Annex 30

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Serving Human Needs
-Nuclear Technology for clean drinking water-

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Clean drinking water

In the last century human population trebled, but fresh water consumption was six folded. Without efficient water resources development, management and use, half of the world's population will be living in water stress region with competition from agricultural, industrial and domestic use. This is what World Water Vision unit of the World Water Council warns. Forty years ago human population was three billion; today it is over six billion. By 2050 it is expected to hit 9 billion. But the availability of water to meet the growing demands remains unchanged. Without water we cannot survive more than three days. As of now one out of five people on the planet earth does not have access to safe drinking water. Every year more than three million people die of waterborne diseases of which two million are young children. A blue circle appeared to be mostly covered with water as visualized from outer space, the earth is in fact two third filled with water. However over 95% of earth's water is salty or brackish. Of the remaining 3% about seventy five percent is locked in ice caps and glaciers. In fact the inventory of fresh/clean water available for human use is less than one tenth of one percent of all water on the earth. No wonder the Ancient Mariner Lamented " water, water every where nor any drop to drink."

Bangladesh Scenario

Against the backdrop of such global scenario, the water situation in Bangladesh is very alarming. A land of rivers, tributaries and covered by Ganges-Bramaputra-Meghna delta which is one of the largest delta in the world, the country is facing an unforeseen tragedy with a clean source of water for avoiding water borne infection. Up until early 70's most of the rural population got its drinking water from surface ponds and nearly quarter of a million children died each year from waterborne diseases. Then ground water became a major source of drinking water. The provision of tube well water accounting for 97% of drinking water of rural population resulted in significantly reducing high incidence of diarrheal diseases. However, paradoxically the same wells that saved so many lives now pose a serious threat due to unforeseen hazard of arsenic. A survey of well waters (n=3534) from throughout Bangladesh has shown that water from 27% of the shallow tube wells i.e. wells less than 150m deep, exceeded the Bangladesh standard for arsenic in drinking water (50 µg/L), while 46% exceeded the WHO guideline value (10 µg/L). Figures for deep tube wells (greater than 150 m) are 1% and 5% respectively. Since it is believed that there are a total of 6-11 million tube wells in Bangladesh mostly exploiting the depth range 10-50m, some 1.5-2.5 million wells are estimated to be contaminated with arsenic according to Bangladesh standard. About 35 million people are believed to be exposed to arsenic concentration in drinking water exceeding 50µg/L and about 57 million people exposed to concentration exceeding 10µg/L.

A global Problem.

The situation is not unique to Bangladesh the presence of arsenic in drinking water is a world-wide problem causing a wide range of health effects. Millions of people in Argentina, Mexico, Taiwan, India, Mongolia, Hungary and Rumania are exposed to drinking water containing much higher levels of arsenic than WHO guideline. Arsenic is a natural element. It is also a poison. Only about 125 gm is enough to kill a person in a single dose. Arsenic is also hazardous if ingested in drinking water above the safe limit. It takes from 2-15 years to develop arsenicosis.

Table: COMPARISION OF WORLDWIDE LEVEL OF THREAT TO HEALTH POSED BY DIFFERENT WATER SUPPLY DEFICIENCIES

Problem faced	People affected (Magnitude)	Health effect	Remedies available Type	Technical complexity
Limited access	Only	Various	Increase	Moderate

to drinking water	developing countries: 1.5 billion1		coverage by replicating water supply programs	
Gastro-intestinal diseases due to water-carried pathogens	Only developing countries	Diarrhea, cholera, Often fatal	Improve hygiene ehavior, sanitation bids-infect water	Low
Lead in water supply (Distribution pipes)	1 million	Neural/cerebral disorders	Replace lead pipes and fixtures	Low
Fluoride in water supply (Groundwater)	Mostly in developing countries: 5 million	Tooth decay, bone deformation	Remove fluoride, Or provide water from alternative source	Moderate
Arsenic in water supply (Groundwater)	Mostly in developing countries: 50 million	Skin diseases, intestinal cancers; often fatal	Remove arsenic, <u>or</u> provide water from alternative source	Moderate to high

<u>Origin of Arsenic.</u>

Earth crust contains arsenic to the extent of 1.5-1 mg/kg in the form of minerals. Natural leakage from arsenic-rich minerals may cause contamination of soil and ground water. The arsenic is of natural origin and is believed to be released to ground water as a result of a number of mechanisms which are poorly understood. This release appears to be associated with the burial of fresh sediments and the generation of anaerobic (oxygen deficient) ground water conditions. It probably occurred thousands of years ago. The arsenic is thought to be desorbed and dissolved from iron oxides that earlier scavenged the arsenic from river water during their transport as part of normal sediment load. This is called iron oxide reduction hypothesis. Natural variation in the amount of ironoxide at the time of sediment burial may be a key factor in controlling distribution of high arsenic in ground water. From a world wide perspective, drinking water derived from aquifers showing similar characteristics to those of the Bengal Basin should be considered “at risk” and need to be systematically tested for arsenic.

Deeper the better.

Deep groundwater (>150 m deep) where available appear to offer a long-term source of clean drinking water. Experience gained so far indicates that the great majority of these would not only pass current Bangladesh standard for arsenic but would pass all other existing national and international guidelines. As such nationwide availability needs to be established in terms of quality, quantity and sustainability. The possible impact of large-scale extraction of irrigation water on the deep aquifer also needs to be considered.

Nuclear techniques in search of ground water resource

A groundwater system can be a complex and unknown maze hidden deep beneath the surface of the earth. When hydrologists find such a source they need to know its quality, quantity and if there is a water supply renewing it. Otherwise, it will be like fossil fuel which once used is not replenished. The traditional tools to answer those questions are very slow and also not available in most of the developing countries. Isotope hydrology, i.e. the use of heavy isotopes along with other hydrological and geo-chemical methods, have been successfully used to better understand ground water occurrence flow and quality problem. Isotope techniques have been successfully used for groundwater assessment, monitoring of water flow, contamination of water resources improved groundwater utilization and overall water resource management in different regions of Africa and West Asia. In India isotope techniques have been successfully applied for understanding groundwater recharge process in the arid zone. In Ethiopia integration of isotopic techniques into hydrological practices has resulted in successful groundwater resource assessment and management. In Algeria isotopic studies showed differential recharge between the aquifers thus leading to strategic water resource management.

In Bangladesh a IAEA-TC pilot project on groundwater resource investigation was executed during 1999-2000 year cycle in collaboration with BAEC and the end user Bangladesh Water Development Board. The main objective was to obtain the baseline data on isotope in different aquifers for age dating and related geo-chemistry. The findings of that research pilot project demands further study in groundwater pollution, especially arsenic using isotope technique for tapping arsenic free deep aquifer in Bangladesh.

As has been mentioned earlier millions of people in Bangladesh are facing the major public health crisis due to arsenic contamination in the groundwater aquifer, which is the primary source of drinking water.

The World Bank is leading the Bangladesh Arsenic Mitigation and Water Supply Project (BAMWSP) to assist the Government of Bangladesh for providing safe drinking water options. But, reliable criteria are not available to evaluate the long-term consequences of the mitigation option. With a view to developing the alternate solution for mitigation option, the follow-up of the previous Pilot TC project on groundwater arsenic contamination is being undertaken by IAEA and BAEC in collaboration with the end users Bangladesh Water Development Board and Geological Survey of Bangladesh.

Isotope techniques provide invaluable information on the sources, movement and quantity of water in different environments, including rivers and lakes. They are particularly effective in investigating water reserves below the earth's surface, or groundwater. Isotope hydrology provides insights into water's character and helps to build the foundations for rational utilization of this valuable resource.

<u>Some observations</u>

Without a few exceptions, ground water from the deep aquifer seems to be arsenic free. There is no reason to believe that deep aquifer will not be contaminated or remain free of contamination. Proper care must be taken during construction to isolate upper and lower aquifer. The efficient exploitation of ground water requires detailed investigation on the quality and quantity of ground water. It is prudent to integrate isotope techniques in hydrogeologic characterization and study of ground water exploration for sustainable clean drinking water supply. It is believed that the nuclear analytical and isotope hydrology techniques can make more important contributions in this problem. The hydrogeology of the contaminated shallow aquifers and presently uncontaminated deeper aquifers can be investigated using isotopic techniques to identify alternative source of non-contaminated ground water in deeper aquifers. Currently favored mechanisms of arsenic mobilization are inconsistent with isotope data. The most likely process of arsenic mobilization may involve description from the sediments as a result of continuing recharge of fresh, arsenic free water in the shallow aquifers.

Rio '92 and freshwater

At the Rio Conference on environment and development, 1992, governments adopted **Agenda 21,** committing themselves to strive towards a fair and more sustainable development for all people, present and future. Recognizing the importance of freshwater in social and economic activities, **Chapter 18 of Agenda 21** called for action to protect the quality and supply of freshwater resources with following principles.

- Freshwater resources are essential and indispensable part of terrestrial ecosystems.
- Water is needed in all aspects of life.
- The currently poor and deteriorating state of water resources in many parts of the world demand integrated water resources planning and management.
- Trans-boundary water resources and their use are of great importance to States sharing river systems.

From Rio to Johansberg

The World Summit on Sustainable Development will be held in Johannesburg in September 2002 to review the progress made in addressing the underlying issues that influence sustainable development including water. The year 2002 mark not only the 10 year anniversary of that landmark event, but also this year the **World Summit on Sustainable Development** will be held at Johanesberg in September Water and development are intrinsically linked. Once viewed as an infinitely renewable and bountiful resource, water today defines and confines development aspirations—human, social, and economic in many parts of the world.

World Water Day

The UN General Assembly resolved to observe World Water Day on March 22 following the recommendations of Rio de Janeiro. World Water Day 2002 is an important step to reflect on water and development issues, at all levels national, regional and global to recognize successes and challenges, and to strengthen the international collaboration in water related issues.

Conclusion :

One of the key methods of unlocking the water code in nature is isotope hydrology by which we can get a clear picture of underground water source, its age, movement, reactivity, pollution all of which are important to make efficient use of water. It is recognized that one of the main reasons for current and emerging water shortages is often found in inadequate water resources management. The sustainable development of water resources hinges on sound and holistic approaches of water resources management, such as integrated water resources development and demand-side management. The collection of hydrological, meteorological, hydro-geological, ecological and socio-economic information for water resources assessment and monitoring is essential for informed decision-making. Despite innovative information technologies, data collection at the field level remains crucial for sound and accurate water resource management and assessment. Unfortunately, this is often disregarded. Financial constraints have reduced the ability of public service institutions in charge of water resources to collect data at the field level in many developing countries. In many cases there has been a decline in the quantity and quality of information on water resources, and their uses. The techniques of isotope hydrology, play a crucial role in the data collection efforts to better understand freshwater systems in order to be able to manage them in a sustainable manner.

<u>NUCLEAR TECHNIQUES IN DAM SAFETY AND DAM SUSTAINABILITY</u>

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Preamble

Dams and reservoirs are vital to the sustainability of a large part of the world's population for water supply, irrigation, flood protection and hydropower. Their ability to function properly for a long time is crucial to the well being of these population segments. Large investments are therefore necessary each year for maintaining the efficiency of dam and reservoir operations and thereby improving socio-economic development. Leakage occurs when seepage concentrates through a weak area in the dam or works its way in the foundation or abutment. Leakage can present a serious problem, especially if it carries sediment. This is an indication that erosion could threaten dam stability. In most cases, local groundwater and water related to the leakage emerge downstream of the dam with a complex mixing pattern. Among other problems, funds are largely used for engineering and construction to mitigate three types of problems:

- ♦ Leakage/seepage from reservoirs that flows through reservoir bed and abutments,
- ♦ Leakage through dams, and
- ♦ Sediments that are deposited in the reservoir and deplete its storage capacity.

The magnitude of these problems are illustrated by the following facts:

- Millions of US dollars are invested each year for grouting and sealing following real and suspected leaks from reservoirs.
- Studies show that, world-wide, on average 1% of reservoir capacity is lost every year due to sedimentation, and the average age of reservoirs is limited to around 22 years.

<u>Types of Dam</u>

Manmade dams may be classified according to the type of construction material used, the methods used in construction, the slope or cross-section of the dam, the way the dam resist the forces of the water pressure behind it, the means used for controlling seepage and, occasionally, according to the purpose of the dam.

Two principal parts of two typical dam types are defined here:

(i) **Embankment Dams –** Embankment dams are the most common type of dam in use today. Materials used include natural soil or rock, or waste materials obtained from mining or milling operations.

An embankment dam is termed as ‘Earthfill’ or ‘Rockfill’ dam depending on whether it is compacted earth or mostly compacted or dumped pervious rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass weight, type and strength of the materials from which the dam is made.

(ii) **Concrete Dams –** Concrete dams may be categorized into gravity and arch dams according to the designs used to resist the stress due to reservoir water pressure. The mass weight of concrete and friction resist the reservoir water pressure.

Major Issues Facing the Dam Safety Community

A. Risk of Failure

Driving every other issue and all the activities within the dam safety community is the risk of dam failure. Dam failures are most likely to happen for one of the five reasons:

- Overtopping, caused by water spilling over the top of a dam,
- Structural failure of materials used in dam construction,
- Stability failure of the dam foundation,
- Cracking caused by movements like the natural settling of a dam,
- Inadequate maintenance and upkeep, and
- Piping – when seepage through a dam is not properly filtered and soil particles continue to progress and form sink holes in the dam.

Historically, dams that failed had some deficiency, as characterised above, which caused the failure. These dams are typically termed ‘unsafe’.

B. The Increasing Hazard

Dams are innately hazardous structures. Failure or misoperation can result in the release of the reservoir contents – this includes water, mine wastes or agricultural refuse – causing negative impacts upstream or downstream or at locations remote from the dam. Negative impacts of primary concern are loss of human life, economic loss including property damage, lifeline disruption and environmental damage.

C. Financing for Maintenance, Upgrade and Repair

Dams must be maintained to keep them safe. Occasional upgrade or rehabilitation is necessary due to deterioration, changing technical standards and improved techniques, better understanding of the area’s precipitation conditions and increase in downstream populations and changing land use. The lack of funding for dam upgrade has become a serious national problem, especially within the private sector.

D. The Aging Issue

With age comes, the potential deterioration is observed. Many dams in different countries around the world have been designed for an effective life of 50 years (although a properly designed dam can last much longer if it is maintained and cared for).Many dams around the world are quickly approaching the aging issues, and rehabilitation of these structures is a major concern.

E. Lack of Adequate Authority and Resources for Dam Safety Program

Although most countries have legislative authority to carry out a comprehensive dam safety program, many are lacking in specific areas

F. Lack of Emergency Preparedness in case of Failure

Emergency Preparedness is lacking in many countries. It reflects that most dam owners and local authorities are not prepared for a sudden dam failure and the ensuing downstream consequences.

G. Lack of Public Awareness

Intersecting almost all the issues above and spiking them with a lack of understanding and misinformation is the issue of public education about dams.

Emergency Nature of the Project

The safety conditions of the dams involved in the project are very serious, probably alarming. The reported deficiencies (i) insufficient stability of dam bodies; (ii) inadequate spillway capacities; (iii) inadequate bottom outlet capacities; (iv) leakage and internal erosion of dam bodies; and (v) settlements of dam crests, represent the most dangerous limit states in the case histories of failures of embankment dams.

Role of Nuclear Techniques

It is evaluated that the nuclear technology is required to promote the use of environmentally safe isotope techniques for development purposes. *Dam sustainability and* *safety is an area where the application of isotopes has proven on socio-economic development.* The impact has been in terms of cost saving as well as dam safety. The plan is to identify the end-users for these technologies; and to draw up strategy for adapting its technical co-operation to augment the socio-economic impact through the end-users and transfer of technology to the end users. Synergies will be sought with partner organisations, so it is expected that the expanded use of isotope methods in dam management will assist RCA member states.

Information Gap

The role of nuclear techniques in dam management is to generate information to help end-users make decisions that will guide, optimise and protect investments in dam safety and sustainability. Isotope investigations can help identify and contribute to the solution of problems. From the point of view of the problem-holders/end-users of the technology (mainly dam owners, dam operators and private sector engineering consultants and contractors) isotope techniques are among many available technical tools.

However, one of the main implements to effective integration of isotope techniques in dam safety and sustainability is the lack of knowledge and understanding for their role among end users. *It is estimated that less than 5% of end-users in the dam sector are aware of the existence and potential of isotope hydrology in dam management.* Likewise, the Agency's counterparts in isotope hydrology laboratories are largely unaware of the needs and requirements of the engineers, who are hired to solve the dam operator's problems.

Technical Solution

Isotope tracer studies can assist in site selection, site investigations, watershed studies, dam and reservoir design, dam construction, dam and reservoir leakage investigations, sediment control and improving reservoir longevity. Most techniques play a catalytic role by supplementing conventional technology for solving dam management problems from planning through operations. However, three techniques were identified as having a primary role for investigating certain types of problems common to dam management:

- Isotope "fingerprinting" to identify the origin and pathways of water in the hydrological cycle during all phases of a dam project from planning through operations,
- Investigation of sedimentation of the reservoir resulting from erosion in the watershed operations for purposes of managing the sediment and
- Investigation of leakage pathways through and around the dam and through the reservoir bed during the first filling and subsequent operations, if leakage is observed.

Some isotope methods, while having the potential of providing new and unique technologies for addressing specific dam and reservoir problems, need further research and development. This includes isotope methods such as tracing the origin of sediment within the watershed system. These methods must be validated before they can become accepted tools for dam management.

Outreach Strategy

The TC approach for achieving project impact is to make sure that its investments in institutional capacity building reach the end-user the last link in the chain that connects the Agency counterpart with the problem holder. Since most of the end-users of analytical technology for dam safety and sustainability are commercial enterprises, interaction with the private sector is crucial to ensure the successful application of isotope techniques in this area. This presents a special challenge since the IAEA/RCA generally does not deal directly with the private sector. The main objective for the Agency's strategy must therefore be to bridge the gap between the technology providers and the problem-holders and to foster partnerships that will help achieve this objective.

The commonality of the issues identified by the participating countries necessitates a regional approach to solve the problems. The experiences and efforts of each member State in addressing its specific problems, when combined under one umbrella are expected to produce a more meaningful impact, with lesser chances of redundancy of efforts (and hence, improved cost savings) than when the approach is on a level of a series of national projects. Certainly with the coming decade being tagged as the Water Decade, the high priority placed by the region in protecting and developing its water resources cannot be undermined.

Experience gained in the implementation of successful dam safety projects around the world points to the need for: (I) proper documentation of the pre-project status of dam safety; (II) Careful attention to both structural and non-structural remedial measures, and (III) Putting in place effective mechanisms for maintaining the level of safety achieved at the end of the project

Use of Environmental and Artificial Isotopes

Samplings of groundwater, spread over a year, around the dam site, regular recording of inputs/outputs at dam site, discharge of nearby springs, piezometric level measurements etc. are generally made. Different types of waters can be distinguished by their natural isotopic composition. In the water molecule, it is the relative abundance of the stable isotopes, deuterium (^{2}H) and ^{18}O, that are used for identification.

Soil sampling (or coring) in the watershed area and dam reservoir for determination of soil erosion rate and dating of reservoir sediment using Cs-137 and Pb-210 can be carried out. Other isotopic techniques like Rn-222 measurements, for residence time distribution of seeping water, can also be introduced wherever possible.

Radiotracing for identification of entry zones of leakage and leakage path within the dam body are generally carried out. Single well technique using artificial radiotracer (e.g. ^{131}I or ^{82}Br or ^{198}Au) in boreholes for localisation and measurement of groundwater flows can be validated through further research. With these tracing techniques, it is very easy to locate how water is really flowing.

The suitable techniques are depending on the particular case according to its characteristics. The leakage of a reservoir is frequently located at the geological formations surrounding of the dam, also the leakage affects of the dam body in some cases. *In most cases, a combination of radiotracer and non-radiotracer techniques is necessary.* Therefore, the results of these studies are to generate information to help and users make decisions that will guide optimisation and protection of investments in dam safety and sustainability.

Project Activities

The regional project involves both individual activities, specially field investigations which are implemented independently by the respective RCA participating countries; as well as group activities which requires the interaction of all the participating countries in one activity, e.g. training, meeting or workshop. In Asia region, Pakistan, India and Indonesia have successfully applied the nuclear technology in dam safety and dam management.