ISOTOPE TECHNIQUES IN LAKE WATER STUDIES

Scientific Scope

Lakes in a variety of environments (tectonic including rift, glacial, coastal, volcanic and fluvial) cover a significant portion of the surface area of the continent. Freshwater lakes are among the most easily exploitable freshwater resources. Lakes are also recognized as major sedimentological features in which stored material can be used to study recent climate and pollution evolution. To adequately preserve these important landscape features, and to use them as climatic archives, an improved understanding of processes controlling their hydrologic and biogeochemical environments is necessary. The studies of lake processes can be separated in three categories, with specific isotope applications (Table 1) :

IAEA activities related to the study of lakes

Research and Development

The first Advisory Group Meeting (AGM) on the application of nuclear techniques to study lake dynamics was held in 1977 at the IAEA Headquarters in Vienna. Twenty-four specialists reviewed current research trends in order to obtain indications and guidelines for future activities in the field of isotope limnology. In 1992, a joint UNESCO/IAEA consultants' meeting assessed the new state of the art of isotope techniques in limnological studies and recommended a new Co-ordinated Research Programme. This Co-ordinated Research Programme on the "Use of Isotope Techniques in Lake Dynamics Investigations" was initiated in 1994. The programme was aimed at assessing the potential of environmental isotope techniques in studying the dynamics of lakes and related problems such as solute dynamics, sediment focusing, establishing the water balance components, and vulnerability of surface water bodies to pollution. The CRP enabled a number of isotope and geochemical studies to be carried out on small and large surface water bodies, with the general aim to better understand the dynamics of these systems under growing anthropogenic influence. A compilation (TECDOC) of the results of this CRP is in press and is expected to be available in the year 2000.

Further improvement of the techniques used for lake studies is continuing in many laboratories. For water balance studies, sampling of water vapour to determine the evaporation factor is difficult to carry out in remote areas where no power supply is available. Development and testing of new techniques for water vapour sampling are on-going at the IAEA and in some other European laboratories. The tritium-helium isotopes and chlorofluorocarbon concentration methods have recently been used in many studies to determine the mixing processes and the apparent age of lake water. For the first time in 1999, such techniques were tried in Lake Titicaca where water balance parameters are difficult to obtain. These developments are expected to provide a better understanding of the lake processes.

Technical assistance on isotopic lake studies

The support of the IAEA to its Member States in lake studies, through the Technical Cooperation Programme, is often related to the protection of the water reservoirs and to understanding the water dynamics and contamination problems (Table 2). Lakes representing local or regional interests have been studied, like lakes Mogan and Eymir in Turkey, Beseka in Ethiopia, Manzala in Egypt, Titicaca in Bolivia and Peru, Prespa in the Republic of Macedonia, Greece and Albania, and Chapala in Mexico.

Project NIC/8/010 on the study of the water balance of Lake Xolotlan was of particular interest for the possibility of determining underground components (groundwater inflow and outflow rates). The water stable isotopes were used successfully together with pollen, ^{137}Cs and ^{210}Pb of the bottom sediment. Artificial tracers have been used in various countries (Chile, Turkey) to study seepage flow, to determine the turnover time in lakes, and to identify the possible pollution path.

Another important problem encountered in lake system is the water level variations. The Caspian Sea is the world's largest closed basin. The fact that the drainage basins of its major tributaries (Volga, Ural..) are located in humid climatic regions, whereas the Sea is in the semi-arid zone, makes the Caspian Sea sensitive to hydroclimatic changes. This climatic sensitivity is evidenced above all, in the continuous fluctuations of the sea level. Its rapid rise (about 2.25 metres since 1978) is causing great concern to all five riparian countries: Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan. Despite many years of study, knowledge of the causes of the Sea's water-level rise and fall is still limited, although it has been demonstrated that the water budget fluctuations are likely climatically induced. A regional West Asian project (RAW/8/004) provided support for the use of isotopic techniques in tackling sea level rise and its negative consequences on the economies of the riparian countries.

On the other hand, Lake Beseka in Ethiopia presents the particularity of having extended at an astounding rate for three decades. The continuous rise of the lake level creates problem for highways,

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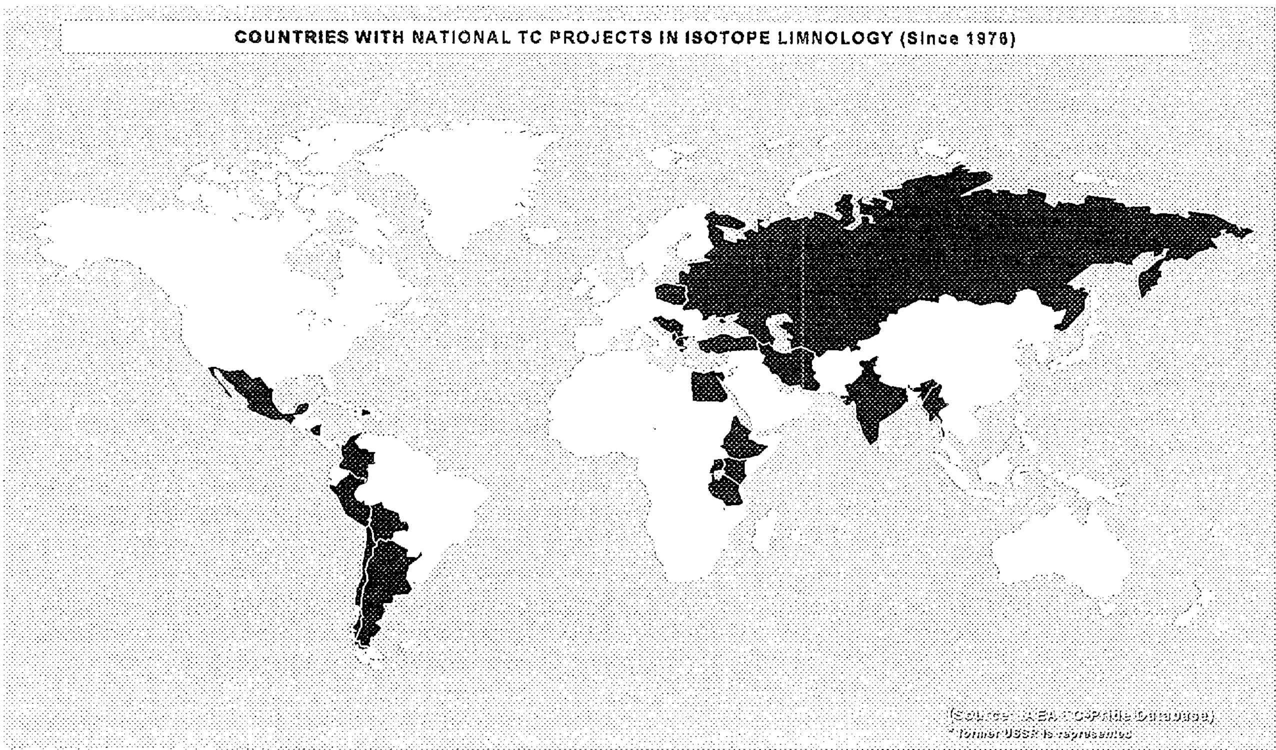

Table 1: Role and application areas of isotopes in limnology

Lake Budget
- evaporation rate estimation
  - ^{18}O, ^{2}H, ^{3}H, ^{36}Cl
- precipitation
  - ^{18}O, ^{2}H, ^{3}H
- underground and subsurface inflow and outflow, origin of water
  - ^{18}O, ^{2}H, ^{3}H, ^{37}Cl, $^{87}Sr/^{86}Sr$

Lake Dynamics
- horizontal and vertical mixing rates, transit time and water velocity
  - artificial tracers; ^{3}H
  - rare gases; $^{3}He/^{4}He$, ^{20}Ne, ^{222}Rn
  - $^{226}Ra/^{222}Rn$
  - ^{18}O, ^{2}H, ^{3}H
- apparent age/time of segregation of deep water from the atmosphere
  - $^{3}H/^{3}He$, ^{36}Cl
  - freons (CCl_2F_2 and CCl_3F)
- redox processes and recycling carbon and lake ventilation
  - ^{13}C, ^{14}C in DOC and DIC, ^{3}H
- sedimentation rate and migration of sediments on the lake floor (sediment dating)
  - ^{210}Pb, ^{137}Cs, ^{14}C, ^{32}Si, ^{10}Be, U/Th series
  - ^{13}C and ^{18}O of carbonates and dissolved water
- migration of chemical species in sediments and the exchange of different substances between sediments and overlying water
  - artificial tracers ^{3}H
  - anthropogenic radionuclides; ^{90}Sr, ^{137}Cs, ^{144}Ce, ^{239}Pu
  - natural radionuclides; ^{7}Be, ^{40}K, ^{210}Pb

Contamination
  - ^{34}S
  - ^{15}N, ^{18}O

Paleolimnological investigation
  - reconstructing hydrological conditions; ^{16}O, ^{13}C
  - ice formation; ^{18}O, ^{2}H

Table 2: IAEA-ongoing TC projects related to lake studies

Country	Title	started
Turkey	Study of lakes using isotope techniques	1993
Nicaragua	Evaluation of anthropogenic impact on Lake Xolotlan	1995
Peru and Bolivia	Isotopic and hydrochemical study of the Lake Titicaca	1997
Turkey	Nuclear techniques for lake and marine pollution studies	1997
Ethiopia	Use of isotopes in the study of Lake Beseka	1997
Colombia	Hydrodynamics of Lake Tota and their effect on pollution	1999
Macedonia Greece Albania	Study of the Prespa lake using nuclear and related techniques	1999

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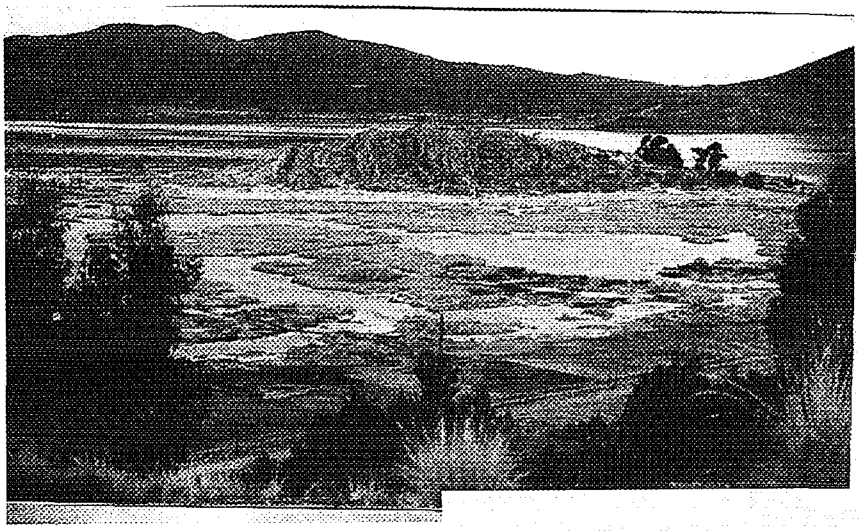
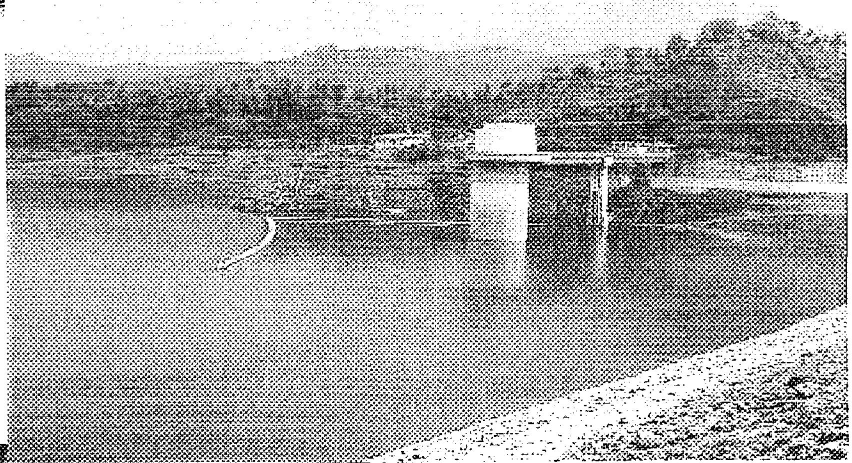
railways and farm lands. Due to high salinity and fluoride concentration, waters of this lake are not considered potable. Stable water isotopes, tritium and carbon-14 of dissolved inorganic carbon were used to provide conclusive evidence that the lake level rise occurred due to a decrease in the lake outflow. This outflow decrease resulted from an increase in the groundwater elevation to the south and east of the lake, most probably due to increased irrigation return over the last three decades.

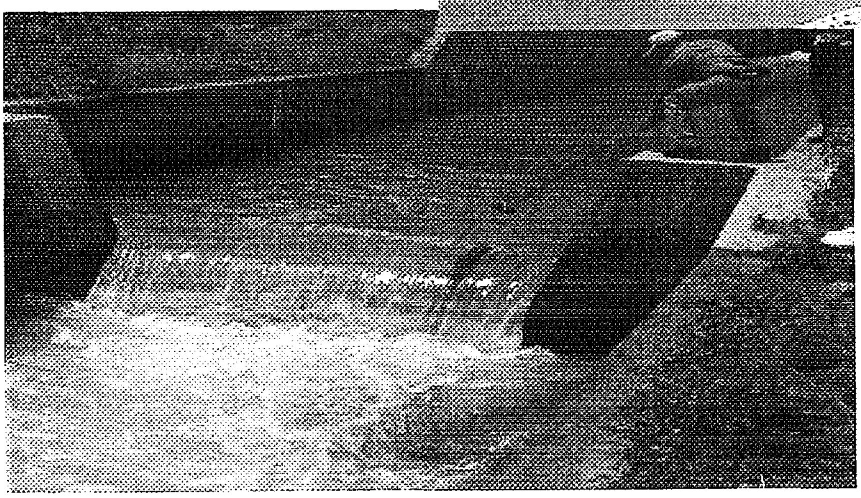
Laurence Gourcy



The highly contaminated Puno Bay (photo credit : L. Gourcy/ IAEA)



Serma dam, Yogyakarta, Indonesia View of the artificial lake. (Photo credit: E. Garcia-Agudo/IAEA)



Serma dam, Yogyakarta, Indonesia Discharge gauging with artificial tracers. (Photo credit: E. Garcia-Agudo/ IAEA)

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