Applications of Isotope Techniques in Hydrological Investigation

I. Aim & Objective

Application of stable and radioisotopes in hydrological investigations for water resources development and management

For acquiring better quality of water, one need the continuation and extension of hydrological research. In this respect, the development and practical implementation of isotope methodologies in water resources management has proved to be very important. Isotope studies applied to a wide spectrum of hydrological problems, related to both surface and groundwater resources, as well as environmental studies in hydro-ecological systems are presently an established scientific discipline, often referred to as "Isotope Hydrology".

II. Introduction

Isotope hydrology is an emerging discipline with expanding investigation tools for many environmental problems. Improved measurement of naturally occurring isotopic abundances (i.e. relative number of atoms of an element with different numbers of neutrons in the nucleus) in waters followed microchip design advances in mass spectrometry has immensely increased the utility of Isotope Techniques in the hydrological investigations. Its impact on subsurface hydrogeology is very significant because of the innate difficulty of imaging subsurface processes with traditional hydrometric tools. It is now possible, for example, to utilize isotopes as conservative tracers of delineating groundwater flow paths, for estimating solute exchange from one phase of a system to another, for determining extents of chemicals reactions in the subsurface, for identifying source regions in watersheds, for identifying recharge areas of aquifers, and for estimating its subsurface residence times.

III. Stable Isotopes

There are natural variations in the ratios of the stable isotopes of many elements. Isotope ratio difference in materials containing hydrogen ($^{2}H/^{1}H$ usually written as D/H), carbon ($^{13}C/^{12}C$), nitrogen ($^{15}N/^{14}N$), oxygen ($^{18}O/^{16}O$) and sulphur ($^{34}S/^{32}S$) are the basis for applying the isotope methodology in hydrology. These relative isotope concentrations can be determined easily with great accuracy by a differential isotope ratio measurement using double collecting mass spectrometers. The relative difference is called δ value and is defined as

$$\delta = \frac{R - R_{std}}{R_{std}},$$ where R represents the isotope ratio of a sample ($^{2}H/^{1}H$, $^{13}C/^{12}C$, $^{18}O/^{16}O$, etc) and R_{std} represents the corresponding ratio in a standard. The δ value is generally expressed in parts per thousand (per mil, ‰) and written as

$$\delta = \left(\frac{R - R_{std}}{R_{std}}\right) \times 10^{3}$$

The selection of standards for reporting stable isotope data is very important in environmental isotope geochemical work for comparison of results obtained from different laboratories. The International Atomic Energy Agency is presently coordinating the preparation, calibration and distribution of internationally acceptable standards for use in hydrological investigations.

IV. Radioactive Isotopes

Tritium and Carbon-14 (along with a number of other radioactive nuclides) exist in the environment due to continuous production in the atmosphere by cosmic ray induced reactions and as a consequence of thermonuclear explosions, operations of nuclear plants and other industrial outputs. The hydrosphere is labeled on a local and global scale with these nuclides. Therefore, measurement of concentration changes in time and space of these isotopes can provide information on the source and dynamics of water bodies and thus, in conjunction with other data, are employed successfully in hydrological investigations in the last few decades.

The "age" of groundwater has important implications for water resources management. Using groundwaters that are not actively recharged is mining. On the other hand, groundwater that is part of the modern recharge hydrological cycle is continuously renewed. Theoretically, many radioisotopes can be used for groundwater dating however, because of several technical limitations, only tritium and radiocarbon are suitable for practical purposes.

Low level tritium concentrations are expressed in Tritium Unit (TU). One TU or TR (Tritium Ratio) corresponds to one tritium atom per 10^{18} atoms of hydrogen. A concentration of 1 TU is equivalent to a specific activity of 0.12 Becquerel (Bq) per litre of water. Measured ^{14}C values are referenced to an international standard known as 'Modern Carbon' (MC), which by definition is the specific activity of wood grown in 1890 (unaffected by any fossil fuel combustion). The activity of this standard is 0.226 Bq (13.56 dpm) per g of carbon.

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V. Isotope techniques can be applied to achieve the following objectives:

- Identification of source and origin of groundwater recharge
- Identification of recharge area of springs
- Surface water-groundwater and aquifer- aquifer interconnections
- Estimation of residence time of groundwater
- Determination of groundwater velocity and flow direction
- Identification of source, mechanism and pathways of groundwater contamination
- Studies on submarine groundwater discharge
- Identifying the origin of geothermal waters and their flow dynamics
- Quantification of various components in the stream flow – Hydrograph separation
- Investigation on hydrological processes and dynamics of Lakes and wetlands
- Investigation on leakages in dams, reservoirs, canals and tunnels
- Estimation of dilution and dispersion of wastewater discharges in surface water bodies

VI. Ongoing studies at BARC as on December 2017:

1. Contamination of uranium in groundwaters of southwest part of Punjab
2. Isotope Hydrogeological Investigations in the Probable Palaeochannels in parts of Rajasthan and Gujarat
3. Isotope Hydrogeological Investigations in the Probable Palaeochannels in parts of Haryana and Uttar Pradesh
4. Isotope Hydrological investigations in geothermal areas of Manuguru (Telangana) and Tatapani (Chhattisgarh)

5. Isotope hydrological investigation at the geothermal sites; Surajkund, Hazaribagh (Jharkhand), Attri, Tarabalo, Athmallik and Taptapani (Odisha), Rajgir (Bihar), Bakreswar, Tantloi (West Bengal), for estimation of reservoir temperature and identification of possible potential recharge area as well as origin of recharging waters
6. Assessing Deep Ground Water Resources for sustainable management through the utilization of isotopic techniques in Patan district of Gujarat
7. Assessment of Groundwater and Surface Water Contamination in Uranium Mining Areas of Gogi Region in Karnataka
8. Fluoride contamination in groundwaters of Odisha, India: exploring the hot spring link through environmental isotopes, geological, geophysical and geochemical studies
9. Environmental isotope investigation to assess the surface water-groundwater interactions
in Karamana River Basin, Kerala with emphasis on water pollution at the lower reaches.
10. Recharging of drying water bodies in mountainous region of Uttarkashi, Uttrakhand through Isotope techniques
11. Isotope hydrological investigations for assessment of recharge potential and understanding of salinization processes in the multi aquifer system along the coastal tract of West Bengal

VII. Major facilities required for Isotope Hydrological Investigations:

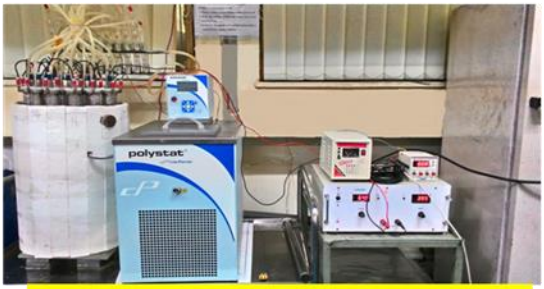
MS- EA and Multiflow

LSC

Uranium Fluorimeter

Ion Chromatography

CO_2 preparation line



Sample preparation for tritium measurement

VIII. A few important completed investigations by BARC

- Borewell water located with Isotope Hydrological techniques at AKRUTI-CARD. At AKRUTI-CARD in Dist. Amravati, Maharashtra, in a water scarce area, sustainable underground water source with capacity of 30,000 LPH has been identified and established, for use of farmers
- Isotope geological investigation at Chiplun, Khed and Ghagar blocks of Maharashtra for the identification of recharge zone under AKRUTI programme.

- Isotope hydrological investigations at NIRMITEE sites in Sudhagad Taluka of Raigad district for identification of recharge zone as well as interconnection of aquifers under AKRUTI programme
- Application of environmental isotopes in identifying source of seepage water in the basement in some parts of Jodhpur city
- Identification of landfill leachate migration at Delhi NCR, India
- Characterization of recharge processes in shallow and deeper aquifers using isotopic signatures and geochemical behavior of groundwater in an arsenic-enriched part of the Ganga Plain in Bhojpur district of Bihar
- Isotope Hydrochemical Approach to Study the Fluoride Contamination in Groundwaters of Ilkal Area, Bagalkot District, Karnataka, India
- Radiotracer investigation to understand pollutant dispersion in surface water bodies
- Isotope hydrochemical investigation for understanding the hydrology of Pilikula Lake, Mangalore, Karnataka
- Isotope hydrological investigation on geothermal springs at Tural and Rajwadi areas, Chiplun, Maharashtra
- Isotope hydrological investigation for recharging of the drying springs in mountainous regions of Uttarakhand and Himachal Pradesh
- Environmental isotope investigation on groundwater recharge from irrigation tanks at Tirumal Village, Madurai, Tamil Nadu
- Isotope hydrological investigation on the impact of mining to the groundwater in the state of Goa
- Understanding the flow generation processes in Lidar and Bhagirathi river basins
- Study of fly ash particles in the Rehand reservoir, entering through ash dyke from the ash pond of Anpara thermal power plant, Sonebhadra, Uttar Pradesh
- Environmental isotope studies along an ‘identified’ palaeochannel, Jaisalmer, Rajasthan
- Isotope investigation of dynamic changes due to long-term exploitation of groundwater in Barmer district of Rajasthan
- Salinisatoin in Groundwater of Purna River Basin, Maharashtra
- Evaluation of Groundwater Recharge to Very Deep Groundwaters of Tiruvadanai in Tamilnadu
- Isotope technology of evaluating utility of tanks for enhance groundwater recharge in hard rock zone of Nalgonda Dist., Telangana
- Isotope techniques for the assessment of hydrological processes and water quality issues of Vembanad Wetland System, Kerala, South India
- Groundwater Salinity Problem in Parts of Mahanadi Delta, Orissa
- Isotope hydrological investigation to assess the groundwater salinity in and around Kelwa and Mahim villages of Palghar Taluka, Thane District, Maharashtra
- Fluoride contamination and its release mechanism in to groundwater in hard rock aquifers of Telangana state of India
- Estimation of snow melt, ice melt, rainfall, run-off and base flow contributions to the Chota Shigri stream in Himachal Pradesh using environmental isotopes.

For additional information visit http://www.barc.gov.in/pubaware/ind.html