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BOARD OF GOVERNORS GENERAL CONFERENCE

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EXTENSIVE USE OF ISOTOPE HYDROLOGY FOR WATER RESOURCES MANAGEMENT

1. Last year the General Conference, in resolution GC(XXXVIII)/RES/9, stated - inter alia - that "the quality and quantity of available water resources, particularly in arid and semi-arid zones, are inadequate and that the availability of clean water is a minimal requisite for sustaining development," that "the availability of clean drinking water is directly linked to human health and has consequent serious economic implications" and that isotope hydrology techniques "are valuable in studying processes like groundwater recharge, surface and sub-surface water interaction, water salination, seepage and the pollution of water bodies and that their use should be integrated with conventional techniques".
2. Also, the Conference requested the Director General "to direct the available expertise and resources to a few concrete and cogent projects which would result in a visible impact in improved water resources management through isotope techniques", urged the Agency "to work in conjunction with other concerned international organizations and solicit their co-operation in such projects" and urged the Secretariat "to endeavour to secure resources needed for this purpose."
3. Lastly, it requested "that the Director General report on the progress achieved in the implementation of this resolution to the Board of Governors and to the General Conference at its thirty-ninth regular session." The present document has been prepared in response to that request and is being issued for the attention of both the Board of Governors and the General Conference.

Extensive use of isotope hydrology for water resources development and management

1. Introduction

Recognizing the vital role of adequate water resources for sustainable development and the potential of isotope techniques in water resources management, the Board of Governors discussed in June 1994 the subject of "Utilizing Isotope Hydrology for Groundwater Management in Arid-and Semi-arid Zones of Africa". In response to recommendations of the Board meeting and the resolution of the subsequent General Conference GC(XXXVIII)/RES/9 on the extensive use of isotope hydrology for water resources management, initiatives were undertaken to strengthen the end-user benefit and socio-economic impact of the utilization of isotope techniques in water resources development and management of Member States. Three of the technical co-operation projects for the 1995/96 programme cycle were designed in accordance with the Model Project concept. Furthermore, activities were launched to provide technical assistance to riparian countries of the Caspian Sea in tackling environmental problems such as groundwater pollution in coastal zones which are caused by the current sea level rise. Through the Agency's technical co-operation programme the specific potential of isotope techniques in addressing such problems will be made available for concerted action. In this context, efforts were made to strengthen the technical co-operation with other UN organizations and to attract donors. New initiatives were also undertaken within the framework of the Agency's research programme. In recognition of the needs for technical support of the practical application of proven isotope techniques in the water sector of Member States, and in promoting the refinement and further development of such techniques, a high-priority activity on the assessment of groundwater renewal and related anthropogenic effects in areas of water scarcity is being launched. This activity includes training in sampling and measurement techniques as well as isotope aided studies.

2. Endeavours to enhance the impact in improved water resources management through isotope techniques

2.1. Model Project Regional Africa RAF/8/022 "Use of Isotopes in Water Resources Development"

Following the June 1994 Board meeting in which special attention was given to the utilization of isotope techniques in the water sector of African countries, a Model Project was designed on the basis of the proposal for a regional African project. In December, the Model Project Regional Africa RAF/8/022 was approved. The project aims to apply isotope

techniques in combination with other hydrogeological investigations to practical problems in the development and optimum management of groundwater resources in nine African countries. It is expected that Algeria, Egypt, Ethiopia, Libya, Mali, Morocco, Niger, Senegal, and Sudan will co-operate in the regional project, which is envisaged to be implemented in two phases over a period of four years. In phase I (1995-96) the following countries are included: Egypt, Ethiopia, Morocco, Senegal. Activities in other countries are expected to commence in 1997-98.

In each country, areas have been identified by end users where adequate assessment of scarce water resources is crucial for water supply of large population centres or development activities. In the short term, the data obtained from hydrological studies will be used in estimating recharge rates and water budgets in the countries concerned, which would lead to the development of guidelines for water policy and optimum management of the existing resources. Accordingly, the water authorities and other end users can undertake development plans of the regions under study. In Phase I, water assessment and reassessment activities will have a significant socio-economic impact on water supply to over 3 million people in the Moyale region (Ethiopia), over 1.5 million people in the Dakar region (Senegal) and about half a million people in the South Atlantic region (Morocco). Furthermore, the results obtained are essential to the reclamation of more than 120,000 Feddans west of the Nile Valley (Egypt) and maintaining 15,000 hectares south of the Atlantic region (Morocco). In phase II, efforts will be devoted to setting up two central laboratories in the region capable of offering analytical and consultancy services to end users and which could play a major role in promoting the use in Africa of isotope techniques in water resources development projects.

The Agency's input will include expert and consultancy services for the planning, co-ordination, implementation and evaluation of project activities; equipment, consumables and supplies for field, laboratory and specific analytical services; training through the organization of regional scientific seminars and workshops, and the exchange of scientists and qualified technicians. A regional expert was appointed to provide continuous assistance during phase I in the implementation of isotope hydrological field work and co-ordination of regional activities to be implemented by the Agency in support of the Model Project.

The first major activity in the implementation of project activities was the Co-ordination Meeting which was held in Addis Ababa from 3 - 7 April 1995. During the meeting, the programme of activities to be carried out in each of the participating countries in 1995-1996 was finalized, the national contributions to the project in terms of scientific and support staff, analytical laboratory facilities, drilling and sampling equipment were reviewed. Inputs to be provided by the Agency in support of country-specific field activities to meet the objectives of the Model Project were determined. The meeting harmonized the countries'

work plans for 1995-96 and discussed the technical backstopping and organizational and managerial support to be provided by the regional expert to assist the countries in launching the field work. Laboratories which will be requested to perform isotopic measurements of the water samples have been identified as well.

In connection with the activities planned in each country, particular attention was given to two national training courses; one of them will be held in Morocco on isotope techniques in unsaturated zones and the other one in Senegal on data gathering and modelling of the Cap Verde Peninsula aquifer. Moreover, a regional training course in hydrochemistry for technicians - in conjunction with an inter-comparison exercise to ensure the quality of hydrochemistry measurements - was agreed to be held in Dakar, Senegal.

Financing for the project is US\$1,776,000 which is distributed over the period from 1995 to 1998. It will be realized by the Agency's technical assistance and co-operation funds (TCF).

2.2. Model Project VEN/8/010 "Groundwater Hydrology of the Caracas Aquifer" (Venezuela)

This Model Project focusses on the use of isotope techniques in tackling the currently existing serious problems in drinking water supply of the city of Caracas. As in many other drastically expanding megacities in Asia, Latin America and Africa, the rapid population growth of Caracas has led to a sharp increase in drinking water demand and consequently to a deficit in drinking water which has been aggravated by the present climatic trend characterized by an increase in the frequency of drought periods. Authorities restrict water usage, and several city districts have access to water only a few hours a day.

A practical attempt to reduce the existing deficit is seen in the exploitation of the "Valle de Caracas" aquifer, an urban aquifer system which so far has scarcely been used for drinking water supply. Therefore, its potential is yet unknown. Currently, the groundwater level is progressively rising, mainly due to human activities such as construction of underground structures, river canalization and leakages in the municipal water supply system.

Consequently, the Ministry of the Environment and Natural Renewable Resources (MARNR), in co-operation with other institutions and local municipalities, is currently investigating the potential of the "Valle de Caracas" aquifer with the final goal of the rational exploitation of the resources for drinking water supply. The IAEA supported Model Project is part of this endeavour and focusses on the following objectives:

- Quantification of the volume of groundwater available for exploitation;
- Identification of recharge sources and mechanisms;

- Assessment of water quality changes in the aquifer;
- Definition of flow paths and interconnection between aquifers;
- Evaluation of contamination risks and definition of protection zones.

The assessment of groundwater dynamics and quality characteristics by means of geochemical and isotopic methods (including tracer experiments) will provide key information for the identification of best areas for drilling additional wells which will diminish the existing water deficit in the metropolitan area. Basic data on the sources and mechanisms of groundwater recharge, the time span for renewal of groundwater and the vulnerability to pollution will also be evaluated for proper management of the water resources in the Caracas Valley. On the basis of this information, local authorities dealing with water resources management will be able to make decisions on the exploitation of the aquifer and in the definition of protection zones to avoid the contamination of areas where groundwater is used for drinking water supply purposes.

Preliminary results obtained from isotope and geochemical analyses and other hydrogeological studies suggest that groundwater recharge mainly occurs locally through direct infiltration of precipitation. The residence time of water in the aquifer appears to be relatively short (from a few years to decades). A shallow groundwater body was identified which corresponds to the most recently recharged waters and is characterized by a high pollution index. Evidence was found for lateral recharge of surface water from the Avila Mountains which has better quality for drinking purposes. The further implementation of the project is expected to provide consolidation of these and other preliminary findings. The project started in 1994 and will be completed in 1997. The total budget of the project is US\$268,900 which will be funded by the Agency's TCF.

2.3. Regional Project RAW/8/004 "Preparing Study of Caspian Sea Water Level Fluctuations" and Footnote a/ Regional Project RAW/8/005 "Study of Caspian Sea Water Level Fluctuations"

The environmental consequences of the recent sea level rise of the Caspian Sea are a matter of great concern to the five riparian countries: Russia, Kazakhstan, Turkmenistan, Azerbaijan and Iran. The flooding of coastal areas and the economic impact of the estimated 2.5 m rise of sea level in the past 15 years and the continuing rise at the rate of about 15 cm per year has attracted the attention of the international community. The causes of the sea level rise are still being debated and there are at present no indications whether the rise will continue and at what rate.

Following consultants' advice and in-house assessment, a proposal for a regional technical co-operation project was conceived, taking into account the expertise available in the Isotope Hydrology Section of RIPC, the Seibersdorf Laboratories, and the Marine Environment Laboratory in Monaco. Subsequent to this proposal, two regional projects on the Caspian Sea were approved for the 1996/97 biennial cycle.

The project "Preparing Study of Caspian Sea Water Level Fluctuations" (RAW/8/004) is of modest scale and meant to initiate and co-ordinate a comprehensive study of the water level fluctuations in the Caspian Sea using nuclear techniques. The budget of US\$34,200 for expert services in 1995 and US\$66,000 for expert services and provision of training in 1996 will be funded by TCF. The Agency's input to the project includes expert services, guidance and group training for preparation of the study; organization and co-ordination of the work; technical and scientific support for the preparation of field investigations; sampling and measurements at the Agency's laboratories. It is expected that the project will provide an assessment of the present environmental situation of the Caspian Sea region which would help in the elaboration of an environmental strategy and formulation of a specific plan of activities for comprehensive studies of the water level fluctuations in the Caspian Sea.

The comprehensive study is expected to be undertaken through the footnote a/ project entitled "Study of Caspian Sea Water Level Fluctuations" which requires extrabudgetary resource allocation of US\$750,000 for a two-year period. The Secretariat is seeking donors to fund this project. The problems to be tackled using isotope techniques in combination with other investigations include: water balance and dynamics of sea water; pollution of the surface water; impact of rising sea level on coastal groundwater resources; training and analytical quality control assistance. The project plan envisages several campaigns for collecting samples. These campaigns would be carried out jointly between the IAEA and local institutes, with logistic support of the riparian countries. The reinforcement of the regional network for precipitation sampling as well as the establishment of a network for river water sampling is expected to be arranged by the concerned riparian countries, if possible by institutes of the hydrometeorological service. The long term impact of the project would include a better understanding of the Caspian Sea hydrology and the mechanisms of sustained water balance of the hydro-system in the region. This will be the basis for formulation of recommendations and programme of measures to be undertaken by the countries to cope with the existing environmental problems.

2.4. Model Project ELS/8/005 "Isotope Hydrology and Geochemistry in Geothermal Fields" (El Salvador)

The geothermal systems in El Salvador, like most other geothermal systems in the world, are water dominated. The geothermal water which originates from rainfall, circulates through greater depths and is heated by magmatic bodies. Large volumes of this water with elevated temperatures up to about 300 °C are tapped for electrical power generation, among other uses.

At present, El Salvador is one of the top 10 geothermal energy producers in the world. It will be expanding its utilization of geothermal energy resources for electrical power generation from the current 14% contribution to the national requirement to 22% in the next five years. Likewise, since the geothermal system is water-dominated it generates large amounts of wastewater which could result to thermal and chemical pollution if disposed to the environment.

The energy development programme of the country requires drilling of about 35 wells in Ahuachapán and Berlín geothermal systems for production of steam and injection of waste water. It also includes the management of surface and groundwater by protecting it from potential pollution by reinjecting to the reservoir wastewater generated from the separation of steam from the geothermal fluids. As a model project with tangible impact on the energy, environment and water sectors, this project has the following objectives:

- (i) Integration of isotope hydrogeochemical techniques in the geoscientific investigations associated with the geothermal electricity development of Ahuachapán and Berlín fields to :
 - determine drilling targets for siting of production and injection wells,
 - develop a reservoir engineering model which will support the management strategies and operational procedures for optimum utilization of the resources.
- (ii) Enhancing local capacity by timely training and technology transfer to improve self-reliance in the use of isotope geochemistry in geothermics and reservoir modelling techniques.

A hydrogeochemical model will be generated with which drilling strategies will be formulated. Under this project the input of the isotopes such as oxygen-18, deuterium and tritium supplemented by geochemical, geological and reservoir engineering data will provide the information to increase the confidence level for identifying suitable drilling targets; e.g., heat flow regions and areas for reinjection. Likewise, artificial tracing experiments with the use of I-131 and I-125 will be conducted to identify flow patterns and flow rates. The Agency will provide direct assistance to the counterpart institution for practical application

of these isotope techniques in identifying suitable areas for production and injection of waste water. The Agency also provides support for monitoring the physical and chemical effects in the reservoir as a result of the reinjection of wastewater and of exploitation. This will prevent pollution of the environment, sustain the geothermal and water resources as well as lengthen the economic life of the reservoir.

Manpower capability for isotope and geochemical data interpretation, as well as for reservoir modelling will be developed through the fellowship programme. Likewise, the analytical capability for the water and gas chemical analyses will be improved through quality assurance interlaboratory comparison. The project duration is 2 years. The total budget of US\$96,000 will be funded by the Agency's TCF.

2.5. Regional and national projects for the investigation of different aquifer systems and water resources

The implementation of a regional technical cooperation project RER/8/002 focussed on isotope field investigations of ten different aquifer systems in the Middle East provided results which help to improve the management of the water resources in this area of water scarcity. The aquifer systems investigated include coastal aquifers in Lebanon and Syria, a karst aquifer in Iran, aquifers with different characteristics in Jordan and in Turkey, over-exploited karst aquifers in the United Arab Emirates, and water movement in the unsaturated zone in Saudi Arabia, Syria and Kuwait. The project facilitated transfer of know-how on isotope applications for groundwater resource assessment and management. Furthermore, a core of well trained staff was created in each of the participating countries viz. the Islamic Republic of Iran, Jordan, Kuwait, Lebanon, Saudi Arabia, Syria, Turkey and United Arab Emirates. The results of the field investigations will be published in an Agency TECDOC. Budget allocations for this regional technical co-operation activity was US\$61,400 in 1994 as compared to allocation of US\$82,800 available for 1995. The source of these funds is TCF. The project will be followed up by the regional project RAW/8/002 included in the 1995/96 TC programme.

Within the framework of ARCAL XVIII, a regional project was started in five Latin American countries namely Brazil, Costa Rica, Cuba, Mexico and Venezuela. The project aims at the use of nuclear and related techniques for the identification of leakages in dams and reservoirs. Leakages endanger the stability of a dam and represent significant water losses. A workshop was held in S. Luis Potosi, Mexico, which provided training to the counterparts in the application of tracer techniques for the identification of leakages as well as the flow paths of the water from leakages.

A number of national projects including those in arid regions of Latin America, the Middle East, Asia and Africa are being continued. Concerning Latin America, in the Peruvian Altiplano (about 4000 m a.s.l), isotope techniques have contributed to identify the origin of groundwater and the altitude of recharge as well as to characterize hydrogeological parameters of the aquifers. These results help to make additional sources of drinking water available which are badly needed in the water-scarce coastal areas of Peru. In a Brazilian project efforts are being made to improve the supply of potable water for the city of Sao Paulo.

2.6. High priority activity on "Isotope-based Assessment of Groundwater Renewal and related Anthropogenic Effects in Water Scarce Areas"

In line with the objectives of the above technical co-operation project RAF/8/022 and related initiatives focussing on the use of isotope techniques in arid zone hydrology, an additional initiative was launched as part of the activities of the Department of Research and Isotopes. The focus is on isotope-aided studies of recharge/discharge processes in the unsaturated zone of arid and semi-arid regions, the understanding of which is crucial for any rational water resources management. The tasks of this undertaking are a workshop on "The use of isotope techniques to determine water and contaminant transport in the unsaturated zone, including the provision of necessary training in sampling soil profiles for isotope and geochemical measurements" and a CRP on this subject. The activities will start in 1996 with moderate funding and be carried over to the 1997/98 planning cycle. The financial estimates for 1996 envisage US\$35,000 for contracts and sampling equipment and US\$15,000 for a workshop. The activities will be funded through the Agency's regular budget.

It is expected that this initiative will have a bearing on the Agency's technical co-operation programme directed towards a more visible impact on the water sector of Member States. This impact includes prevention of over-exploitation and pollution of the groundwater resources and thus ensure sustainable supply of water to the public and the establishment of efficient irrigation schemes for improved food supply.

3. Endeavours to strengthen co-operation with other UN organizations and to approach donors

A number of activities were undertaken to strengthen the co-operation with other UN organizations in the field of water and environment. As far as the technical assistance programme is concerned, the efforts were focussed on concerted actions in the water sector of Africa and on the Caspian Sea environment crisis.

3.1. Caspian Sea environment crisis

The IAEA technical co-operation project on the Caspian Sea environmental crisis attempts to involve the collaboration with UN organizations, known to be interested in Caspian Sea matters. To this end, UNEP, WMO, WHO and UNESCO were invited to join the IAEA pre-project mission to the riparian countries. The Intergovernmental Oceanic Commission (IOC) of UNESCO participated in this mission and since then actively supports the IAEA initiative. Following the pre-project mission, a meeting was called by IAEA in October 1994, to brief the interested UN organizations about the outcome of the mission and the Agency's planned regional technical cooperation project. The deliberations held during the meeting and a follow-up consultation organized by UNEP in January 1995 in Geneva, indicated that a multidisciplinary and multisectoral approach is required to cope with the situation in the Caspian Sea region. The contributions of the concerned UN organizations could address the following:

- WHO: effects of sea level rise on public health; water quality; health and sanitation; health impact of fish waste recycling;
- WMO: hydrometeorological monitoring; sea level rise; water quality;
- IAEA: sea level rise; water balance; water circulation; sea and coastal water pollution;
- UNESCO: organization of workshop/training.
- UNEP: co-ordination of interagency collaboration.

It was agreed that a fact-finding mission of UNEP, UNDP and the World Bank to the riparian countries should be undertaken in the first half of 1995. Following the mission, a proposal for a comprehensive concerted action plan including the above contributions of specialized UN organizations will be prepared and submitted to donors, in particular World Bank and Global Environmental Facility. The IAEA initiatives were recognized as an integral part of the concerted actions and thus, if major donor funding would be secured, the IAEA activities could be financed through this source.

3.2. Water resources in Africa

The IAEA is also seeking concrete support for the technical co-operation projects on water resources in Africa in terms of logistics and financial contributions by other organizations and donors. The United Nations Economic Commission for Africa (UNECA), Addis Ababa, and UNEP, Nairobi, were expected to help integrate the IAEA programme in the scope of the Interagency Group for Water in Africa (IGWA), and to promote concerted action with other UN organizations in the water sector of concerned African countries.

A step in this direction was made during the Third Annual Meeting of IGWA which was organized by UNECA and held on 15 and 16 November 1994 at the Headquarters of the UNEP. The meeting was attended by representatives of the following agencies: WHO, UNEP, UNCHS, UNIDO, IAEA, UNECA, UNESCO, WMO and Niger Basin Authority (NBA). The aim of the meeting was to enhance coordination, collaboration and harmonization of water activities among IGWA member agencies which would make the impact of their assistance to African member states more meaningful and visible. During the meeting an overview was given of the IAEA activities in the water sector in Africa with emphasis on the above Model Project. The other UN agencies represented by IGWA were called on to support/join the IAEA activities. The Agency was recognized as one of the UN organizations effectively involved in the water sector in Africa. The meeting explored priority areas for interagency co-ordination to be led by UNEP, jointly with UNECA. UNEP, through involvement in the Global Environmental Facility and contacts with the World Bank, has the potential to pave the way for funding major field projects in the water sector.

After contacts at a high level between the Director General of the IAEA and the Executive Director of UNEP, close co-operation will be initiated in the framework of the ACC working Group of Availability and Management of Water in the African context.

During the First Co-ordination Meeting of the Model Project Regional Africa RAF/8/022 in April 1995 in Addis Ababa, the opportunity was taken to hold discussions with UNECA on the prospects for future co-operation in the water sector of Africa. UNECA envisages joint programming as an important mechanism to develop future co-operative undertakings in collaboration with the Agency in the Africa region. From these discussions, it emerged that the Agency's involvement with respect to isotope hydrology could be envisaged in connection with the programmes that ECA intends to promote on river basins, to enhance trans-boundary resources, and on water resources and the environment of small islands in Africa. A schedule for exchange of information and consultations between IAEA and UNECA has been agreed upon.