International Nuclear Desalination Advisory Group
to the International Atomic Energy Agency

INDAG NEWSLETTER

No.3 – September 2003

A WORD FROM THE DEPUTY DIRECTOR GENERAL

It is now well recognised that nuclear desalination will be a viable option for sustainable water security in the coming years in many parts of the world suffering from water scarcity/stress. I notice that the activities on nuclear desalination in the Member States is now shifting from feasibility studies to setting of experimental facilities and demonstration projects. International collaboration between interested Member States is also taking place in the development of plans for setting up of nuclear power-desalination plants at suitable sites. The experiences gained from these studies will be useful in deployment of large size desalination plants in future for safe and economic production of fresh water using nuclear energy. Economic research aiming towards further water cost reduction is desirable for large-scale adoption of nuclear desalination.

The efforts of INDAG, in strengthening the Agency's program on nuclear desalination, are quite appreciative. I am pleased with the release of the third issue of the INDAG Newsletter, which is highlighting the current activities of the Agency and from the Member States.

V.M.Mourogov
Deputy Director General
Department of Nuclear Energy, IAEA

To Our Readers

This third issue of the Newsletter is characterised by the key words "demonstration" and "scientific maturity" as opposed to the "winds of change" in the second issue. Nuclear desalination studies in the INDAG member countries have moved from the generic studies to site-specific (e.g. the CRP on economics) studies and now to demonstration projects. The demonstration project at KALPAKKAM (INDIA) is now going on at full speed. That of KANNUP (PAKISTAN) will begin soon. A Similar project for the MEDITERRANEAN region is currently under consideration in France. Similarly, in its latest call for proposals for its 6th Framework programme, the European Commission has launched an ambitious programme of research and technological development in the field of "Management of scarce water resources and mitigation technologies". This programme specifically calls for research in desalination.

On the roadmap of "dream to reality", we are therefore closer to our objective of having full-fledged integrated nuclear desalination plants, not only satisfying the electricity and water needs of the countries but also paving the way for a large scale public acceptance of nuclear energy in the world.

As you can judge from the technical articles and the short presentation of country-wise nuclear desalination activities, our scientific knowledge has now considerably matured, thanks in part to the sustained efforts deployed by the IAEA, both as regards the general understanding (e.g. the Guidebook) and the specific developments in the field (e.g. 3 interregional projects and the new version of the code DEEP, under continued development and validation).

Happy (and informative) reading!

S. Nisan
Chairman, INDAG

INDAG is an Advisory Body to DDG-NE established in 1997.
The next INDAG meeting is planned for 2004.

Recent Activities in Nuclear Desalination in Member States

ARGENTINA:
During the last period, the support of Argentina to the Agency's activities on Nuclear Desalination has continued with particular emphasis on Safety and Licensing aspects. Advances on these issues were presented in several international forums, and were specifically used for the safety assessment and design feedback of the coupling in the Nuclear Desalination Demonstration Plant being under implementation in KANUPP (Pakistan) in the frame of an Inter-regional TC Project.
Argentina (INVAP) contribution to the CRP "Optimization of the coupling of NPP and Desalination Systems" was completed according to the foreseen content and schedule.

CANADA:
In Canada, responsibility for the advancement of nuclear desalination is split between AECL, (development of advanced reactor technology) and CANDESAL, (development of advanced desalination technology and its coupling to reactor systems).
CANDESAL continues to make strides in developing its technology as well as its business plan for commercial development. CANDESAL has been recently awarded funds from the Canadian Government to further develop its advanced reverse osmosis technology. Now that functional testing has been successfully completed the next experimental phase is a pre-commercialization demonstration program to test a full-size (nominal $500 m^3/d$) system.
CANDESAL is also continuing its participation in the EU 6th Framework project, ECOWATER along with France and 19 other partners.
Although not for a nuclear application, CANDESAL has signed an agreement with another Canadian company, Flood-Master Barriers Inc., to deliver small emergency relief systems to regions in need. This non-nuclear commercial development is a significant step forward in acceptance of the technology for eventual application in nuclear desalination.

CHINA:
In order to specify the concept of the nuclear desalination technology and verify its technical feasibility and economic viability, a pre-feasibility study of the Shandong nuclear seawater desalination plant (SNDP) had been carried out in 2001, and a project proposal was approved by the Government in February 2003. The feasibility study of the project, based on the use of a 200MWth nuclear heating reactor (NHR-200) coupled to a MED plant, with a capacity of 120 000 to 160 000 m^3/d, is being carried out at present by the Institute of Nuclear Energy Technology (INET), Tsinghua University. The study is likely to be finished by the end of this year.

EGYPT:
A feasibility study for a nuclear plant at El-Dabaa to co-generate potable water and electricity is completed. A test facility to study the characteristics of SWRO with preheat is under construction. Efforts continue to develop a nuclear desalination simulator for educational purposes, with the support of the IAEA.

FRANCE:
The EURODESAL project, co-ordinated by France, regrouping 6 EU industrial companies and R&D organisations and one Industrial company from Canada, came to a successful completion on February 2003. Important results of this project were the development of innovative coupling schemes using RO and MED systems as well as a coherent economic evaluation of desalination options using fossil, renewable and nuclear energies.
Results have confirmed the rather significantly lower costs for nuclear options, (from 7 to 60%, depending upon the desalting capacity, fossil fuel prices and discount rates), as compared to fossil fuelled options.
Desalination costs by renewable energies are generally an order of magnitude higher than fossil or nuclear energy based systems.
France is also continuing its bilateral collaborations with Tunisia (The TUNDESAL project under the aegis of the IAEA inter-regional project INT/4/134) and with Morocco (The AMANE project).
Site specific studies for la Skhira (Tunisia) and Agadir and Laayoun (Morocco) have begun through the detachment of one Tunisian Engineer (from the utility, STEG) and one Moroccan Engineer (from the water company, ONEP). Three more Engineers from Tunisia (from the utility STEG, the water company SONEDE and the research centre, CNSTN) and two from Morocco (one from ONE and one from CNESTEN) are also expected from September 2003.

INDIA:
The 6300 m^3/d MSF-RO Hybrid Nuclear Desalination Plant at Kalpakkam consists of 4500 m^3/d MSF plant and 1800 m^3/d SWRO plant. The SWRO plant has been commissioned in August 2002 and being operated in round the clock shifts.
The seawater intake and reject disposal system including pipelines from MAPS to NDDP have been completed. The work on steam tapping from MAPS I for MSF has been completed. The LP and HP isolation heat exchangers and brine heater including accessories have been installed. The fabrication and installation of MSF modules is in full swing at site.
The LTE desalination plant utilizing waste heat of nuclear reactor for desalination has been connected to CIRUS reactor for demonstration of coupling to a nuclear research reactor. The cold runs have been successfully completed.
The product water from this plant after minor polishing will meet the make up water requirement of the research reactor.

ISRAEL:

The first large national desalination plant is now under construction at the southern Mediterranean coast. The 2-unit SWRO BOOT is at an advanced stage of the civil engineering works, each unit nominal capacity is 50Mm^3/year (150-160 km^3/day), consisting of 3 subsystems. The commissioning of the first subsystem is expected by the end of 2004 and the entire plant is planned to be fully productive in 2005.

A 2nd SWRO plant of 45 Mm^3/year is at the end of bidding procedures.

4 additional bids for plants of 30Mm^3/year each have been completed, 3 of which have been already contracted. Bidding procedures started for a 2nd large national desalination SWRO plant of 2 units, 50Mm^3/year per unit nominal capacity, at the northern-central Mediterranean coast.

7 brackish water RO plants totalling about 65Mm^3/year have been already contracted or are under bidding procedures.

JAPAN:

In Japan, several types of small nuclear reactors have been designed to supply electricity and for other applications, such as seawater desalination, heat supply, H_2 production and so on.

The seawater desalination plant with the capacity of 50,000 ton/day is now under construction in Kyushu Island. The RO technology with 60 % recovery ratio was applied. An advanced seawater intake system, which is laid under the sand in order to get more clear seawater and to reduce the filtration system, is also being used.

The desalination plant will start its operation from 2005.

KOREA, REP. OF:

Basic design of SMART is completed. In parallel with out-pile tests a one-fifth scale pilot plant SMART-P is being planned to be constructed.

A joint study with BATAN, Indonesia, started on economic feasibility of a nuclear desalination plant on Madura Island.

LIBYA:

In the framework of CRP's, working groups are studying and investigating viability and competitiveness of nuclear energy for seawater desalination in the country.

MOROCCO:

A standing commission (COPSAN) was created in order to establish an adequate and sound legal and institutional framework. The Commission will prepare a unique nuclear safety law, which will create an independent nuclear safety regulatory authority under the prime minister.

PAKISTAN:

PAEC is actively participating in the IAEA Interregional Technical Cooperation Project on Integrated Nuclear Power and Desalination System design, and has proposed Karachi Nuclear Power Plant (KANUPP), a 137 Mew, PHWR, as a site for nuclear desalination demonstration plant. With the technical assistance from IAEA, the coupling of a MED thermal desalination plant (DP), of about 4800 m^3/d capacity, with KANUPP, using low cost steam available from the reactor is being studied.

An IAEA expert mission visited Pakistan in June 2003 to review the technical and safety aspects of design of the coupling scheme. According to the present plan, the plant is expected to be commissioned in the year 2005.

RUSSIAN FEDERATION:

R&D programmes for applying Russian small reactors KLT-40C, NIKA and RUTA to nuclear desalination have continued. Construction of a Floating Power Unit (FPU) pilot plant with KLT-40C reactors is planned for 2006. The co-generation plant will be sited at the shipyard in the western North Sea area where the FPU is being manufactured

TUNISIA:

In order to meet the water shortages in the years to come, Tunisia has started a feasibility study aiming to elaborate a strategy for the possible application of nuclear energy for seawater desalination and to provide the relevant authorities with all necessary detailed information needed to decide on the implementation of the project. The project, known as TUNDESAL, started in January 2002 and is being carried out under a bilateral collaboration agreement between France (CEA) and Tunisia (CNSTN, along with STEG, the national utility and SONEDE, the national water company) as well as under the aegis of the IAEA interregional technical cooperation program (INT4/134).

The basic aim of the work is to estimate the realistic costs (under Tunisian conditions) of an integrated nuclear desalination system, operating in the co-generation mode at a specific site (la Skhira). Optimised and innovative schemes are being investigated to couple MED and RO (with and without preheating) with existing and innovative nuclear reactors.

UNITED STATES:

The Generation IV roadmap report will include a detailed discussion of potential nuclear energy products, recognizing the important role that future nuclear energy systems must play in producing fresh water.

In the framework of CRP-2 existing nuclear desalination experience at the Diablo Canyon Nuclear Power Plant will be documented.

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. It envisions the plant operation in 2015 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 two of the four initial work packages (pre-dimensioning and optimised coupling schemes) have already been completed.

- **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 2003."

- **Morocco and France**
  An agreement, similar to France and Tunisia has also been made (March 2002) between CEA and CNESTEN (Morocco). The project, called AMANE, will study the feasibility of nuclear desalination for two sites: Agadir and Laayoun. Data collection for the water and electricity needs, as well as for the specific sites has started.

- **Russia and Canada**
  Russia (Minatom/Rosenergoatom/Malaya Energetika) and Canada (CANDESAL) have agreed to jointly develop a floating nuclear desalination system based on Russian KLT-40C reactor technology and CANDESAL's advanced RO desalination technology. The project is moving forward, with the next project coordination meeting scheduled for late 2002.

- **ECOWATER**
  France is coordinating a preparation of a follow-up project to EURODESAL, for an ambitious proposal under the 6th Frame Work Programme of the European Commission. This project, regrouping 20 partners from the EU, North Africa, with Cyprus, Turkey, Jordan and Saudi Arabia, is designed to propose sustainable solutions based on wastewater recycling and desalination for possible specific sites in the Mediterranean region.

Current Members of INDAG, Term II (2001-2004)

ARGENTINA:
Mr. N. Masriera, INVAP SE
masriera@invap.com.ar

CANADA:
Mr. J.R. Humphries, Candesal
JRHumphries@candesal.com

CHINA;
Mr. Zong Xin Wu, INET
Tsinghua University
wuzx@mail.tsinghua.edu.cn

EGYPT:
Mr. S.B. Abdel Hamid, NPPA
nppa1@idsc.net.eg

FRANCE:
Mr. Simon Nisan (Chairman) CEA
simon.nisan@cea.fr

INDIA:
Mr. P.K. Tewari, BARC
pktewari@magnum.barc.ernet.in

ISRAEL:
Mr. A. Barak, IAEC
extrel@ndc.soreq.gov.il

JAPAN:
Mr. A.Minato, CRIEPI
minato@criepi.denken.or.jp

KOREA, Rep. of:
Mr. S.H.Kim, KAERI
shkim@kaeri.re.kr

LIBYAN ARAB JAMAHIRIYA:
Mr. S.Ghurbal, TNRC
ghurbal55@yahoo.com

MOROCCO:
Mr. Y. Bouabdallaoui, PMO
bouabdellaoui@pm.gov.ma

PAKISTAN:
Mr. M. Tariq, PAEC
energy@comsats.net.pk

RUSSIAN FEDERATION:
Mr. Y.Baranaev, IPPE
baranaev@ippe.rssi.ru

SAUDI ARABIA:
Mr. A. Al-Kheliewi, AERI
akheliwi@kacst.edu.sa

TUNISIA:
Mr. N. Reguigui, CNSTN
n.reguigui@cnstn.rnrt.tn

USA:
Mr. J.Binder, ANL
jlbinder@anl.gov

IAEA (Scientific Secretary):
B.M.Misra, NENP
b.m.misra@iaea.org

TECHNICAL BRIEFS

NUCLEAR DESALINATION IN PAKISTAN

M.M.Tariq, PAEC, Pakistan

1. Introduction

Facing acute water stress, Pakistan has to depend on sea and brackish water desalination to satisfy the ever-increasing demands. Apart from Karachi, the coastal regions of Sindh and Balochistan are also witnessing rapid urban and industrial growth, which require good quality water.

PAEC is actively participating in the IAEA International Technical Cooperation Project on Integrated Nuclear Power and Desalination System design, and has proposed Karachi Nuclear Power Plant (KANUPP), a 137 MWe, PHWR, as a site for nuclear desalination demonstration plant.

A study is in progress, with the technical assistance from IAEA, for coupling a thermal Desalination Plant (DP), of about 4800 m3/d capacity, with KANUPP, using low cost steam available from the reactor. A small (2 x 227 m3/d) Sea Water Reverse Osmosis (SWRO) plant, already installed at KANUPP, is operating satisfactorily since Feb. 2000.

2. Main Features of Existing Seawater RO Desalination Plant at KANUPP

The SWRO plant, designed for a maximum salinity of 35000 ppm, presently draws its raw water supply from tube wells with an average salinity of 24000 ppm. The salient features of the RO plant at KANUPP are:

Capacity	2 x 227 m3/d
No of Vessels	4 per Train
No of Membranes	4 per Vessel
Type of Membranes	MAGNUM TFC 2832
Membrane size	8"x 60" long
Design raw water inlet	21 m^3/hr per train
Design permeate flow	9.5 m^3 /hr per train
Recovery Rate	45%

SWRO Plant at KANUPP

3. Proposed Nuclear Thermal Desalination Demonstration Plant at KANUPP

3.1 Motivation

Main purposes of the demonstration plant are to:

a. Demonstrate safe and economic production of potable water by nuclear seawater desalination.

b. Provide reliable data (technical and economic) for the design of a large scale, low temperature desalination plant connected to a nuclear power plant (dual purpose nuclear power plant).

c. Develop a local team of engineers for design, construction, start-up and O&M of the desalination plant.

d. Build-up local manufacturing capabilities to maximize the local content for the future desalination plants to meet the growing water requirements for socio-economic development in the coastal areas.

The work is in progress and an IAEA expert mission visited Pakistan in June 2003 to review the technical and safety aspects of design of the coupling scheme and MED plant. The plant is expected to be commissioned in the year 2005.

3.2. Desalination plant

The Multi Effect Distillation (MED) plant has been selected for coupling with KANUPP. The selection of MED has been made considering the extraction steam conditions to be used as thermal energy for desalination and due to significant advantages MED over the other distillation processes. Main parameters of the MED plant are given in Table 1:

Table 1: Characteristics of the thermal desalination plant

Parameter	
Plant capacity (m^3/d)	4 800
Type	MED, LT-HTME, without TVC
Gain Output Ratio (GOR)	10
Seawater TDS (mg/l))	42 000
Steam consumption	19.4 t/h at 75°C, saturated

3.3 Description of Coupling Scheme (Isolation Loop)

Considering various options for tapping steam from KANUPP, as a source of heat energy to the proposed desalination plant, it was found that the primary steam bled from high-pressure turbine to the feed water heater COW-HX3 (a regenerative heat exchanger) closely matches the requirements, and electrical energy losses are also lower as compared with other options.

The desalination plant will be coupled with KANUPP through an intermediate pressurized closed water loop, incorporating L-H-L design concept. The coupling scheme is designed to prevent both the ingress of brine or seawater into the turbine cycle of the NPP and ingress of contaminants (e.g. radionuclides) from the power plant to the product water. The boiler feed water heater COW-HX3 is in a good service condition and will be integrated into the coupling circuit, keeping it at its original location. The existing steam bleed line will be utilized and the boiler feed water to COW-HX3 will be bypassed in order to take the HX out of turbine cycle and make it a part of the intermediate pressurized water loop (isolation loop). This will minimize the required reengineering in the turbine-hall for thermal coupling of DP and KANUPP.

The bled steam conditions at COW-HX3, corresponding to power plant output of 85 MWe, are: T= 113^{o}C, wetness= 25%, P= 1.57 bara, flow= 27700 kg/h. This steam will transfer heat to the pressurized water loop and the condensate will return to the condenser. The secondary steam, produced in the evaporator (HX), at a temperature of 77^{o}C. 0.408 bara, will be used in the first effect of the desalination plant and its condensate will return to the evaporator. The schematic diagram of coupling desalination plant with KANUPP is shown in Figure 1.

The existing intake structure of KANUPP will be used to pump raw seawater for the desalination plant.

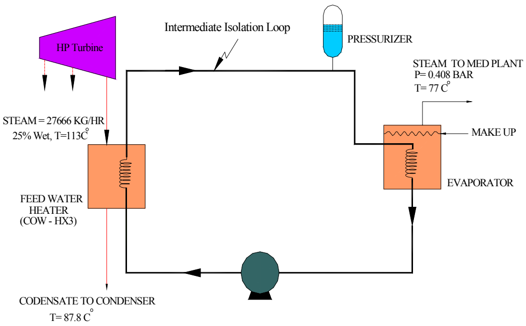

Fig 1: Schematic Diagram of Coupling a Desalination Plant (MED) with KANUPP

EL-DABAA PREHEATED RO EXPERIMENTAL FACILITY

Mohamed M. Megahed[1]

1. Background

In view of the limited Egyptian resources of both primary energy and fresh water, Egypt has been considering for a number of years the introduction of nuclear energy for electricity generation and seawater desalination. The commercial seawater desalination processes which are proven and reliable for large-scale freshwater production are MSF and MED for evaporative desalination and RO for membrane desalination. Studies have shown that there is a potentially significant economic and performance benefit through the combined effects of feed water preheating and system design optimization. These conclusions have been drawn from analyses and preliminary design studies with little experimental validation, which is of extreme importance in the confidence building process, particularly when some experts argue that elevated temperatures may result in higher product water salinity, more rapid membrane fouling, greater membrane compaction, reduction in membrane lifetime and that saving in total water cost by elevating temperature from 15~18^{o} C to 30^{o} C would be in the range of 3% only.

In response to the increasing interest in nuclear desalination, the IAEA has performed a two-year Options Identifications Programme (OIP), to identify candidate reactor and desalination technologies that could serve as practical demonstration of nuclear desalination The OIP identified three possible

[1] Nuclear Power Plants Authority, 4 El-Nasr Ave., P.O. Box 8191, Nasr City, Cairo 11371, Egypt
e-mail: nppa_dabaa@ahram0505.net

approaches to the demonstration of nuclear desalination technology, as well as a number of intermediate steps to reduce unknowns and risks aiming at gradual, partial and progressive confidence building. These intermediate steps included small-scale preheated seawater desalination with RO.

Based on the above recommendations, the fact that Egypt does not posses any nuclear power plants, and the existing financial limitations, NPPA decided to construct an experimental RO facility at its site in El-Dabaa to validate the concept of feed water preheating.

2. Objectives

a. *Overall*: to investigate experimentally whether the projected performance and economic improvements of preheated feed water can be realized in actual operation.

b. *Short-term (~3 years)*: to study the effect of feed water temperature and pressure on RO membrane performance characteristics over a range of temperatures (20-45° C) and pressures (55-69 bar).

c. *Long-term*: to study the effect of feed water temperature and pressure on RO membrane performance characteristics as a function of time. The intent is to select one of the membranes used during the short-term program for extended study to investigate possible reduction in membrane lifetime due to effects such as increased fouling or membrane compaction.

3. Configuration of the Test Facility

The test facility (Figure 1) consists of two identical units: one unit operating at ambient seawater temperature and the other with preheated feed water at 25, 30, 35, 40 and 45ºC, as called for by the experimental sequence. This configuration is considered practical with 4" membranes, and has the benefit of giving direct comparison of performance characteristics for the preheated and no-preheated cases at all values of preheat temperature. The test facility consists of the following main components:

a. *Beach Wells and Pumps,* to ensure clean feedwater with minimum pretreatment requirements and lower operational costs.

b. *Pretreatment System,* designed to allow for the various pretreatment requirements for the different commercial membranes to be tested.

c. *Water Heating System (for one unit only),* the feedwater will be heated by freshwater/seawater heat exchanger. The hot fresh water shall be obtained from an electric water heater. To reduce energy consumption during continuos operation, the hot brine and permeate shall be used to preheat the feedwater, utilizing permeate/seawater and brine/seawater heat exchangers. This will give the following advantages:
   - Reduction of electricity consumption in the water heater.
   - Reduction in permeates temperature.
   - Reduction in the brine temperature before disposal, which will be advantageous from the environmental point of view.

d. *Other systems*, common to commercial RO are also included.

4. Current Status of the Project

The construction work started in January 2001, however, national economic difficulties that resulted in the effective devaluation of the Egyptian currency lead to difficulties in importing the equipment and increase in prices. In addition, some problems occurred during the execution phase between NPPA and the Contractor, which lead to long delays. To date, the following milestones in the construction of the unit have been completed:

- Major part of the civil work (Figure 1)
- The Beach Wells (Figure 2)
- Acquisition of electro-mechanical equipment.

It is hoped to start the experimental programme by the end of 2003.

Figure 1: Main Building of Test Facility

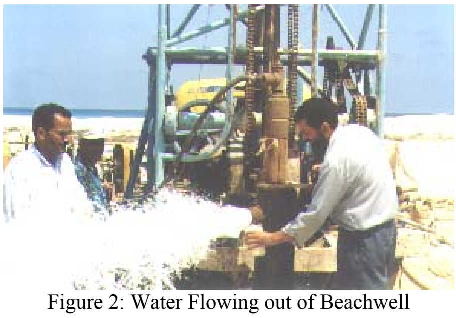

Figure 2: Water Flowing out of Beachwell

Recent IAEA publications relevant to nuclear desalination

1. Safety aspects of nuclear plants coupled with seawater desalination units, IAEA TECDOC-1235 (2001)
2. Status of design concepts of nuclear desalination plants, IAEA TECDOC-1326 (2002)
3. Market potential for non-electrical applications of nuclear energy, TRS-410 (2002)
4. Considerations in the development of safety requirements for innovative reactors: Application of HTGCR, IAEA TECDOC-1366 (2003)

How to get IAEA publications: Orders and requests for information may be addressed directly to:
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E-mail: sales.publications@iaea.org, Web site: http://www.iaea.org.wordatom/Books

International Conferences

The Agency co-operated in organising the international conference "Nuclear Desalination: Challenges and Options", which was held jointly by the World Council of Nuclear Workers and the Moroccan Association of Nuclear Engineers in October 2002, in Marrakech. About 150 participants from 37 countries attended the conference. It highlighted technology features, including design, coupling, economics and safety aspects of nuclear desalination plants. From the presentations by the participants, there was clear evidence of ever-increasing shortage of fresh water in many parts of the world. There was also a clear emphasis on economics and safety as the two main issues driving the future of nuclear desalination. Several participants referred to the Agency's DEEP code as their main tool for economic evaluation of nuclear desalination designs and expressed the need for the Agency to take a leading role in its further upgrading.

More information on the overall conference program can be found at www.wonuc.org.

IAEA presence at International Conferences

1. IAEA Nuclear Seawater Desalination Activities, International Conference on Nuclear Desalination: Challenges and Opportunities, Marrakech, Morocco (2002)
2. Nuclear Desalination a Viable Option for Producing Fresh Water, European Desalination Society Conference on Desalination and Environment: Fresh Water for All, Malta (2003)
3. Coupling and Thermodynamic aspects of Seawater Desalination using High Temperature Gas Cooled Reactors, IDA World Congress, Bahamas (2003)
4. Optimization of the Coupling of Nuclear Reactors and Desalination Systems, International Conference on Advanced Nuclear Power Plants and Global Environment (GENES4), Kyoto, Japan (2003)

Highlights of on-going and future activities at IAEA (2002/2003)

CRP-1 on "Optimization of the Coupling of Nuclear Reactors and Desalination Systems" is in the concluding stage towards its completion in 2003. Libya and Morocco newly joined. The fourth and final RCM was held in February 2003.

CRP-2 on "Economic Research on, and Assessment of, Selected Nuclear Desalination Projects and Case Studies" has been launched early 2002 with participating institutes from 13 Member States. The first RCM was held in July 2002. The second RCM is planned for October 2003.

The web-based DEEP Users Group (DUG) has been launched as a forum for free and open exchange of information, working experience, and suggestions for future software improvements. DUG is open to all DEEP users. The first meeting of DUG was held in Obninsk in May 2003.The upgradation of DEEP 2.2 version is foreseen in the near future.

The Power Reactor Information System (PRIS) is being extended to accommodate relevant information of non-electric applications at NPPs: design characteristics and operating performance. Data collection on the INTERNET will start in 2003 with the initiative of NPES.

For further information, visit our web site at http://www.iaea.org/nucleardesalination

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