investment is zero

$$\mathbf{NPV = \Sigma[CF_t / (1 + IRR)^t] - I_0 = 0}$$

In this case, the project has neither profits nor losses.The project is worth investing when IRR of the project is higher than the discount rate The **PBP** is the length of time it takes to recover the initial cost of a project; i.e;

$$\mathbf{\Sigma[CF_n / (1 + i)^n] - I_0 > 0}$$

The most profitable project is the one with the shortest payback period

Some results are given in Table 1.The desalting capacity is 48 000 m^3/day at La Skhira (Tunisia). Discount rate is 8% and fossil fuel price is 18 $/bbl.

Table 1: Financial profitability of divers systems.

	SCOR600			GT-MHR		CC600		FUEL600	
	+ MED	+ RO	+ ROph	+ MED	+ RO	+ MED	+ RO	+ MED	+ RO
NPV	318	356	377	794	816	-249	-27	-662	-631
IRR	10	10.2	10.4	15.6	15.8		7.3		
PBP	24	23	22	12	12	>30	>30		

We observe that:

- Under no conditions the FUEL600 based systems would be profitable.
- The IRR of fossil energy based systems (CC600 and FUEL600) are not calculable because their NPVs are already negative. The only option which is almost profitable is the CCIN600 + RO system, whose IRR is very close to 8%.
- The lowest PBP is for the GT-MHR+ RO system (13 years), compared to 25 years for SCOR600+RO.
- The PBP of fossil fuelled options is greater than their lifetimes.

HYBRID SYSTEMS

Pradip K. Tewari, BARC, India

The R&D work presently carried out worldwide is oriented towards improving the efficiency and technoeconomics of the desalination system for large scale production of fresh water from sea water. One of the methods to achieve the objective is by combining one or several desalination systems based on thermal and membrane processes or their combination known as hybrid desalination. A hybrid system has enough potential to offer performance improvement, savings in pretreatment and cost reduction. A carefully designed hybrid system has several advantages such as provision for redundancy, utilization of streams from one to another and production of two qualities of product water for their best utilization.

Bhabha Atomic Research Centre (BARC) has been engaged in R&D work in thermal and membrane desalination technologies since last several years. A number of pilot plants have been tested successfully. Utilizing the design and operational experience of these plants, a hybrid MSF-RO seawater desalination plant of 6300 m3/day capacity coupled to a nuclear power station based on pressurized heavy water reactor (PHWR) in south east coast of India is being set up to demonstrate the reliability and economics of hybrid desalination technology as a future viable alternative to meet the water shortage. The hybrid desalination demonstration plant (Fig.1) comprises of 4500 m3/d MSF desalination plant and 1800 m3/day RO plant. A part of the high purity product water from the MSF will be used to prepare makeup boiler grade water for the power station. Blending of the product water from the RO and MSF plants will provide requisite quality drinking water. The RO plant will continue to be operated to provide the minimum quantity of water essential for drinking purposes.

Fig. 1: Hybrid MSF-RO Desalination Demonstration Plant, Kalpakkam

The Reverse Osmosis (RO) desalination plant needs elaborate feed pretreatment for removal of scaling constituents, suspended impurities, organics and microbial load. Present day desalination plant uses conventional filtration and chemical treatment. Ultrafiltration (UF) unit installed upstream of RO plant can be effectively used for the pretreatment. The economics of UF vs. conventional treatment however need to be investigated in detail.

Preliminary studies have been carried out recently on use of nanofiltration (NF) as a means to improve the performance of Multi-Stage Flash (MSF)/Multi-Effect Distillation (MED) and RO. NF unit reduces the hardness ions Ca++, Mg++, SO4—and HCO3- to a great extent. It also partially reduces TDS of seawater. This will result in reduced chemical addition for sea water pretreatment. A NF-MSF-RO or NF-MED-RO unit could provide higher top brine temperatures offering higher Gain Output Ratio (GOR) for MSF/MED plant and significantly improve the product output due to increased recovery in RO unit.

Hybrid system (MSF/MED-RO) set up at same location may contribute significantly in reducing the operation and maintenance (O&M) cost of desalted water by taking the advantage of producing both process and drinking quality water, common pretreatment to a considerable extent and possibility of using reject streams from one plant to the other. Hybrid system using UF/NF as a pretreatment of seawater coupled to MSF/MED or RO has a high potential in future.

Major International Collaboration underway

- **Indonesia and Korea, Rep. of**

Korea Atomic Energy Research Institute (KAERI) and National Atomic Energy Agency of Indonesia (BATAN) jointly evaluate economic feasibility of a nuclear desalination plant on Madura Island using SMART. The final drafts of the PFS and the URD are ready. It envisions the nuclear desalination plant operation in 2018 producing 4000 m^3/d of fresh water.

- **Tunisia and France**

CEA (France) and CNSTN (Tunisia) signed a collaboration agreement on January 15, 2002 for a technical and economic evaluation of Nuclear Desalination for the site of La Skhira. Preliminary studies on three of the four initial work packages (pre-dimensioning, optimised coupling schemes and economic evaluation,) have already been completed. The draft PFS will be ready by September 2004.

- **Pakistan**

In proceeding with engineering details of coupling a thermal desalination unit with KANUPP, PAEC is receiving technical assistance through IAEA from international experts including from Argentina and Germany. PAEC plans to start the project work after completing the design related studies during 2004."

- **INNOMED**

France is coordinating the preparation of a follow-up project to EURODESAL, for an ambitious proposal under the International Cooperation with Mediterranean countries (INCO/MED programme) of the 6th Frame Work Programme of the European Commission This project, regrouping 4 partners from the EU (Cyprus, France, Germany, Italy) and three from North Africa (Egypt, Morocco, Tunisia) is designed to propose sustainable solutions based on wastewater recycling and desalination for possible specific sites in the Mediterranean region.

Highlights of on-going and future activities at IAEA (2003/2004)

CRP-1 on "Optimization of the Coupling of Nuclear Reactors and Desalination Systems"ended in December 2003. The draft of the TECDOC forming part of the studies of the CRP is prepared and is under review.

CRP-2 on "Economic Research on, and Assessment of, Selected Nuclear Desalination Projects and Case Studies" launched in 2002 has participating institutes from 11 Member States. . The second RCM was held in October 2003.Synergy between the CSI's studies was discussed and TECDOC contents prepared. Suggestions for DEEP upgradation were made.

The Programme Evaluation of the nuclear desalination project was conducted in early 2004 by the External Evaluation Panel, which recognised a job well done and supported continuation of the programme

INDAG met in July 2004 and presentations of the status of activities in the Member States were made by the members. INDAG reviewed the Agency's current and future activities and made several recommendations. The follow- up actions are being discussed.

IAEA presence at International Conferences

1. Nuclear Desalination a Viable Option for Producing Fresh Water, European Desalination Society Conference on Desalination and Environment: Fresh Water for All, Malta (2003)
2. Coupling and Thermodynamic aspects of Seawater Desalination using High Temperature Gas Cooled Reactors, IDA World Congress, Bahamas (2003)
3. Optimization of the Coupling of Nuclear Reactors and Desalination Systems, International Conference on Advanced Nuclear Power Plants and Global Environment (GENES4), Kyoto, Japan (2003)
4. Role of Nuclear Desalination in Meeting the Potable Water Needs in Water Scarce Areas in the Next Decades; EuroMed 2004, Marrakech, Morocco (2004)
5. DEEP: A tool for Evaluating Co-generated Power and Desalination Strategies, EuroMed 2004, Marrakech, Morocco (2004)

Recent IAEA publications relevant to nuclear desalination[1]

1. Status of design concepts of nuclear desalination plants, IAEA TECDOC-1326 (2002)
2. Market potential for non-electrical applications of nuclear energy, TRS-410 (2002)
3. Considerations in the development of safety requirements for innovative reactors: Application of HTGCR, IAEA TECDOC-1366 (2003)

[1] **How to get IAEA publications**: Orders and requests for information may be addressed directly to:
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