National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

(August 2005)

Principal Co-ordinator
Dr. S.K. Gupta (PRL, Ahmedabad)

Co-Principal Co-ordinators
Prof. S.K. Bhattacharya (PRL, Ahmedabad)
Prof. R. Ramesh (PRL, Ahmedabad)

Principal investigators
Dr. Bhishm Kumar (NIH, Roorkee)
Dr. P. S. Datta (NRL, IARI, New Delhi)
Dr. P. M. Muraleedharan (NIO, Goa)
Dr. Hema Achyuthan (Anna University, Chennai)

Co-Investigators
Prof. Shyam Lal (PRL, Ahmedabad)
Mr. R.D. Deshpande (PRL, Ahmedabad)
Dr. S.V. Navada (BARC, Mumbai)
Dr. A. Sarkar (IIT, Kharagpur)
Mr. P. Nagabhushanam (NGRI, Hyderabad)

Collaborating Institutions
Central Research Institute for Dryland Agriculture, Hyderabad
Central Pollution Control Board, Delhi
Central Water Commission, New Delhi
Central Ground Water Board, New Delhi
India Meteorology Department, New Delhi

Physical Research Laboratory (PRL)
Navrangpura, Ahmedabad 380 009

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Cover sheet to be filled in by the Investigator
**** To be filled by DST**

File No**_______________

1. Title: **National Programme on Isotope Fingerprinting of Waters of India (IWIN), A Project Proposal**

2. Proposed Budget for 5 years:

2.1 Total: Rs. 6,54,69,600/=

The Director, Physical Research Laboratory (PRL) has agreed to contribute Rs. 68,35,000/= towards provision of Salary, minor equipments and others including such civil infrastructural facilities as may be required to run the National Programme.

Therefore Grant requested from DST: Rs. 5,86,34,400/=

2.2 Equipments :
(Please give list of major/ minor equipment)

1	A new Stable Isotope Ratio Mass Spectrometer system **at PRL****	Imported	1,75,00,000 (US$3,89,000)
2	UPS, Vacuum pumps and other minor equipments **at PRL**	Imported	15,00,000 (US$34,000)
3	# PC + Printer + Standard Software + Statistical & Mathematical packages **at PRL**	Indigenous	1,00,000
4	# Fabrication cost of special precipitation sampler 40 Nos. @Rs.1250/ sampler **at PRL**	Indigenous	50,000
5	# Fabrication cost of atmospheric vapour sampler 40 Nos. @Rs. 1250/ sampler **at PRL**	Indigenous	50,000
6.	Raingauges (5Nos) **at AU**	Indigenous	50,000
7.	Hand held GPS (2Nos) **at AU**	Locally available	70,000
8.	Digital recording Thermometers (2Nos.) **at AU**	Locally available	10,000
9	Digital recording salinometers (2Nos.) **at AU**	Locally available	50,000
10.	PC + accessories **at AU**	Locally available	60,000
11.	MW21 DigiCORA III Vaisala Radiosonde including workstation and software **at NIO**	Imported	46,50,000 (US$1,06,500)
12.	PC + accessories **at NIH**	Locally available	60,000
13.	PC + accessories **at NGRI**	Locally available	60,000
	Total (at all institutions)		**2,42,10,000 (US$5,29,500)**

2.3 Staff (proposed research staff): (At PRL, NIH, NIO, NGRI, AU) — Rs. 69,24,000/= (Total Eleven Nos.)
Post Doctoral Fellow/ Project scientist (Seven),
Scientist 'SC (Tech)' (Two),
Secretarial Assistant (One)
Lab Assistant (One)

2.4 Other Recurring costs :

Consumable :	Rs. 1,46,61,000/=
Travel :	Rs. 30,00,000/=
Contingency / Others:	Rs. 57,63,000/=
Any other expenses : (Administrative)	Rs. 1,09,11,600/=

3. Date of receipt**:

4. Principal Co-ordinator, Name, Designation & Address:

Dr. S.K. Gupta Scientist 'SG'	Physical Research Laboratory Navrangpura, Ahmedabad 380 009	Date of Birth: 27th Sept. 1946

5. Co-Principal Co-ordinator details:

Prof. S.K. Bhattacharya Sr. Professor	Physical Research Laboratory Navrangpura, Ahmedabad 380 009	Date of Birth: 4th January, 1948
Prof. R. Ramesh Professor	Physical Research Laboratory Navrangpura, Ahmedabad 380 009	Date of Birth: 2nd June, 1956

6. Principal Investigators:

Dr. Bhishm Kumar Scientist F and Head	Hydrological Investigations Division National Institute of Hydrology Roorkee-247 667 (Uttaranchal).	Date of Birth: 15th March,1954
Dr. P. S. Datta Project Director & Professor	Nuclear Research Laboratory Indian Agricultural Research Institute, New Delhi-110012	Date of Birth: 3rd June, 1950
Dr. P. M. Muraleedharan Scientist EII	National Institute of Oceanography, Dona Paula, Goa 403004	Date of Birth: 8th October, 1955
Dr. Hema Achyuthan Assistant Professor	Dept. of Geology, Anna University, Chennai 600025	Date of Birth: 24th Nov., 1956

7. Co-Investigators:

Prof. Shyam Lal Professor	Physical Research Laboratory, Navrangpura, Ahmedabad 380 009	Date of Birth: 25th Dec. 1951
Mr. R.D. Deshpande Scientist 'SE(Tech)'	Physical Research Laboratory, Navrangpura, Ahmedabad 380 009	Date of Birth: 29th Sept. 1964
Dr. S.V. Navada Scientist 'SG' & Head Isotope Hydrology Section	Isotope Hydrology Section, Isotope Application Division, BARC, Trombay, Mumbai 400 085	Date of Birth: 25th July, 1948
Dr. A. Sarkar Associate Professor	Dept. of Geology & Geophysics Indian Institute of Technology Kharagpur	Date of Birth: 1st January, 1959
Mr. P. Nagabhushanam Scientist E II	National Geophysical Research Institute, Uppal Road Hyderabad 500007	Date of Birth: 6th August 1952

8. Other projects with the Principal Co-ordinator: NIL

PHYSICAL RESEARCH LABORATORY
(An Autonomous Unit of Department of Space, Govt. of India)
Navrangpura, Ahmedabad - 380 009 (India)
Phone:(91)079 26308550; Fax:(91)079 26300374
Cable: 'RESEARCH'; E-mail: director@prl.ernet.in

भौतिक अनुसंधान प्रयोगशाला
(भारत सरकार, अंतरिक्ष विभाग की स्वायत्तशासी यूनिट)
नवरंगपुरा, अहमदाबाद – 380 009 (भारत)
फोन: (91) 079 26308550; फैक्स: (91) 079 26300374
तार: "रिसर्च"; ई-मेल: director@prl.ernet.in

Endorsement from the Head of the Institution

Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

1. Certified that the Physical Research Laboratory (PRL) welcomes participation of Dr. S.K. Gupta, Scientist-SG as the Principal Co-ordinator for the above multi-institutional National Programme. The Programme falls in line with the approved research activities of the PRL.

2. PRL also welcomes participation of Professor S.K. Bhattacharya and Professor R. Ramesh as Co-Principal Co-ordinators, Professor Shyam Lal and Mr. R.D. Deshpande, as Co-Investigators on this National Programme.

3. Certified that PRL will adopt the proposed National Programme and provide necessary help for setting up a New Stable Isotope Mass Spectrometer Laboratory and associated facilities as described in the project proposal.

4. The PRL will contribute approximately Rs.68,35,000/- towards provision of Salary, minor equipments and Others, including such civil infrastructural facilities as may be required to run the National Programme.

5. Certified that in the event (Dr. S.K. Gupta / Prof. S.K. Bhattacharya / Prof. R. Ramesh / Prof. Shyam Lal / Mr. R.D. Deshpande) are not able to function as Principal Co-ordinator / Co-Principal Co-ordinators / Co-Investigators with the National Programme, PRL will either appoint other persons as Principal Co-ordinator / Co-Principal Co-ordinator / Co-Investigators or request DST to appoint other Senior PIs of this National Programme from one of the participating Institutions as Principal Co-ordinator / Co-Principal Co-ordinators in consultation with the Heads of the concerned institutions including PRL. In the latter event, PRL will continue to shoulder its other obligations to the National Programme.

6. PRL also assumes to undertake the financial and other management responsibilities of the National Programme to the extent the funds are received for utilization at PRL from DST.

7. Certified that PRL will provide space and other infrastructure facilities as required to undertake the PRL component of the National Programme.

(1/2)

8. This National Programme Proposal is in collaboration with National Institute of Hydrology, Roorkee, National Institute of Oceanography, Goa, Indian Institute of Technology, Kharagpur, Bhabha Atomic Research Centre, Mumbai, Nuclear Research Laboratory, Delhi, Anna University, Chennai, Central Research Institute for Dryland Agriculture, Hyderabad, Central Pollution Control Board, Delhi, Central Ground Water Board, Delhi and India Meteorology Department, Delhi. The roles and responsibilities of respective Institutions have been defined in the proposal of the National Programme.

9. Certified that equipment and other basic facilities as enumerated in section 420 and such other administrative facilities will be extended to the investigators for five years or through the duration of the project, whichever is less.

10. A few other issues pertinent to the endorsement of the proposal, particularly on commitments of PRL, are addressed in the attached letter from Director, PRL.

Date: 22/8/2005
Place: Ahmedabad

(Name and Signature of the Head of the Institution)

M.R.G. Murthy
Controller / Registrar
PHYSICAL RESEARCH LABORATORY
(Unit of Department of Space, Govt. of India)
Navrangpura, Ahmedabad-380 009.

(2/2)

भौतिक अनुसंधान प्रयोगशाला
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दूरभाष : 6302129 ई-मेल : root@prl.ernet.in

PHYSICAL RESEARCH LABORATORY
(A UNIT OF DEPT. OF SPACE, GOVT. OF INDIA)
NAVRANGPURA, AHMEDABAD-380 009, INDIA.
CABLE : "RESEARCH" FAX : 91-(0)79-6301502
PHONE : 6302129 E-mail : root@prl.ernet.in

Certificate from the Principal Co-ordinator

Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the projects. I shall not request financial support under this project, for procurement of these items.
4. I undertake that spare time on permanent equipment (listed in Section 350) will be made available to other users.
5. I have enclosed the following materials:

Items	**Number of copies**
a) Endorsement from the Head of Institution (on letter head)	One
b) Certificate from Investigator(s)	One
c) Details of the proposal from Section 101 to 500 (stitched) + one soft copy on CDR, in MS Word and as .pdf file	**20**
d) Name and address of experts/institution interested in the subject/outcome of the project.	One
e) Sheet containing sections 101 to 192	One
f) Cover sheet by the Investigator	One

Date: 02-08-2005
Place: Ahmedabad

(S.K. Gupta)
Name and signature of Principal Coordinator

IWIN Project Proposal at a Glance

Title:

National Programme on Isotope Fingerprinting of Waters of India (IWIN).

Total Budget: Rs. 6,54,69,600/=

The Director, PRL has agreed to contribute Rs. 68,35,000/= towards provision of Salary, minor equipments and Others, including such civil infrastructural facilities as may be required to run the National Programme. This amount represents approximately 1/3rd cost of the Stable Isotope Mass Spectrometer.

Therefore, Grant requested from DST: Rs. 5,86,34,400/=

Project Partners:

1. Physical Research Laboratory (PRL)
2. National Institute of Hydrology (NIH)
3. Bhabha Atomic Research Centre (BARC)
4. Nuclear Research Laboratory (NRL), IARI
5. Indian Institute of Technology, Kharagpur (IIT-KGP)
6. National Institute of Oceanography (NIO)
7. National Geophysical Research Institute (NGRI)
8. Anna University (AU)
9. Central Pollution Control Board (CPCB), Delhi
10. Central Water Commission (CWC), New Delhi
11. Central Ground Water Board (CGWB), New Delhi
12. India Meteorology Department (IMD), New Delhi
13. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad

Principal Co-ordinator:

Dr. S.K. Gupta, Scientist 'SG', Physical Research Laboratory (PRL), Ahmedabad

Co-Principal Co-ordinators:

Prof. S.K. Bhattacharya, Sr. Professor, Physical Research Laboratory (PRL), Ahmedabad.

Prof. R. Ramesh, Professor, Physical Research Laboratory (PRL), Ahmedabad.

Objectives:

1. To generate isotopic data for addressing important hydrological questions related to origin of water sources and the processes of redistribution by evapo-transpiration, stream flow generation, ground-water recharge/ discharge – from watershed to continental scale.
2. To give quantitative estimates of residence time of the water/ vapour in each hydrological reservoir/setting and the fluxes across them in temporally and spatially distributed manner.

Justification:

About 1,500 isotope analyses of various water sources made over more than three decades in India have enabled extracting limited qualitative information on atmospheric and surface processes concerning the hydrological cycle components over India. These pioneering studies have shown that hydrological processes and interactions between various components do leave identifiable signatures in isotopic variations of water constituents. Extracting quantified process related information from isotopic signatures that can provide important inputs to resource development planning and management, however, requires that thousands of measurements from different hydrological reservoirs be made in a short time of few years and data interpreted in conjunction with conventional measurements of meteorological and geographical parameters, river discharges, groundwater pumping, shallow subsurface geology etc. Over the vast country, this may seem like a Herculean task, but is accomplishable with the team of multidisciplinary researchers such as the present. Only then can this activity provide improved understanding of the hydrological cycle and a database for large scale development planning of water resources in the country.

Methodology:

1. Monthly sampling of atmospheric moisture, rain, river water across the country and from AS and BOB using a network of monitoring stations.
2. Daily sampling of precipitation and atmospheric moisture from seven stations for detailed investigation of atmospheric processes.
3. Spatially distributed groundwater sampling from shallow unconfined aquifers across the country.
4. Standardized procedures for water sample collection and storage will be used.
5. A new dedicated Stable Isotope Mass Spectrometer Laboratory to be set up at PRL, Ahmedabad.
6. Analyses of tritium $\delta^{18}O$ and δD at PRL, NIH, NIO, IIT-KGP, BARC, NGRI and NRL.
7. Approximately 30,000 isotopic analyses to be made in 5 years with nearly 50% at PRL.
8. Approximately 800 tritium analyses of water samples to be made in 5 years.
9. ECMWF reanalysis data of past 20 yrs to be used in conjunction with isotope analyses to validate models atmospheric and ground surface hydrologic processes.
10. A new, very precise DigiCORA III Vaisala Radiosonde upper air system to be installed and operated at NIO, Goa for monitoring air pressure, temperature, humidity and wind during 150 launches over the first two years. Additional 30 launches from Ahmedabad using the Vaisala Radiosonde available at PRL during monsoon months of two years.
11. Salinometers to be used for measurement of sea water salinity on board to establish seasonal relationships to be established between surface water salinity and isotopes in coastal AS and north BOB.

Group Expertise:

Physical Research Laboratory (PRL)

- Dr. S.K. Gupta – Groundwater hydrology, isotope data interpretation, mathematical modelling.
- Prof. S.K. Bhattacharya – Isotope laboratory techniques, isotope data interpretation in terms of atmospheric processes/ hydrology.
- Prof. R. Ramesh – Isotope geosciences and atmospheric processes.
- Prof. Shyam Lal – Atmospheric Sciences.
- Mr. R.D. Deshpande – Isotope measurements, data interpretation, web site creation and maintenance.

National Institute of Hydrology (NIH)

- Dr. Bhishm Kumar – Isotope hydrology, isotope laboratory techniques, surface and groundwater studies.

Bhabha Atomic Research Centre (BARC)

- Dr. S.V. Navada – Isotope hydrology, isotope laboratory techniques, surface and groundwater studies.

Nuclear Research Laboratory (NRL), IARI

- Dr. P.S. Datta – Isotope hydrology, agricultural science, pollution studies.

Indian Institute of Technology, Kharagpur (IIT-KGP)

- Dr. A. Sarkar - Isotope laboratory techniques, geology.

National Institute of Oceanography (NIO)

- Dr. P.M. Muraleedharan – Atmospheric modeling, physical oceanography, application of microwave Satellite data.

Anna University (AU)

- Dr. Hema Achyuthan – Arid & fluvial geomorphology, palaeoclimatology.

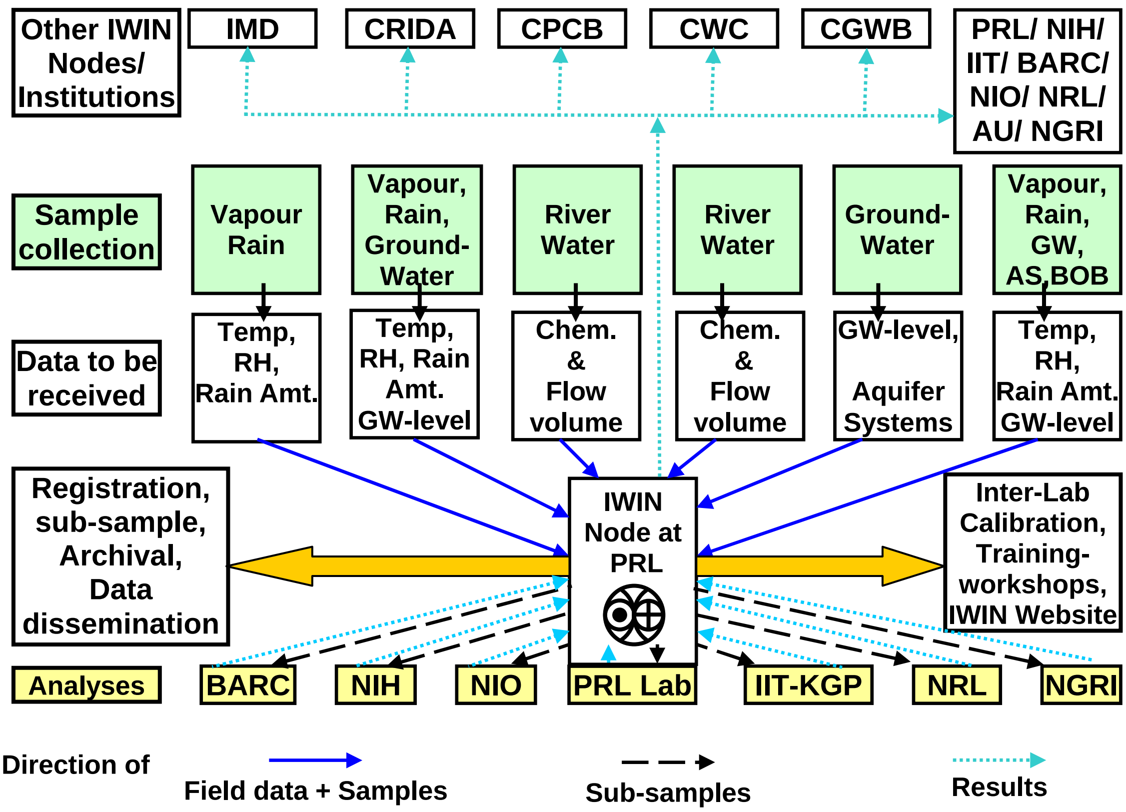
National Geophysical Research Institute (NGRI)

- Mr. P. Nagabhushanam – Radio- and stable-isotope investigations in hydrology.

The following partners have functional network of sample collection and have agreed to provide samples and relevant data for isotopic analyses and to participate in interpretation of results.

- Central Pollution Control Board (CPCB), Delhi
- Central Water Commission (CWC), New Delhi
- Central Ground Water Board (CGWB), New Delhi
- India Meteorology Department (IMD), New Delhi
- Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad

IWIN Task Organisation:



Deliverables:

- A new dedicated functional Stable Isotope Hydrology Laboratory at PRL.
- Close links between isotope laboratories at PRL, NIH, IIT-KGP, BARC, NIO, NGRI, NRL-IARI and the National Agencies having functional networks for sample collection leading to new research in areas of isotope applications.
- About 30,000 water isotopomer analyses from samples of water vapour, precipitation, surface water bodies, groundwater and surface waters of AS and BOB.
- About 800 tritium analyses from samples of water vapour, precipitation, surface water bodies, groundwater.

- Functional upper air Vaisala Radiosonde at NIO, Goa and profiles during onset, active and withdrawal phases of monsoon and relationship of moisture transport and precipitation processes to observed isotope variations.
- Maps showing spatial distribution and temporal variation of water isotopes in different components of the hydrological cycle over India.
- Seasonal maps and relationships of salinity-isotope distribution in the AS and BOB.
- A functional network for collection and monitoring of water isotopes from major water sources of India. Integratable with similar regional and global networks.
- A web resource giving isotope hydrology data facilitating detailed area/ problem specific isotope studies/ investigations.
- A new group of isotope scientists creatively applying isotope techniques to all disciplines where oxygen and hydrogen isotopes participate in interactions.
- Large number of international level research contributions.

Distribution of Scientific work:

Science Team
S.K. Gupta, S.K. Bhattacharya, R. Ramesh, Shyam Lal, Bhishm Kumar, P.S. Datta, S.V. Navada, A. Sarkar, R.D. Deshpande, H. Achyuthan, P. Muraleedharan, P. Nagabhushanam

Work Assigned

Principal Coordinator
The Scientist holding this position will be responsible for overall execution and management of the project, Seeding of satellite projects at Univ. and collaborating agencies, organizing: periodic inter laboratory calibration, meetings, training programmes and workshops.

Isotope Analyses:
S.K. Bhattacharya/ R.Ramesh / R.D. Deshpande (at PRL), Bhishm Kumar (at NIH), A. Sarkar (at IIT, KGP), S.V. Navada (at BARC), P. S. Datta (at NRL), P. Nagabhushanam (at NGRI), P. Muraleedharan (at NIO)

Interpretation of Results:
Science Team and Collaborators

Radiosonde Operation
P. Muraleedharan (at NIO),
Shyam Lal (at PRL)

Sea Water Samples (Salinity/ Isotopes)
P. Muraleedharan (AS from NIO)
H. Achyuthan (BOB from AU)

Coordination with IWIN stations, Sample inventory, data Compilation, analyses and presentation, IWIN Web resource building: R.D. Deshpande (from PRL)

Sample collection:
Coordinators from IMD, CRIDA, CPCB, CWC, CGWB, NIH, IIT-KGB, NIO, AU, NGRI etc

What new will be learned?

1. Estimation of relative water vapour contribution from different oceanic and land sources at different regions in different seasons.
2. Proportion of rain contributed by evapo-transpiration over land areas in different seasons.

3. Relative proportion of plant transpiration in the land derived vapour.
4. Spatial and temporal distribution of rain and groundwater to stream flow in different catchments.
5. Contribution of groundwater drainage to different streams and other surface water bodies in different seasons and vice-versa.
6. Contribution of water draining into the BOB to vapour influx in a large scale hydrological cycle during the later part of the rainy season.
7. Mixing of heavy runoff draining the Western Ghats into AS.

Ownership and data dissemination:

1. The network stations for sample collection will be owned and operated by the respective Institutions.
2. The results of the analyses will be communicated in standard format to (i) sample providing Institution and (ii) the central data warehouse for the IWIN programme to be maintained by the PRL.
3. The data will be jointly owned by the particular sample providing Institution, the particular isotope analysis laboratory and the IWIN programme through Principal Coordinator.
4. Periodic workshops/group meetings of all participating scientists in the network programme will be held to review the progress and to discuss knowledge increments from the work of the programme.
5. All results would be discussed in these workshops before publication.
6. At the time of first reporting of results, authors list will include the names of officers /scientists from the Joint Owners in 3 above, in alphabetical order.
7. Thereafter, the results will form part of the public domain and will also be communicated to IAEA/GNIP programme.

Project Review Committee:

A Project Review Committee will be constituted by the Department of Science and Technology in consultation with the Head of the Nodal Centre and Principal Coordinator to periodically review/ monitor the progress and to guide the IWIN National Programme from time to time.

National Programme on

Isotope Fingerprinting of Waters of India (IWIN)

A project proposal

Executive Summary of the Project

A national programme of research for investigating the spatial and temporal fingerprinting of water sources of India using stable isotopes and tritium is proposed. The aim of this study is to improve understanding of the geographic and seasonal evolution of the components of the local and regional hydrological cycles, interactions between the various components and controls exercised by geographic factors and climatic forcing. This programme is also considered vital for predicting the consequences of the impending engineered modification of the hydrological cycle of the country necessitated by increase in population and the need to develop and exploit the water resources on a massive scale.

It has been estimated that by the year 2050, the demand for water will almost triple to ~1,450 km^3/yr. Whichever way the demand is met, there will be large scale modification of the natural hydrological cycle in the country not just due to engineered structures and controlled stream flows but also by changing the residence time of water in aquifers and by increasing water vapour content of the atmosphere over India, significantly during non monsoon months.

The data collected over the next 2-3 years will be baseline against which it will be possible to monitor the anthropogenically induced hydrological change at later date. In water balance studies, evapotranspiration is the most uncertain parameter estimated either from empirical formulae or by applying a fractional coefficient to the pan evaporation data. Isotopic investigation yield independent estimates based on degree of isotope fractionation that in turn depend on the progress of the hydrologic process. Similarly, any intensification of the hydrological cycle can be estimated with greater accuracy using isotope monitoring and should provide vital inputs to models for predicting the consequences of engineered modification.

Specific objectives of this programme include: (i) identifying dominant sources of water vapour supply (Arabian Sea/ Bay of Bengal/ local and long distant continental sources) at different locations within the country during different seasons; (ii) quantifying the partitioning of vapours into rain and re-partitioning of rain into various components as evapotranspiration, soil moisture, stream flow and groundwater; (iii) quantification of the extent and rates of interactions between these components, and (iv) the controls that geographical and climatic factors exercise over the entire hydrological cycle both temporally and spatially.

The proposal, in its present form, is a modified version following the recommendations of the Review Committee set up by the Department of Science and Technology, Govt. of India. This modified proposal includes the two satellite projects that were submitted separately by the National Institute of Oceanography, Goa and the Anna University, Chennai. In addition the scope of the proposal is enhanced to include radiosonde measurements at Goa and the spatial and temporal variations in isotopic ratios and salinity of the Arabian Sea surface waters in a similar way as in the Bay of

Bengal.

Identifying the dominant sources of vapour influx to India is vital to improve the understanding of (i) continental scale hydrological circulation and (ii) land-ocean-atmosphere interaction.

Some insight is available as a result of the investigations that involved measurement and monitoring of atmospheric pressure, temperature, humidity, rainfall and wind velocities from ground level and air borne platforms conducted over almost a century by the India Meteorology Department. However, identifying the vapour and water sources and their temporal evolution in response to changes in meteorological and geographical controls and to estimate the hold-ups in different reservoirs and their spatial distributions require data that can trace water molecules through their annual hydrological cycle. This can be achieved through studies of stable isotopes of oxygen and hydrogen (^{18}O and ^{2}H or D) in the water molecules in different reservoirs together with other data pertaining to volume measurements and fluxes.

Realising the importance of stable isotopes in hydrology, the International Atomic Energy Agency (IAEA) and the World Meteorological Organisation (WMO) established a Global Network of Isotopes in Precipitation (GNIP) in which samples are collected regularly to monitor the $\delta^{18}O$ and δD of precipitation. Over the last 3 decades, this data has been useful in understanding the systematics of isotope hydrology as also in tracing large scale atmospheric vapour transport systems.

Unfortunately, long term precipitation isotope data is available only for two Indian stations, namely, New Delhi and Bombay. Additional data (approximately one full year) is also available from Kozikode, Shillong, Allahabad, Hyderabad, Nainital and stations in North Gujarat and Lower Maner Basin in Andhra Pradesh. No data on isotopes in precipitation from anywhere along east coast of India exists.

There are **very few seasonal river water isotopic measurements**, except in the Ganga and Yamuna basins, to establish identity and origin of stream waters in different parts of the year. Even in these two basins it is not possible to identify the areas of effluent groundwater discharge and the volumes involved in different parts of their catchments.

Fairly large numbers of groundwater isotopic measurements in different parts of the country have been made by different workers. Using the groundwater $\delta^{18}O$ values from the Calcutta-Delhi segment, and the departure from the expected continental gradient due to rainout, it was estimated that ~40% vapours contributing to precipitation were recycled by transpiration. In southern India with dual monsoon influence, ground waters from the regions dominated by NE monsoon have been shown to be distinctly depleted in stable isotopic compositions compared to those dominated by SW monsoon.

It is thus seen that **even with the limited available data on isotopes, it has been possible to make some general inferences and estimates about regional scale vapour sources and hydrological processes.** These **estimates can be made more quantitative** if systematic sampling of precipitation, vapour, stream water and groundwater could be collected from a bigger network and analysed for their $\delta^{18}O$ and δD. Already, a large number of published works are available to provide models for interpretation of isotopic data when it becomes available.

In addition to the main programme of sample collection and stable isotope analyses from the mainland area of the country, **the proposed project includes three related research studies.** These are:

(i) The seasonal water balance and mixing in the Bay of Bengal using salinity and isotopic variations of surface water with Dr. Hema Achyuthan of Anna University Chennai as PI.

(ii) Studying the atmospheric components of the hydrological cycle using isotopes and ECMWF and Indian reanalysis data including the setting up of a Vaisala Radiosonde at Goa with Dr. P. M. Muraleedharan of National Institute of Oceanography as PI. As part of this component, existing Radiosonde facility at PRL will also be used. This project also includes studying Water Balance and Mixing in the Arabian Sea Using Salinity and Isotopic variations of surface water.

(iii) Study of tritium concentrations in precipitation, surface water and groundwater from selected IWIN locations jointly by BARC, Mumbai and NIH, Roorkee.

The present proposal has been formulated taking advantage of the expertise and experience; analytical capabilities established in the country and/or are in the process of being established.

The strategy is to monitor spatial and temporal variations of isotopic composition of water in all its phases and major water sources, namely (i) atmospheric vapour; (ii) precipitation; (iii) surface flows in streams and lakes; (iv) groundwater; (v) Arabian Sea; and (vi) Bay of Bengal. Within the country, annual variations in precipitation itself are fairly large, and this variation transcends to all other components of the hydrological cycle. Therefore, to describe both the average features and the spatial variations associated with annual variations, a period of 3-5 consecutive years of monitoring is planned. To describe the temporal variations, monthly collections of samples for all the four hydrological reservoirs of water are planned. About thirty (30) stations are planned to give a reasonably good spatial coverage of the entire country in a manner such that temporal and spatial variations of up to 1‰ in $\delta^{18}O$ can be tracked. Therefore, over the entire project period it is planned to collect and analyse about (30 x 4 x 12 x 5 =) 7200 water samples from the land area of the country. In addition, the AS and BOB components require analyses of another 1500 samples. Analyses of these samples will provide seasonal synoptic image of the isotope hydrology of the country. This number will double if temporal and spatial variations of up to 0.5‰ in $\delta^{18}O$ are targeted. Instead of this, it is proposed to undertake daily collection of precipitation and atmospheric vapour for two consecutive years at seven stations, viz., Ahmedabad (PRL), Kharagpur (IIT), Roorkee (NIH), Sagar (NIH Regional Centre), Goa (NIO), Hyderabad (NGRI), Delhi (NRL), Mumbai (BARC) and Chennai (AU). These stations have been selected to act as regional representatives and taking into consideration availability of a PI/Co-PI at the respective Institution. This will yield another 6,000 samples. Thus a total of about 15,000 samples or ~30,000 analyses ($\delta^{18}O+\delta D$) are proposed to be made as part of this project. Considering that on an average a standard Stable Isotope Mass Spectrometer laboratory makes about 3000-4000 analyses annually, there is a need to have two dedicated machines for this programme. The present proposal, however, incorporates only one new mass spectrometer to supplement the stable isotope laboratory at Physical Research Laboratory (PRL) and the project partners, at IIT-KGP, NIH-Roorkee, NGRI-Hyderabad, NIO-Goa and BARC-Mumbai, NRL-New Delhi will share the remaining sample analyses. Some of these facilities are in the process of being installed. However, since all institutions, other than PRL, have already planned other research programmes, they will only be able to analyse a limited number of samples for this Programme. in addition about 800 tritium analyses from selected IWIN samples are proposed to be made over the 5-year project period at BARC, NIH and NGRI.

The success of the programme also critically depends on sample collection and its storage ensuring no isotopic modification from collection to measurement. The sampling programme being very extensive and geographically wide-spread requires the help of agencies such as India Meteorology Department (IMD)/ Indian Agricultural Research Institutes (IARI)/ Central Water Commission (CWC)/ Central Pollution Control Board (CPCB)/ Central Groundwater Board (CGWB). These and a few other agencies have established networks and a regular programme for monitoring of weather and precipitation, surface water flow/ water table/ or ground water quality from well established locations/ stations for their own work. The proposed programme of isotope monitoring will latch on with the programmes of the respective agencies at selected 30-35 stations to organise the sample collection. The agencies will be partners in the programme sharing data and publication credits. The required supplemental data for achieving the project objectives are: (i) weather data (precipitation, temperature, relative humidity, pan-evaporation, wind velocities); (ii) surface water volumetric flow and (iii) ground water level fluctuations. The PRL will be responsible for overall coordination of the project.

The network data generated as part of this project will form basis of detailed hydro-geological investigations in different river/ groundwater basins of the country. **Some of the important questions concerning the continental hydrological cycle over India that one expects to get answers from the project are:**

1 What are the seasonal sources of water vapours in different regions of the country?

2 How fast is the dispersion of 'oceanic vapour front' ahead of the 'rain front' before the rainy seasons?

3 How much of rain is contributed in different regions and climatic regimes by recycling through evapo-transpiration over land areas?

4 What is the relative proportion of plant transpiration and direct evaporation in the land derived vapour?

5 How much water is contributed by slow surface drainage over land areas and from which part of the catchment in major rivers of the country?

6 How much water is contributed by groundwater drainage to different streams and other surface water bodies in different seasons and vice-versa?

7 Is the water draining into the Bay of Bengal recycled and to what extent through re-evaporation from northern Bay of Bengal in a regional large scale hydrological cycle?

8 Do Arabian Sea and Bay of Bengal contribute to the atmospheric vapour during the dry season?

The proposal in its present form represents the consensus between the Investigators (Coordinators, PIs and Co-investigators) from Institutions with laboratory responsibilities and the collaborating institutions with primary responsibility of field sample collection. This consensus was arrived at after three formal meetings held on 14^{th} Nov., 2003 at Nuclear Research Laboratory New Delhi, on 4^{th} March, 2004 at CPCB New Delhi, on 3^{rd} May 2004 at NIH Roorkee and also during the DST Review meeting on 2^{nd} May, 2005 at PRL.

The following operational aspects also form part of the project:

The network stations for sample collection will be owned and operated by the respective institutions. The collected samples will be sent along with a copy of sample collection record sheet for isotopic analyses to any of the pre-designated laboratory from among the PRL Ahmedabad/ IIT-KGP/ NIH Roorkee/ NGRI Hyderabad/ NIO Goa/ NRL New Delhi. The results of the analyses will be communicated in standard format to (i) sample providing Institution and (ii) the central data warehouse for the

IWIN programme to be maintained by the PRL. The data will be jointly owned by the particular sample providing Institution, the particular isotope analysis laboratory and the IWIN programme. The PRL isotope laboratory will organise periodic inter laboratory calibration experiments to ensure that all network data conforms to the same high quality standards. Periodic workshops/group meetings of all participating scientists in the network programme will be held to review the progress and to discuss knowledge increments from the work of the programme. Only those results that have been discussed in these workshops will be cleared for publication. All publications will be jointly issued at the time of first reporting of results. Thereafter, the results will form part of the public domain and will also be communicated to IAEA/GNIP programme. Efforts will also be made to generate 'area or problem specific' detailed investigation satellite projects as and when interesting problems, interested scientists and institutions can be found to handle these projects.

The isotope laboratories at PRL/ NIH/ IIT-KGP/ NGRI/ NIO will also act as national facilities for research in stable isotope hydrology by the universities and other academic Institutions. As part of this national facility, yearly training programmes for post graduate students will be conducted with hands on experience in mass spectrometric isotope analysis and sample collection & storage procedures at these laboratories.

A Project Review Committee will be constituted by the Department of Science and Technology in consultation with the Head of the Nodal Centre and Principal Coordinator to periodically review/ monitor the progress and to guide the IWIN National Programme from time to time.

Although, the present proposal is for a five year period, the National Programme has a 10 years perspective during which several new programmes of local and regional characters will be undertaken in the field of hydrology with several Universities and Academic institutions. Some of these programmes, though not forming part of the present proposal, have been indicated in the detailed project proposal.

The total cost of the main project for the first five years is estimated to be Rs. 65,469,600/=. This **includes the cost of a new dedicated Stable Isotope Ratio Mass Spectrometer system at PRL and Viasala Radiosonde at NIO**. The Director, PRL has agreed to contribute Rs. 68,35,000/= towards provision of Salary, minor equipments and Others, including such civil infrastructural facilities as may be required to run the National Programme.

Therefore Grant requested from DST: Rs. 5,86,34,400/=

FORMATS FOR SUBMISSION OF PROJECTS

(To be filled by applicant)

{Sections 101 to 192 to be on separate sheet(s)}

101. Project Title: **National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal**

102. Broad Subject: Earth & Atmospheric Science

103. Sub Area: Earth Science

104. Duration in months: 5 years (60 months)

105. Total cost: Rs. 6,54,69,600/=
(FEC =US$5,80,500)

Grant requested from DST: **Rs. 5,86,34,400/=**

106. FE Component: (US$ 5,80,500)

107. Project Category: Basic Research

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Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

Registration No....................................... (To be filled by DST)

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195. Project summary (maximum 250 words)

A national programme of research on investigating the spatial and temporal fingerprinting of water sources of India using stable isotopes is proposed to study for detailed study of the components of the local and regional hydrological cycles, their seasonal evolution, interactions between the various components and controls exercised by geographic factors and climatic forcing.

This programme is considered vital for predicting the consequences of the impending engineered modification of the hydrological cycle of the country necessitated by increase in population and the need to rapidly develop and exploit the water resources of the country on a massive scale.

A detailed understanding of the natural hydrological cycle involving feedbacks and interactions between its various reservoirs is, therefore, vital to predict the consequences of the emerging hydrological changes.

The strategy is to monitor spatial and temporal variations of isotopic composition of

water in all its phases and major water sources, namely (i) atmospheric vapour; (ii) precipitation; (iii) surface flows in streams and lakes; (iv) groundwater; (v) Arabian Sea; and (vi) Bay of Bengal; and improving hydrological flow models through combination of isotope data with conventional data of flux across hydrological reservoirs at local/ regional/ national levels.

Although, the present proposal is for a five year period this programme has a 10 years perspective during which several new programmes of local and regional characters will also be undertaken.

196. Key words: Stable isotopes fingerprinting, tritium, hydrological cycle, India, Arabian Sea, Bay of Bengal.

200. Technical details:

About 30,000 isotopic analyses are proposed to be made as part of this project involving both $\delta^{18}O$ and δD. This number will double if temporal and spatial variations of up to 0.5‰ in $\delta^{18}O$ are targeted. In addition, it is hoped, that as the project proceeds some new satellite projects will be added as and when interesting problems, interested scientists and institutions can be found to handle such projects. These satellite programmes will require additional measurement capabilities. Considering that on an average a standard Stable Isotope Mass Spectrometer laboratory makes about 3000-4000 analyses annually, there is a need to have two dedicated machines for this programme. The present proposal, however, incorporates only one new mass spectrometer to supplement the stable isotope laboratory at PRL and the project partners, at IIT-KGP, NIH-Roorkee, NGRI-Hyderabad, NIO-Goa and BARC-Mumbai, NRL-New Delhi will share the remaining sample analyses. Some of these facilities are in the process of being installed. However, since all institutions, other than PRL, have already planned different research programmes of their own, they will only be able to analyse a limited number of samples for this Programme.

Tritium measurements will be made at BARC Mumbai, NIH Roorkee and NGRI Hyderabad.

A Vaisala radiosonde will be installed and operated at NIO Goa to study seasonal variations in atmospheric wind, temperature and vapour content profiles. Existing upper air radiosonde facilities at PRL will supplement this work from Ahmedabad during monsoon months for two years. Together with ECMWF reanalysis data, this will provide input for modelling of atmospheric processes leading to isotope fractionation and characteristic signatures to precipitation and water vapour.

Ships of opportunities from the DOD and the commercial shipping will be used to collect surface water samples from the Arabian Sea (AS) and the Bay of Bengal (BOB) respectively.

210. Introduction (under the following heads)

211. Origin of the Proposal:

As a result of research and applications of isotope hydrology in the country during the last few decades, a stage has been reached where it has now become possible to study continental scale hydrological cycle and trace the movement of water molecules from their origin on the surface of the ocean through rain bearing clouds to precipitation to evapotranspiration and groundwater recharge and back to ocean and atmosphere. It is also realised that this process of tracking the journey of water molecules using stable isotopes of oxygen and hydrogen can lead to quantitative understanding of the involved physical processes because of the isotopic fractionation being proportional to the extent the process has advanced. However, this exercise can not be attempted without a large enough network of stations regularly collecting and measuring isotopic content of vapour and water in different components of the hydrological cycle on a nationwide scale.

The present proposal has been formulated keeping the above goal in view and taking advantage of the expertise and experience, analytical capabilities established in the country and/or are in the process of being established.

212. Definition of the Problem:

The annual hydrological cycle begins with the onset of SW monsoon over Lakshadweep, Minicoy and Kerala. Slowly the monsoon current advances over the entire Western Ghats and the southern peninsular region and crosses over to the east coast. This is the AS branch of the SW monsoon. Over the BOB, the monsoon current turns anti-clockwise and re-enters India across the central and northern parts of the east coast, giving rise to the BOB branch. During winter and spring, winds originating in east and central Asia and moving towards south-west direction pass over the BOB before entering the SE parts of India in the form of NE monsoon. Roughly around the same period, north and NW part of the country receive rains due to Western Disturbances that originate over the Mediterranean and West Asia.

Pondering over this annual hydrological cycle some questions naturally arise. These, for example, are:

1. How fast is the dispersion of ‘vapour front’ ahead of the ‘rain front’ before the beginning of respective monsoon / rainy seasons?
2. How much of the precipitating vapour in the advancing ‘rain front’ is contributed by re-evaporation over land areas from behind the ‘rain front’?
3. Can the vapour originating from the ‘Indian Ocean/Arabian Sea’ and the ‘Bay of Bengal’ be identified and used to demarcate parts of the country that receive rains originating dominantly from either of the two primary vapour sources?
4. What fraction of the precipitation is returned to the atmosphere through transpiration by plants and what fraction by direct evaporation from surface water bodies / surfaces of leaf material, bare ground surface and soil moisture regime?
5. What fraction of precipitation flows overland (or via subsurface drainage) to the streams and other channels?
6. Which geographical areas contribute to large flow volumes in respective river basins and with what delays?
7. It is known that the winds associated with NE monsoon arise in Central Asia and pass over the BOB before reaching the SE coast of India. Is it possible to estimate the fraction of water vapour that originates in Central Asia and the amount picked up en route from the BOB.
8. Does the fresh water draining into the Arabian Sea and the BOB contribute to monsoon vapour influx to the country during the later part of the rainy season? This question is important in the context of the very large volume of monsoon river drainage from the Ganga-Brahmaputra river system into the northern Bay of Bengal and from the Western Ghats into the Arabian Sea.
9. Do the two external sources of vapour (AS and BOB) into India contribute to the atmospheric water vapour distribution in the country during November to February and subsequently during the dry season? What is the role of wetlands and surface water bodies to atmospheric vapour flux?

Apart from the purely academic quest of probing the Nature, this understanding is likely to be useful in modelling air-sea-land interaction at the beginning and during the two monsoons and may help in better predicting their advance through more focussed knowledge based monitoring of the various parameters. We shall also know the degree of control that meteorological, geographical, geological and anthropogenic processes exert on the redistribution of water into various sub-components with attendant benefits to water resource planning in India.

In short the motivation for this project is to understand continental scale hydrological cycle and Land-Ocean-Atmosphere interaction in quantitative terms to satisfy an important academic quest and to provide inputs to water resource development strategies.

213. Objective:

Important hydrological questions relate to (i) identifying dominant sources of water vapour during different seasons; (ii) their partitioning into rain which subsequently sub-partitions into evapo-transpiration, soil moisture, stream flow and groundwater; (iii) quantification of the degree and rates of interactions between these components seasonally, and (iv) the controls that geographical and climate factors exercise over the entire hydrological cycle both temporally and spatially.

The primary objective of the project is to generate the isotopic data that has bearing on these important questions and also those in the previous section. The other important objective of the project is to utilise the generated data to give quantitative estimates of residence time of the water/vapour in each reservoir and the fluxes across them in temporally and spatially distributed manner. Already, a large number of published works are available to provide models for interpretation of isotopic data when it becomes available. Combining the isotope systematics into the models of hydrological process (atmospheric and/or land surface process) will provide independent control on the volumes/ fluxes involved and lead to better quantification of the estimates of fluxes. This is because the degree of isotope change in a hydrologic process is directly related to the involved flux.

Another important objective of the project is to nucleate detailed isotope hydrology activity in universities and academic institutions first by providing a framework of basic isotope hydrology data and then by providing measurement facilities and hands on experience to selected satellite projects.

220. Review of Status of Research and Development in the Subject:

221. International Status:

Stable isotope hydrology received a big boost with the identification of the co-variance of hydrogen and oxygen isotopes in precipitation first by Friedman (1953) and later in the form of GMWL by Craig (1961). The International Atomic Energy Agency (IAEA), in collaboration with World Meteorological organisation (WMO) established the Global Network of Isotopes in Precipitation (GNIP) at which samples are collected to monitor the $\delta^{18}O$ and δD of precipitation. The data produced by this network are essential for environmental isotope hydrology. They are available on the World Wide Web at http://www.isohis.iaea.org. The regression line for the long-term average of $\delta^{18}O$ and δD measured for precipitation at the 219 stations in the network adds some precision to the Craig's line (Rozanski et al, 1993).

$$\delta D = 8.17(\pm 0.07)\delta^{18}O + 11.27(\pm 0.65) \quad ‰\ VSMOW \quad \ldots \quad \ldots \quad (1)$$

The GMWL was developed as a world-wide average and is useful as a baseline comparison of stable isotope data. A local MWL was developed from IAEA network stations for North America and is described by the equation (Yurtsever and Gat, 1981):

$$\delta D = 7.95\delta^{18}O + 6.03 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

The small difference in slope between this LMWL and the GMWL is insignificant. However, the smaller intercept probably reflects smaller kinetic effects during evaporation over the North Pacific Ocean or over North America than for the worldwide average.

The analyses of GNIP data (Craig, 1961; Dansgaard, 1964 and many others since then) have shown that isotopic composition of precipitation at any location is controlled by (i) temperature (which controls the fractionation factor,α) and (ii) the proportion of the original water vapour that still remains in the parcel of air that is undergoing precipitation (f). These are also the two variables in the Rayleigh distillation equation. From the GNIP data of geographic and temporal variations, the following controlling factors have also been identified (Dansgaard, 1964; Friedman et al., (1964) :

The continental effect is the observation that meteoric waters are more depleted farther from the source (the ocean) of water vapour. This effect is the result of the evolution of parent condensing vapour becoming progressively depleted in heavy isotopes by continued rain out. Ingraham and Taylor (1986; 1991) have observed a continental effect from as large as 45‰ per 100 km in δD on North coast of California to as little as 2‰ across the Great Basin in Northern Nevada. Salati et al (1979) observed only 0.075 ‰ depletion per 100 km in $\delta^{18}O$ across the Amazon Basin. This lack of continental isotope depletion in precipitation in Amazon Basin is thought to be the result of isotopic complexities introduced by the recycling of evapo-transpired vapour.

The altitude effect is the observation that stable isotopic compositions of meteoric waters are more depleted at higher elevation. This effect is caused by increased rain at the higher elevations due to continuous cooling of air mass pseudo-adiabatically to below dew point in an orographic precipitation system. The progressive isotopic depletion of the rain is exacerbated by increased fractionation between liquid and vapour at cooler temperatures. The elevation effect is caused by both the evolution of the parent condensing vapour and the temperature of condensation and in large measure cannot be entirely separated from the continental effect. Values of elevation effect have been reported by Friedman and Smith (1970) to be approximately 40‰ in δD per 1000m increase on the west slope of the Sierra Nevada. Siegenthaler and Oeschger (1980) reported an elevation effect in Switzerland of 0.56‰ in $\delta^{18}O$ per degree Celsius or 3.2‰ decrease in $\delta^{18}O$ per 1000m increase in elevation. Elevation effects are well defined on windward side of mountain ranges and not so well on the leeward side probably caused by spill over of precipitation formed in the rising air across, the crest of the range to the leeward side (Friedman and Smith, 1970).

The latitude effect is the observation that stable isotope compositions of meteoric waters are more depleted at higher latitudes. This effect is caused by cooler temperatures prevalent at higher latitudes and the fact that Polar Regions are situated at the end of Rayleigh rainout process. Dansgaard (1964) reported a good world-wide correlation for coastal and polar stations between mean δD and $\delta^{18}O$ values of precipitation and the mean annual air temperature (MAAT) with an average decrease of >5.6‰ for δD and 0.7‰ for $\delta^{18}O$ per degree Celsius. These observed variations are consistent with temperature dependence of equilibrium fractionation factor again indicating that condensation is an equilibrium process.

The amount effect is the observation that meteoric waters collected during smaller rain storms are generally more enriched in heavier isotopes than the waters collected during larger rain storms. During brief rain showers, the liquid reaching the ground may have become more enriched by evaporation during its descent. This effect may be observed in light rains or in rain from early part of the storm as in both cases the rain evaporates as it falls to the ground through an atmosphere of low relative humidity. Friedman et al (1962) first showed that evaporation from falling raindrops would shift the water away from the meteoric water line along an evaporation slope < 8.

The amplitude of seasonal variations in temperature increases with continentally of the site. Greater seasonal extremes in temperature generate strong seasonal variation in isotopes of precipitation. These variations in $\delta^{18}O$ and δD provide an important tool to determine rates of ground water circulation, watershed response to precipitation, and time during the year when most recharge occurs (Clark and Fritz, 1997). Unlike the continental stations, the seasonal variation for $\delta^{18}O$ for tropical marine stations correlates poorly with temperature, owing to strong seasonality of monsoon precipitation.

Water vapour plays a central role in the water and heat budgets of the atmosphere, particularly in the tropics. Several models have simulated some of the major observed spatial and temporal variations of isotopic rations and have elucidated processes that determine the relation between isotopic rations and climate variables. A typical assumption in simple models is that the vapour at sea surface is in isotopic equilibrium with sea water. General circulation models also utilise simplified assumptions about the isotopic exchanges that take place between falling raindrops and the ambient vapour and at sea surface but, the effect of evaporating sea spray on isotope ratios is ignored (Jouzel and Koster, 1996; Gedzelman et al, 2003). Lawrence and Gedzelman (2003) showed that $\delta^{18}O$ values varied widely according to the weather regime. The highest $\delta^{18}O$ values occurred during quiescent weather or in regions of isolated or disorganised convections. The lowest $\delta^{18}O$ values occurred in or downwind from regions of organised mesoscale weather disturbances. Thus indicating that, water vapour isotope ratios in tropical cyclones are markedly lower than in isolated thunder storms. It has also been shown that isotope equilibrium between rain and water vapour occurs on average but not for individual events. In fact, for major rain events, $\delta^{18}O$ values of vapours continue to decrease for 12 to 24 hours after the cessation of rainfall (Lawrence et al, 2004) indicating that departure from isotope equilibrium involves advection and is therefore, more than a local phenomenon. Lawrence and White (1991) showed that the amount effect is in some measures due to recycling of water vapour in storms. There are indeed very few studies on isotopic ratios in atmospheric water vapours and it would seem that a concerted programme of research involving study of precipitation and atmospheric vapour both over short and long term intervals along vapour trajectories may reveal considerable new knowledge.

In spite of the large amount of work in understanding the hydrological cycle, it is difficult to give answer to a simple question regarding the origin of today's rain. Many studies have related this question to precipitation recycling (well reviewed in Eltahir and Bras, 1996 and Burde and Zangvil, 2001). Studies that identify water by its origin and incorporate tagged water into general circulation models (GCMs) are a direct way to estimate water recycling and to answer the question of where rains originate (e.g. Koster et al., 1986; Numaguti, 1999; Bosilovich and Schubert, 2002). But GCM studies have failed to reproduce short-term variability in the isotope composition of precipitation. The short-term variability is often greater than seasonal or monthly variability. Recently, a global simple one-layer isotope circulation model that includes Rayleigh distillation and uses external forcing has reproduced short-term (daily) variability over Thailand (Yoshimura et al., 2003). Another study named "coloured moisture analysis" (CMA) using the results from a global run forced by 1998 data from

Global Energy and Water Cycle Experiment (GEWEX) Asian monsoon experiment (GAME) reanalysis data (Yamazaki et al., 2001) was able to provide an integrated view of temporal and spatial changes in atmospheric circulation field of Asian monsoon activities (Yoshimura et al., 2004).

In the foregoing, an attempt was made to summarise the basic knowledge acquired through application of stable isotopes to hydrological studies and also to show that based on data from global network of isotopes in precipitation significant advancements have been made in improving hydrological process. The emphasis is now shifting to detailed understanding of hydrological cycle at regional scales. Only a few benchmark papers having global significance have been referred to. It may, however, be noted that at regional and local scale, a very large amount of work has been and is being done by isotope hydrologists in different parts of the world.

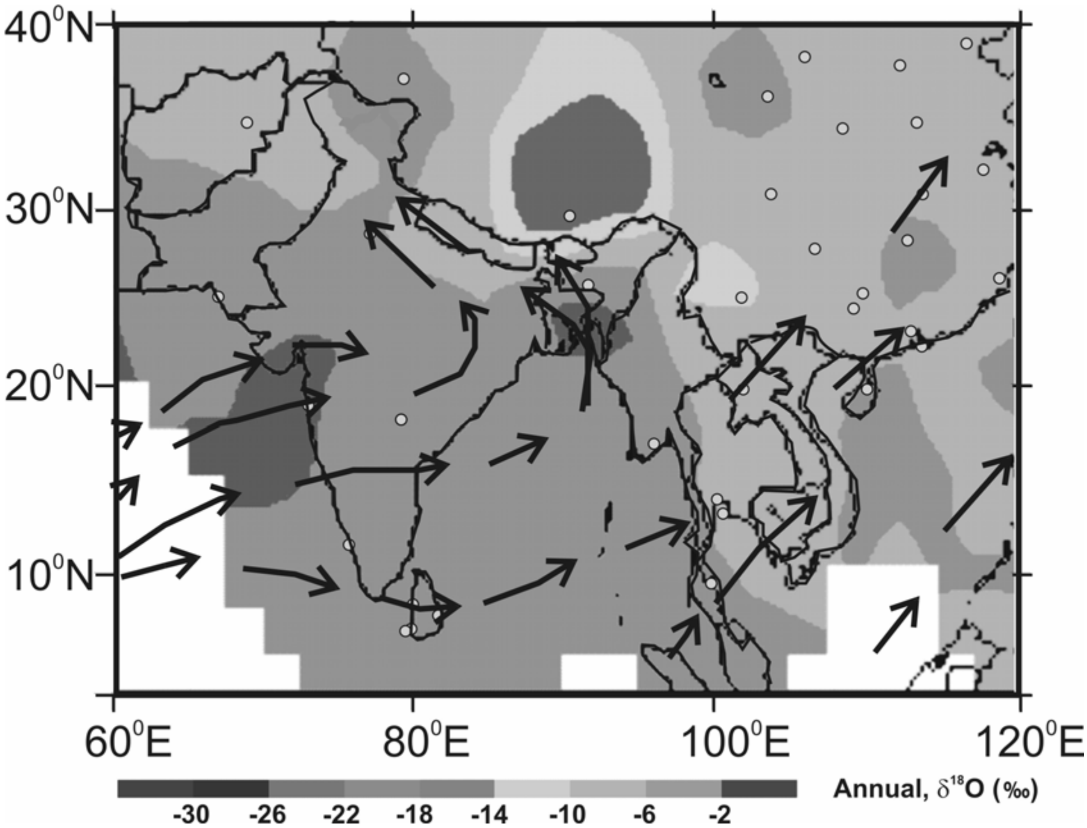
222. National Status:

Unfortunately in India reasonably long data series of isotopes in precipitation exist only for two stations, namely, New Delhi and Bombay. Other Indian stations for which at least one year of record of isotopes in precipitation can be downloaded from http://www.isohis.iaea.org are Kozikode, Allahabad, Shillong, Hyderabad and a few closely spaced stations in Lower Maner Basin. Recently data for the year 1994 has also become available from Nainital (Nachiappan et al., 2002). There are no stations from the East Coast of India. It may be noted that influx of vapour from BOB occurs over India along this coast during both SW and NE monsoon seasons. During SW monsoon, it is the northern part of India that receives vapour influx from the BOB, whereas it is the southern part that receives vapour influx from BOB during the NE monsoon. The average surface water isotopic composition of BOB has been shown to be ~1‰ depleted in $\delta^{18}O$ with respect to (wrt) the AS (Duplessy et al 1981; Prell et al., 1980). Due to large influx of monsoon runoff from Himalayan rivers, it is expected to have large (3-4‰) seasonal changes in isotopic composition of its surface water very much similar to large (~12‰) seasonal surface water salinity changes. This seasonal change in the isotopic composition of surface waters of BOB is expected to lead to different imprinting of the seasonal vapour influx which in turn will transfer to all other components namely rainfall, stream flow, soil moisture, surface- and ground-water reservoirs.

222.1 Isotopes in precipitation

From the average annual distribution (Figure 1a) it was shown by Gupta and Deshpande (2003a) that the $\delta^{18}O$ of precipitation progressively decrease from <–2 ‰ along the northern part of the west coast to ~ –6 ‰ towards the east coast. In fact, rains over much of India have $\delta^{18}O$ values between –2 ‰ to –4 ‰. The Himalayan region and the foothills have isotopically lighter precipitation. Qualitatively, the observed distribution can be explained by a dominant source of vapour originating from the Arabian Sea/ Indian Ocean during the SW monsoon (JJAS) and rainout largely along the Indicated trajectory coupled with such geographical effects as orographically induced heavy rainout on the western Ghats. The rainout effect along the Bay of Bengal branch of the SW monsoon can also be identified in the observed isotopic depletion between Kolkata and New Delhi. Additionally, altitude effect of the Himalayas is a contributing factor for rains in the lower and high Himalayas.

Another striking feature of the annual precipitation over India is that *d* (Figure 1b) rarely reaches 10 ‰ even along the west coast, expected for GMWL. In addition, a pronounced region of *d* <4 ‰ is seen in central and eastern India (receiving little rain during the NE monsoon, ONDJ). The low *d* of precipitation over India, compared to GMWL, is interpreted to be the result of minor to significant evaporation from the falling raindrops in a relatively dry atmosphere. It is important to note that the region of d <4 ‰



overlies areas that also have low rainfall.

Figure 1a

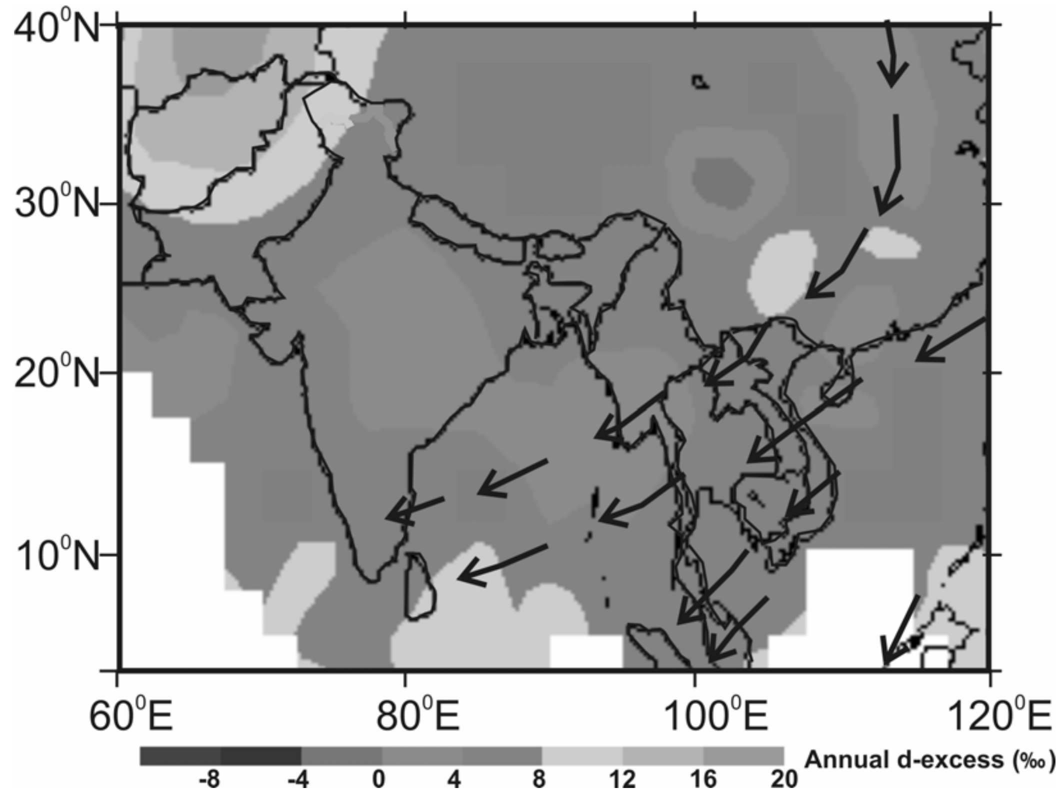


Figure 1b

Gupta and Deshpande (2003b) have also shown from the seasonal distribution of $\delta^{18}O$ and *d* in precipitation that primary oceanic vapour influx areas along west and east coasts both during SW summer and NE winter monsoons are characterised by *d* in the 8-12‰ range. Due to continued aridity even during the period of summer monsoons, the rain shadow zone of Western Ghats, parts of southeast coast, central and northwest India, show clear indication of evaporation from falling raindrops in the form a belt of low (<8‰) *d*. The region over Bangladesh and the eastern states of Tripura, Manipur and eastern Myanmar show high (>12‰) *d* values in precipitation for most part of the year except at the beginning of the May. From August onwards, the area covered by this high *d* region progressively increases and spreads westwards indicating evaporative recycling of vapour from the very large area of wetlands and soil moisture during the monsoon and post monsoon seasons.

Another region of persistent recycled vapour of land origin lies over Afghanistan and Pakistan. It spreads to Jammu & Kashmir during winter-spring under the influence of Western Disturbances as seen clearly in the low $\delta^{18}O$ (–14‰ to –6‰) values of precipitation. This spread of land derived vapour during winter-spring is not so clearly seen in enhanced *d* over Jammu & Kashmir as evaporation from the falling raindrops reduces their high *d* to ~10‰. The lowering of $\delta^{18}O$ values in May seen in eastern India and Bangladesh indicates onset of vapour influx from the northern BOB. This is also indicated by decrease in *d* value of precipitation from the previous season (from >12‰ to ~10‰).

It is thus seen that even with limited availability of the data of isotopes in precipitation, it is possible to postulate on regional scale vapour fluxes and hydrological processes (Bhattacharya et al 2003). These interpretations can be sharpened and reasonably good quantitative estimates can be made if systematically monitored data from bigger network on both precipitation and vapour could be collected.

222.2 Isotopes in groundwater studies

Investigations of groundwater isotopic character over past 2-3 decades have generated a dataset that covers a large part of the country, albeit with large gaps in between. It was shown that the observed distributions (Figure 2a and 2b) of $\delta^{18}O$ and *d* are governed by several factors namely: (i) vapour sources for primary precipitation; (ii) isotopic character of primary precipitation; (iii) physiographic features; (iv) annual precipitation amount; (v) annual mean potential evapotranspiration and (vi) surface soils (Gupta and Deshpande, 2005a; Deshpande et al, 2003; Gupta et al, 2005).

In spite of the limitations of data in space and time, the following points emerge from the available data:

1. Ground waters show a very significant evaporation related modification of isotopic signal of precipitation in large parts of the country, particularly in the western and central parts of the country comprising the states of Rajasthan, Gujarat, Haryana, MP, on the eastern side of the Western Ghats in Maharashtra, Karnataka, parts of Andhra Pradesh and Orissa. The ground waters are enriched wrt the precipitation in $\delta^{18}O$ and show lower values of *d* (Bhattacharya et al, 1985; Deshpande et al, 2003; Datta, 1991, 1999; Das, 1988; Ramesh et al, 1993).
2. This indicates that there is minor to significant kinetic evaporation of the precipitated water before groundwater recharge.
3. Datta et al (1994) in a study of groundwater in Pushkar valley found that there was a decrease in $\delta^{18}O$ with depth of water table which may be due to stratification of groundwater with shallower zones being recharged from relatively modern rainfall.

4. In a study from Lower Maner basin in Andhra Pradesh, Kumar et al (1982) showed that groundwater samples were enriched wrt the weighted mean isotopic ratios for precipitation. The extent of enrichment was found to vary with recharge characteristics of various soils and rock types in the basin.

5. Several other cases, particularly from Rajasthan and Gujarat in India and Bangladesh have indicated that older ground waters have lower $\delta^{18}O$ suggesting a somewhat different climatic regime with less aridity and / or increased precipitation (Navada et al, 1993; Nair et al, 1997; Aggarwal et al, 2000).

6. Using the groundwater $\delta^{18}O$ values from the Calcutta-Delhi segment, Krishnamurthy and Bhattacharya (1991) used the departure from the expected continental gradient due to rainout to estimate ~40% return back by transpiration.

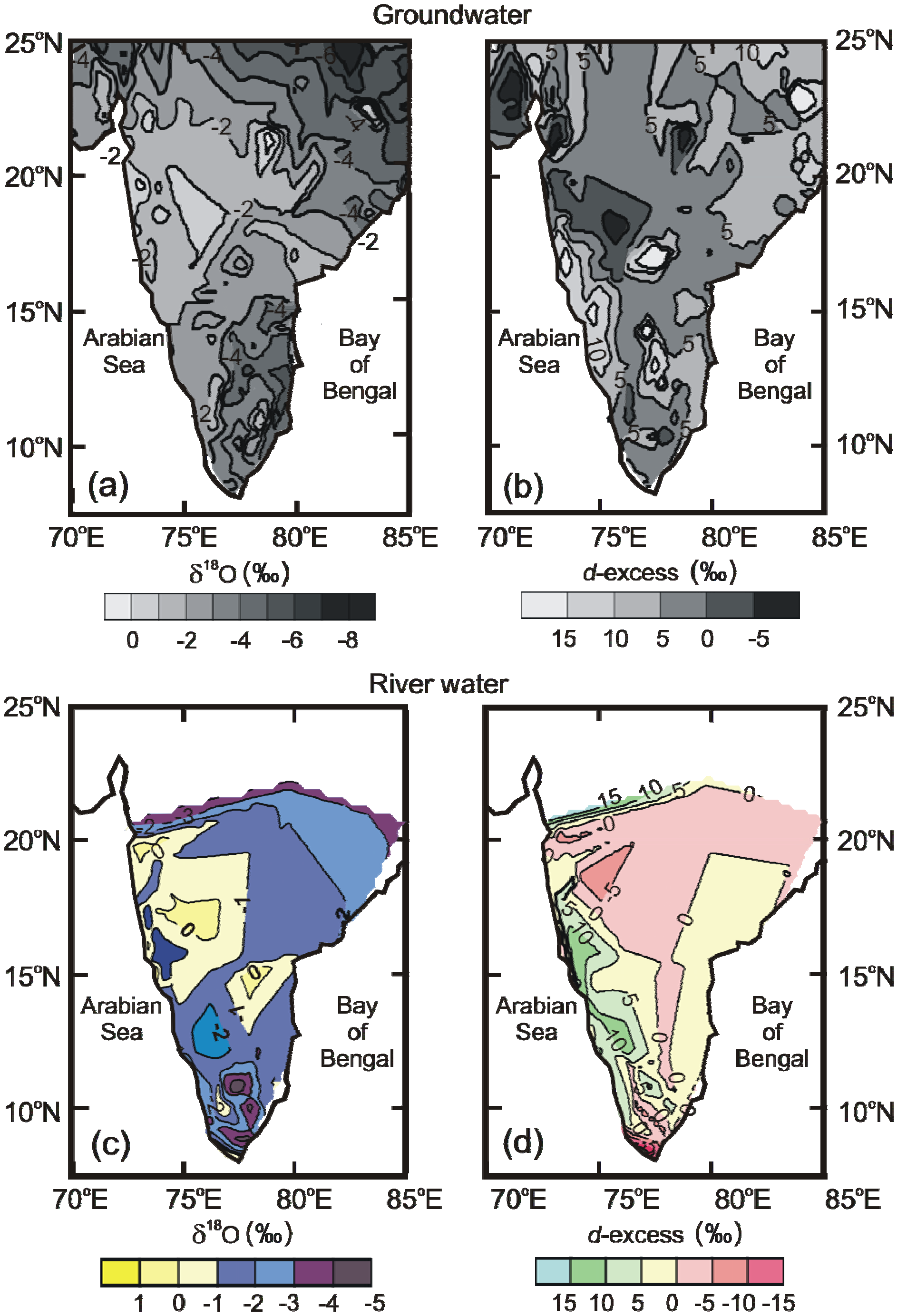


Figure 2

7. Deshpande et al (2003) showed that in southern India with dual monsoon influence, ground waters from the regions dominated by NE monsoon show distinctly depleted stable isotopic compositions compared to those dominated by SW monsoon.

   It was also shown that the $\delta^{18}O$–δD regression line slope ~6 in the east coast region is lower than that expected for local precipitation suggesting secondary evaporation.

8. However, in the coastal regions both along west and east coast, the ground water samples exhibit a reasonable correspondence with the precipitation isotopic data suggesting only minor modification of the isotopic signal during groundwater recharge. One very interesting aspect of groundwater data from coastal regions is that the average $\delta^{18}O$ of groundwater samples along the west coast is –1±1‰ as against a much lower $\delta^{18}O$ value (–5±2‰) from the east coast. In either case the *d* values vary around 10‰. This large difference in $\delta^{18}O$ values in ground water samples from the west and east coast samples confirm the inferred $\delta^{18}O$ difference (see Figure 1a) in precipitation along the two coasts during principal rainy seasons. It may be noted that there is no direct precipitation isotope data from any station along the east coast of India and the isotopic signatures of precipitation on this coast have been interpreted from neighbouring stations of Hyderabad and Shillong in India and few stations in Sri Lanka, Myanmar and Thailand with only few years of data.
9. It has long been known that compared to the AS the surface waters of the BOB are ~1‰ lighter in $\delta^{18}O$ due to very large influx of surface runoff from surrounding continental areas (Duplessy et al, 1981; Duplessy 1982; Prell et al, 1980; Ostbund et al, 1987; Delaygue et al, 2001). This would explain only a part of the observed difference in $\delta^{18}O$ from west coast east coast.
10. To account for the balance of the observed difference, it is necessary to hypothesise that the vapour source in the BOB during SW monsoon is largely the north BOB that receives large runoff from Ganga-Brahmaputra river system during the rainy season. In some way it is necessary to invoke a seasonally active regional hydrological cycle between the Northern BOB and the Ganga-Brahmaputra river system. In this seasonal cycle the northern BOB supplies the vapour that precipitates inland over Himalayas and the Ganga Plains and river system quickly return a large part back through runoff that spreads widely due to large salinity (hence density) difference and re-evaporates to start the cycle.
11. A further indication of such a hypothesised seasonal cycle is provided by the limited number of stream water isotopic measurements (Ramesh and Sarin, 1992) from the Ganga river system during the SW monsoon season that indicate a very low values of $\delta^{18}O$ (<–11‰) and δD (<–69‰). This further suggests that the surface water of the northern BOB during at least the later part of SW monsoon season (late July to September) can have very significantly lower $\delta^{18}O$ (≈3‰) to provide the required isotopically light source of vapour into the proposed seasonal hydrological cycle of regional dimensions.
12. Nachiappan et al (2002) used the temporal variations in the isotopic composition of Nainital Lake to estimate subsurface components to the water balance of the Lake.

222.3 Isotopes in surface water studies

The distribution of $\delta^{18}O$ and *d* in the lean season river water from the Southern half of Indian subcontinent is shown in Figures 2c and 2d. It is seen that the river waters essentially mimic the isotope distribution of ground waters in the lean season. This suggests that during non-monsoon months most streams derive their base flow from very local effluent groundwater discharge. The small isotopic enrichment seen at few locations over local groundwater indicates evaporation after effluent discharge of groundwater during stream flow. Isotopic characters of different rivers systems in India have been studied to understand the factors that significant influence the isotopic character of river in the specific part of the basin. Additionally,

1. The headwaters of Indus and its tributaries, surface ice in glaciers, saline and fresh water lakes and thermal springs in Himalayan and Kashmir region showed (Pande et al, 2000) high *d* that was identified as due to precipitation from 'Western Disturbances' with unique signature of vapour source in the Mediterranean region (Raina, 1977).
2. High altitude tributaries of Ganges showed $\delta^{18}O$-δD relationship close to GMWL, but those from the lowland region showed a significant evaporation effect (Ramesh and Sarin, 1992).
3. At high altitude, Yamuna and its tributaries showed isotopically most depleted water during the monsoon season. This has been explained in terms of amount effect (Dalai et al, 2002). But, rainout and temperature effects could also be the contributing factors. High values of *d* were seen during October and ascribed to the inherent signature of a precipitation deriving from the Western Disturbances (Dalai et al, 2002).
4. Along Ganga River between Hardwar and Naroda, stream water showed isotopically depleted character during monsoon with little spatial variation. With progression of dry season the stream water tended to acquire the isotopic character of the local groundwater (Navada and Rao, 1991).
5. Gupta and Deshpande (2004) used the data set of Nachiappan et al (2002) from Nainital Lake in Kumaon Himalayas to investigate the seasonal dynamics of this lake using simple 2-Box model. It was shown that stratification in the lake was maintained by inflow to hypolimnion of cold and depleted groundwater recharged from higher elevations. This inflow peaks in winter (Nov to Jan); whereas epilimnion inflow peaks around Oct. The average flushing time of the Lake was estimated as 1.63 years.

From the forgoing, it is clear that even the limited isotopic data on water sources has contributed significantly to better description of the dynamic hydrological process over India. However, the available data are not enough to quantitatively describe the hydrological cycle in terms of exchanges and interactions between its various components and to fully utilise its potential for decision making on large scale water resource management. This can be accomplished if spatial and temporal isotope fingerprinting of all the water sources of India is carried out systematically and at closer spatial and temporal resolution. This however, is a Herculean task and can be accomplished only by a multi-institutional collaborative efforts spanning over a couple of years. Gupta and Deshpande (2005b) have described in detail the need and potential applications of such a programme involving a network for monitoring of isotopes in waters of India.

222.4 Isotopes in Arabian Sea and Bay of Bengal

Some measurements of $\delta^{18}O$ of sea water, both from Indian Ocean/ AS and BOB, have been made to derive $\delta^{18}O$-salinity correlation. In the BOB, $\delta^{18}O$ and salinity display a northward decrease from equator to ~15^0N, most measurements range between 33-35 PSU for salinity and 0-0.5‰ for $\delta^{18}O$. Further northwards, salinity and

$\delta^{18}O$ decrease down to <23 PSU and <-2‰ respectively. A linear relationship [$\delta^{18}O$ = (0.18±0.01).S – (5.9±0.2); r=0.97] has been given for the BOB (Delaygue et al, 2001). In the AS, typical enriched values are found with salinity up to 36.6 PSU and $\delta^{18}O$ up to +0.9‰. Both salinity and $\delta^{18}O$ display a very limited range of values; ~1.5 PSU for salinity and ~0.5‰ for $\delta^{18}O$ with a linear relationship [$\delta^{18}O$ = (0.26±0.02).S – (8.9±0.7); r=0.79] for the AS (Delaygue et al, 2001).

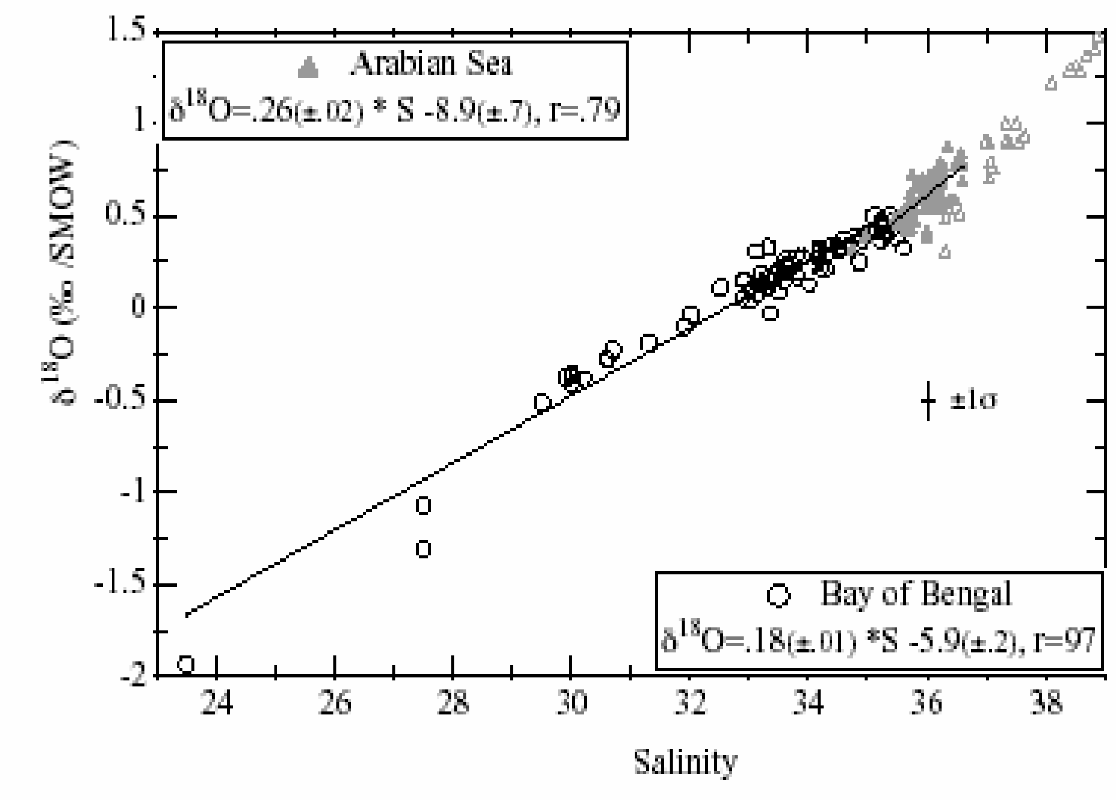


Fig. 3. Surface $\delta^{18}O$ - salinity relationship for the AS and BOB. Data points represent only one set of samples collected during Jan/Feb, 1994. Reproduced from Delaygue et al (2001).

The contrasting $\delta^{18}O$ and salinity distributions and relationships between the two northern Indian seas are explained as due to stronger precipitation (+runoff) – to – evaporation ratio in the BOB compared to AS. However, the respective roles of precipitation and runoff to the observed dilution in the surface water of the BOB and their seasonal variations still need to be understood (Delaygue et al, 2001). In addition, the effect of this seasonal distribution on isotopic composition is also somewhat enigmatic. Based on the stable isotope data of precipitation and groundwater from the west and east coast of India, it has been shown that the $\delta^{18}O$ composition of groundwater on the west coast of India averages -1±1‰ and that on the east coast averages -5±2‰ (Deshpande et al, 2003; Gupta et al, 2005).

This implies that vapour influx entering the subcontinent from the AS branch and the BOB branch of the summer monsoon are required to be significantly different to explain the observed isotopic distribution.

It is thus seen that, both direct precipitation and its proxy groundwater isotopic distributions indicate that the west coast of India receives precipitation with $\delta^{18}O$ content of -1±1‰ originating from the AS surface water with $\delta^{18}O$ of 0.5±0.5‰ – an offset of ~-1.5±1.2‰ (Deshpande et al, 2003; Gupta et al, Subtd). But, for an average BOB surface water of ~-0.3±1.0‰, the $\delta^{18}O$ of precipitation on the east coast, particularly north of ~18^0N, was earlier inferred as ~-5±2‰ (Deshpande et al, 2003; Gupta et al, Subtd). – an offset of ~-4.7±2.2‰. This large offset between known isotopic value of surface sea water and the East Coast precipitation is the Isotopic Enigma of the BOB.

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223. Importance of the Proposed Project in the Context of Current Status:

In addition to improving the basic understanding of the hydrology of the country at different spatial and temporal scales, this programme is vital for predicting the consequences of the impending engineered modification of the hydrological cycle of the country necessitated by increase in population and the need to rapidly develop and exploit the water resources of the country.

It has been estimated that by the year 2050, the per capita availability of flowing water in the country will decrease from the present ~1,700 m^3/yr to ~1,140 m^3/yr. The demand for water will almost triple to ~1,450 km^3/yr. This will require massive effort in conservation of water through rainwater harvesting and groundwater recharge, renovation and reuse of waste water, construction of medium and large surface storage reservoirs and even inter basin transfer of water. Whichever way the water demand is met, there will be large scale modification of the natural hydrological cycle in the country not just due to engineered structures and controlled stream flows but also by changing the residence time of water in aquifers and by increasing water vapour content of the atmosphere over India, significantly during non monsoon months.

The data collected over the next 2-3 years will be baseline against which it will be possible to monitor the anthropogenically induced hydrological change at later date. In water balance studies, evapotranspiration is the most uncertain parameter estimated either from empirical formulae or by applying a fractional coefficient to the pan evaporation data. Isotopic investigation yield independent estimates based on degree of isotope fractionation that in turn depend on the progress of the hydrologic process. Similarly, any intensification of the hydrological cycle can be estimated with greater accuracy using isotope monitoring and should provide vital inputs to models for predicting the consequences of engineered modification.

Identifying dominant sources of seasonal vapour influx to India is also vital to improve understanding of (i) continental scale hydrological circulation and (ii) land-ocean-atmosphere interaction as Indian monsoon is an important component of global atmosphere circulation and source of all important water to India.

In addition to the main programme of sample collection and analyses from the mainland area of the country, the proposed work includes collection and analyses of samples from the AS and the BOB. Both coastal AS and the north BOB undergo large seasonal fluctuations in salinity due to influx of fresh water from rivers draining Western Ghats and Himalayas during the SW monsoon. Whereas salinity and isotope variations represent the same parameter if dilution and mixing are the only two components involved. If there are multi-component, multi-process interactions, particularly those involving atmospheric transport via rain, stream water and through evaporation, the two parameters may not vary parallely. This may well be true in the case of North Bay of Bengal particularly during the period of SW monsoon. It should also be noted that north BOB is an important source of vapour for the storms that bring in rains to Himalayas and the Indo-Gangetic plains, thereby suggesting a regional hydrologic cycle involving atmospheric transport form BOB to land and return via streams draining Himalayas and the Indo-Gangetic region.

In yet another associated study, the vapour budget of India and the adjoining oceans during the last two decades is proposed to be investigated in detail using ECMWF reanalysis Data. In addition the atmospheric process and their effects on precipitation isotopic ratios over smaller (daily to weekly) intervals of time depending on contemporary rainfall are proposed to be investigated using Radiosonde investigation of lower atmosphere data of wind, temperature humidity by establishing a Vaisala Radiosonde at NIO, Goa. Here, rain and water vapour samples at shorter (daily to weekly) interval will also be collected and isotope data analysed in relation to Radiosonde data. In this project, using seasonal atmospheric water vapour balance, attempts will be made to compute the isotopic composition of the monthly precipitation and the models will be calibrated using the isotopic data.

224. Review of Expertise Available with Proposed Investigating Group/Institution in the Subject of the Project:

A very large part of the available primary data on isotopes in waters of different components of the hydrological cycle over India has been generated from the Physical Research Laboratory (PRL). A few Ph.D.s have also been produced. These Ph.D.s are now contributing to front line research in the field of isotope hydrology and/or are in the process of setting up new isotope hydrology laboratories in different parts of the country. The PRL continues to support their efforts through technical guidance and laboratory materials.

The Principal Coordinator and Co-Principal Coordinators from PRL and PIs from the collaborating institutions have contributed most of the publications in the field of isotope hydrology in reputed national/ international journals. PRL also has a working isotope mass-spectrometer laboratory.

In addition to PRL mass-spectrometer laboratory, the upcoming mass spectrometer laboratory at IIT, Kharagpur, NIO Goa, NIH Roorkee and the NGRI, Hyderabad will be used for making isotopic analyses for this national programme. The supporting institutions of CGWB, CWC, IMD, CPCB, and CRIDA have established stations and field infrastructure that will be used to collect vapour and water samples for isotopic measurements and the data on flux and volume flows.

225. Patent Details (domestic and international):

U.S. Patent No. 5229005 Issued on July 20, 1993 "Ocean Depth Reverse Osmosis Freshwater Factory" – S.K. Gupta.

226. How the Generated Data would be used to achieve the Broad Objectives of the Programme?

The dominant sources of water vapour supply to Indian sub-continent have been identified as Arabian Sea, Bay of Bengal, and continental vapour locally derived or transported over long distance, e.g., from Mediterranean in North India during winter. Each of these sources has a distinct isotopic character which will be reflected in the isotopic composition of the resulting precipitation in different seasons. A qualitative picture of this has been presented by Gupta and Deshpande (2003) based on available IAEA/WMO GNIP data. Bhattacharya et al (2003) have described a possible mechanism to explain the observed isotopic variation in monsoon precipitation at Bombay and New Delhi.

The amount of water vapour in different parts of the country and at different seasons can be known only from the meteorological data. Some of this data, though in reanalysed form, can be obtained from ECMWF web site and the modelling exercise can be improved when actual measured data becomes available.

The amount, falling as rain is measured during the collection process and the fraction can be computed using column precipitable water/ wind directions/ total water from ECMWF or other meteorological data sets. This can be verified by using isotope fractionation calculations. From the available data of isotopes using groundwater as proxy, Gupta et al (2004) have estimated ~32% rain out of the vapour influx from the Arabian Sea before crossing over to Bay of Bengal.

The groundwater recharge is conventionally estimated from water balance calculations of a region wherein evapotranspiration is the most uncertain fraction. Isotopes are ideally suited for estimating evapotranspiration as was shown by Krishnamurthy and Bhattacharya (1991).

The interaction/exchange between rainwater and atmosphere is estimated by Craig-Gordon model (1965). This model has recently been used by Gupta and Deshpande (2004) to estimate the isotopic composition of atmospheric vapour for the months for which no data was available. The project however proposes to measure isotopic composition of the atmospheric vapour throughout the year and will therefore help in verifying/ improving the model applicability over India where conditions vary from near dry to saturated atmosphere during the course of the year.

Several models for describing interaction between surface water bodies and the atmosphere are available (e.g. Machavaram and Krishnamurthy, 1994). Interaction of groundwater and surface water bodies is clearly seen in the limited isotopic data of streams from the country that indicate discharge of groundwater to streams during the dry season (Gupta et al 2004). Shivanna et al (2003) studied the contribution of storms to groundwater recharge in the semi arid regions of Karnataka. Nachiappan et al (2002) have studied the interaction of groundwater and Nainital Lake and Gupta and Deshpande (2004) have modelled the Nainital lake dynamics using the seasonal variations in isotopic data.

The controls of geography and climate will be determined from the geographical distributions of isotopes in various water phases and their seasonal variations. Altitude and temperature effects on isotopic distributions, as examples of geographic and climate control, are well known. Deshpande et al (2003) and Gupta et al (2004) have used groundwater isotopic data to identify some of the geographical features, e.g., Western and Eastern Ghats, Deccan Plateau that seem to control the isotopic distribution. Since both geography and climate also control rainfall distribution, their control over isotopic distribution may be quite complex.

In short it is submitted that a large number of published works are available to provide models for interpretation of isotopic data when generated. The collected data will certainly show that all of it can not be explained by the known processes and this will present opportunity for advancing the frontiers of knowledge in this subject.

In the forgoing, attempt has been made to show that even with the limited data availability Indian geoscientists have made important contributions and many more can be expected in varied scientific disciplines that depend on water in its different forms.

227. What is the Current Thinking of Meteorologists and Hydrologists on Geographical and Climate Control of the Hydrological Cycle and How the Isotope Work Would Test/ Enhance/ Challenge These?

The meteorologists also derive information on geographical and climate control using distribution of rainfall, temperature, humidity etc. Their information, however, relates to, for example, amount of rainfall and not its source or if there has been evaporation from the falling raindrops or the water vapour that originated from the oceanic flow stream and had component of evaporation and transpiration added to it. Information about these aspects can contribute to improving the understanding of the hydrometeorology of India. The modelling of isotopic fractionation effects in terms of fractions involved may challenge some of the current hypothesis, as for example, based on even limited isotopic data one requires existence of a regional hydrological cycle involving Bay of Bengal and Himalayan Rivers during the period of SW monsoon. Some studies of tropical cyclones using short term isotope variations in rain and water vapour have already indicated that isotopic ratios of the two in organised storms are not in equilibrium and that isotopic ratios in vapour continue to decrease for 1-2 days after the cessation of the storm activity. One can expect to improve the understanding of meteorological processes from similar studies over India by combining radiosonde data with isotope data and the process models.

228. What is “New” Expected as an Outcome of this Project?

Some of the interesting questions concerning the continental hydrological cycle over India that one expects to get answers from the project are:

1. How fast is the dispersion of ‘oceanic vapour front’ ahead of the ‘rain front’ before the rainy seasons?
2. What are the seasonal sources of water vapours in different regions of the country?
3. How much of rain is contributed in different regions and climatic regimes by recycling through evapo-transpiration over land areas?
4. What is the relative proportion of plant transpiration and direct evaporation in the land derived vapour?
5. How much water is contributed by slow surface drainage over land areas and from which part of the catchment in major rivers of the country?
6. How much water is contributed by groundwater drainage to different streams and other surface water bodies in different seasons and vice-versa?

7. Is the water draining into the Bay of Bengal recycled and to what extent through re-evaporation from northern Bay of Bengal in a regional large scale hydrological cycle?
8. Do AS and BOB contribute to the atmospheric vapour during the dry season?

230. Work Plan

231. Methodology:

As indicated in the foregoing, it is required to monitor spatial and temporal variations of isotopic composition of water in all its phases, namely (i) atmospheric vapour; (ii) precipitation; (iii) surface flows in streams and lakes; (iv) groundwater; and surface waters in (v) coastal AS and (vii) the north BOB. It, therefore, becomes necessary to devise a programme of sample collection and analyses that is practical and at the same time rigorous enough to preserve the isotope record from sampling till measurement. The objective is to address the issues raised above in detail and also provide reliable information concerning movement, fluxes and residence time of water in different components of the hydrological cycle in the country. Within the country annual variations in precipitation itself are fairly large, and this variation is reflected in all other components of the hydrological cycle. Therefore, to be able to describe both the average features and the spatial variations associated with annual variations, a period of 3-5 consecutive years of monitoring is planned. To describe the temporal variations, monthly collections of samples for all the four hydrological reservoirs of water are planned. About thirty (30) stations are planned to give a reasonably good spatial coverage of the entire country in a manner such that temporal and spatial variations of up to 1‰ in $\delta^{18}O$ can be tracked. Therefore, over the entire project period it is planned to collect and analyse about (30 x 4 x 12 x 5 =) 7200 water samples from the land area of the country. In addition, the AS and BOB components require analyses of another 1500 samples. Analyses of these samples will provide seasonal synoptic image of the isotope hydrology of the country. This number will double if temporal and spatial variations of up to 0.5‰ in $\delta^{18}O$ are targeted. Instead of this, it is proposed to undertake daily collection of precipitation and atmospheric vapour for two consecutive years at seven stations, viz., Ahmedabad (PRL), Kharagpur (IIT), Roorkee (NIH), Sagar (NIH Regional Centre), Goa (NIO), Hyderabad (NGRI) and Chennai (AU). These stations have been selected to act as regional representatives and taking into consideration availability of a PI/Co-PI at the respective Institution. This will yield another 6,000 samples. Thus a total of about 15,000 samples or ~30,000 analyses ($\delta^{18}O+\delta D$) are proposed to be made as part of this project.

A major task connected with the programme is sample collection and storage that would ensure no isotopic modification in their isotopic composition from collection to measurement. The India Meteorology Department/ Indian Agricultural Research Institutes/ Central Water Commission/ Central Pollution Control Board/ Central Groundwater Board and others have agreed to help us in this task. These and a few other agencies have established networks and regular programmes of weather, water flow/ water table/ surface water or ground water quality monitoring for their own work. The proposed programme of isotope monitoring needs to latch on with the programmes of the respective agencies at selected 30 stations to organise the sample collection programme. The agencies have agreed to become partners in the programme and have also agreed to sharing data and publication credits. The required supplementary data for achieving the project objectives are: (i) weather data (precipitation, temperature, relative humidity, pan-evaporation, wind velocities); (ii) volumetric flow data and (iii) ground water table fluctuations. Possible locations from the networks of IMD, ICAR, CPCB and CWC are shown in Figures 4 to 7. The isotopic analyses will be done at Physical Research Laboratory, Ahmedabad, which will also be responsible for overall coordination of project. The network data generated as part of this project will form basis of detailed hydro-geological investigations in different river / groundwater basins of the country.

Model derived reanalysis data product such as NCEP/NCAR and ECMWF are extensively used to study the upper air dynamics. ECMWF data set has some superiority over the NCEP data set as the later has shown discrepancies in computing moisture over the tropics especially over land mass (Mo and Higgins, 1996). It is, therefore, proposed to use ECMWF reanalysis data for computing moisture transport across various ocean and land boundaries. It is also proposed to validate the ECMWF data using very precise DigiCORA III Vaisala sonde upper air system to filter out the discrepancies inherent in any reanalysis product. This would ensure the accuracy of computation to the achievable limit. Computation of moisture transport across various ocean and land boundaries are planned using specific humidity and Zonal and Maridional component of wind speed at various pressure levels (1000 mb to 300 mb) following the methodology adopted by earlier investigators (Saha, 1970; Saha and Bavadekar, 1977; Fasullo and Webster, 2002). The net moisture trapped inside the country as a whole and in the designated land segments are then computed for further analyses. Fractions of precipitated water recycled into the atmosphere through evaporation and plant transpiration will be estimated using the vapour balance and the isotopic data in tandem. Similarly, isotopic data will be used for estimating groundwater recharge and runoff using the stream flow data. For the purpose of this study, the landmass of India is subdivided into 9 contiguous segments (Fig. 8) having characteristic geographic and hydro-meteorological characters (Table 4).

The net water vapour available within the specified land segment recycles through precipitation and evapo-transpiration. Because of the varying hydro-meteorological characters the rainfall in each subdivision is expected to have a distinct isotopic characters grading into the neighbouring sub-divisions. Investigation of spatial and temporal distribution of stable isotopes in precipitation and groundwater will lead to the estimation of water vapour involved in the recycling process.

Rain water and Atmospheric Vapour Collection, to be chosen from: - IMD Stations

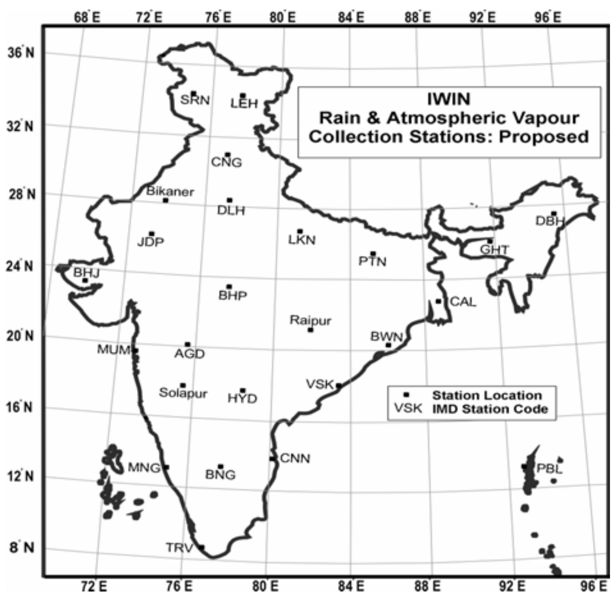

Figure 4

Table 1

Sr. No.	IMD Code	Stn. Name	Sr. No.	IMD Code	Stn. Name
1	AGD	Aurangabad	14	CAL	Kolkata
2	BNG	Bangalore	15	LEH	Leh
3	BHP	Bhopal	16	LKN	Lucknow
4	BHJ	Bhuj	17	MNG	Mangalore
5		Bikaner	18	MUM	Mumbai
6	BWN	Bhubaneshwar	19	PTN	Patna
7	CNG	Chandigarh	20	PBL	Port Blair
8	CHN	Chennai	21		Raipur
9	DLH	Delhi	22		Solapur
10	DBH	Dibrugarh	23	SRN	Srinagar (J&K)
11	GHT	Guwahati	24	TRV	Thiruvananthpuram
12	HYD	Hyderabad	25	VSK	Vishakhapattnam
13	JDP	Jodhpur			

Rain water and Atmospheric Vapour Collection, to be chosen from: - CRIDA Stations

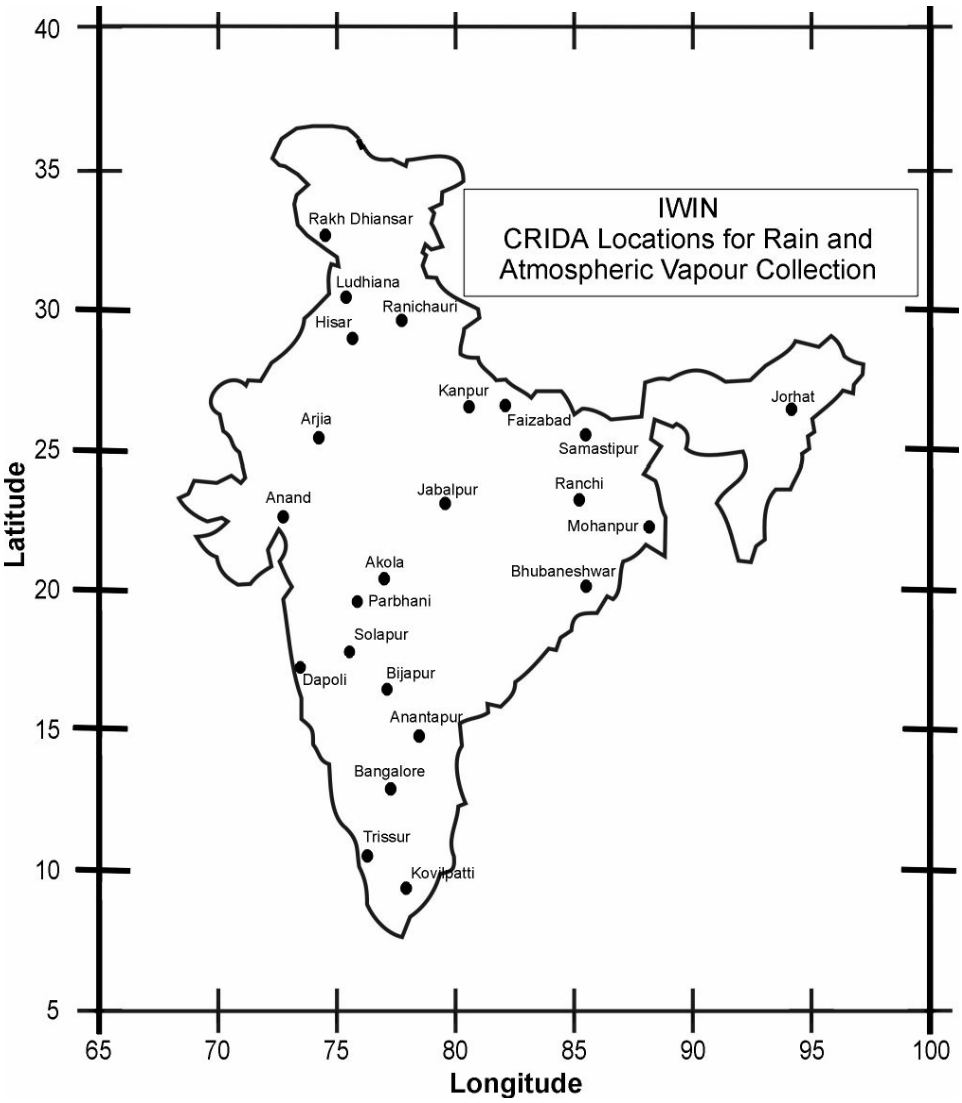

Figure 5

River Water Monitoring, to be chosen from: - CPCB Stations

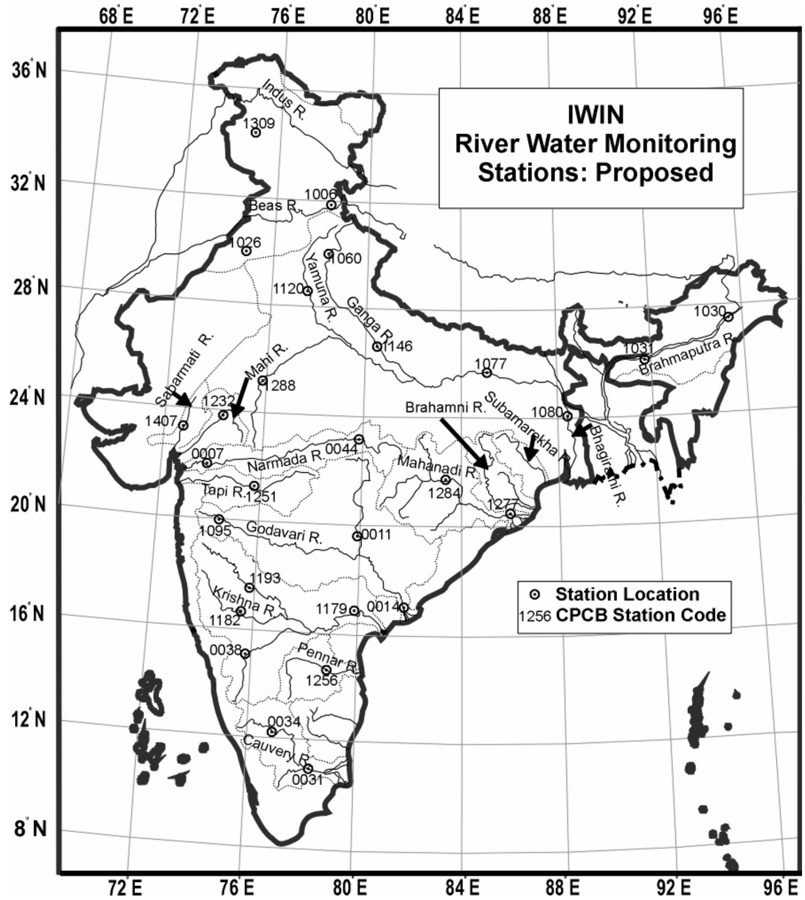

Figure 6

Table 2

Sr. No.	CPCB Code	Location
1	0007	Narmada at Garudeshwar
2	0011	Waiganga at Ashti
3	0014	Godavari at Polavaram
4	0031	Cauvery at Musiri
5	0034	Cauvery at Sathyamangalam
6	0038	Tungabhadra at Honnali
7	0044	Narmada at Sethanighat
8	1006	Beas at Mandi
9	1026	Ghagghar at Sirsa
10	1030	Brahmaputra at Dibrugarh
11	1031	Brahmaputra at Pandu
12	1060	Ganga at Rishikesh
13	1077	Ganga at Khurji, Patna
14	1080	Ganga at Behrampur
15	1095	Godavari at Gangapur Dam, Nasik
16	1120	Yamuna at Wazirabad, Delhi
17	1146	Ganga at Bithoor, Kanpur
18	1179	Dindi at Osmankuntha
19	1182	Krishna at u/s of Ugarkhurd Barrage
20	1193	Bhima at Solapur
21	1232	Mahi a/c R. Chap at Kadana
22	1251	Tapi at Bhusaval u/s
23	1256	Pennar a/c R. Papagni at Puspagiri
24	1277	Mahanadi at Cuttack u/s
25	1284	Mahanadi b/c R. Mand at Chandrapur
26	1288	Chambal at Kota
27	1309	Indus at Dal Lake inlet, Srinagar
28	1407	Sabarmati at Gandhinagar

River Water Monitoring, to be chosen from: -
CWC Stations

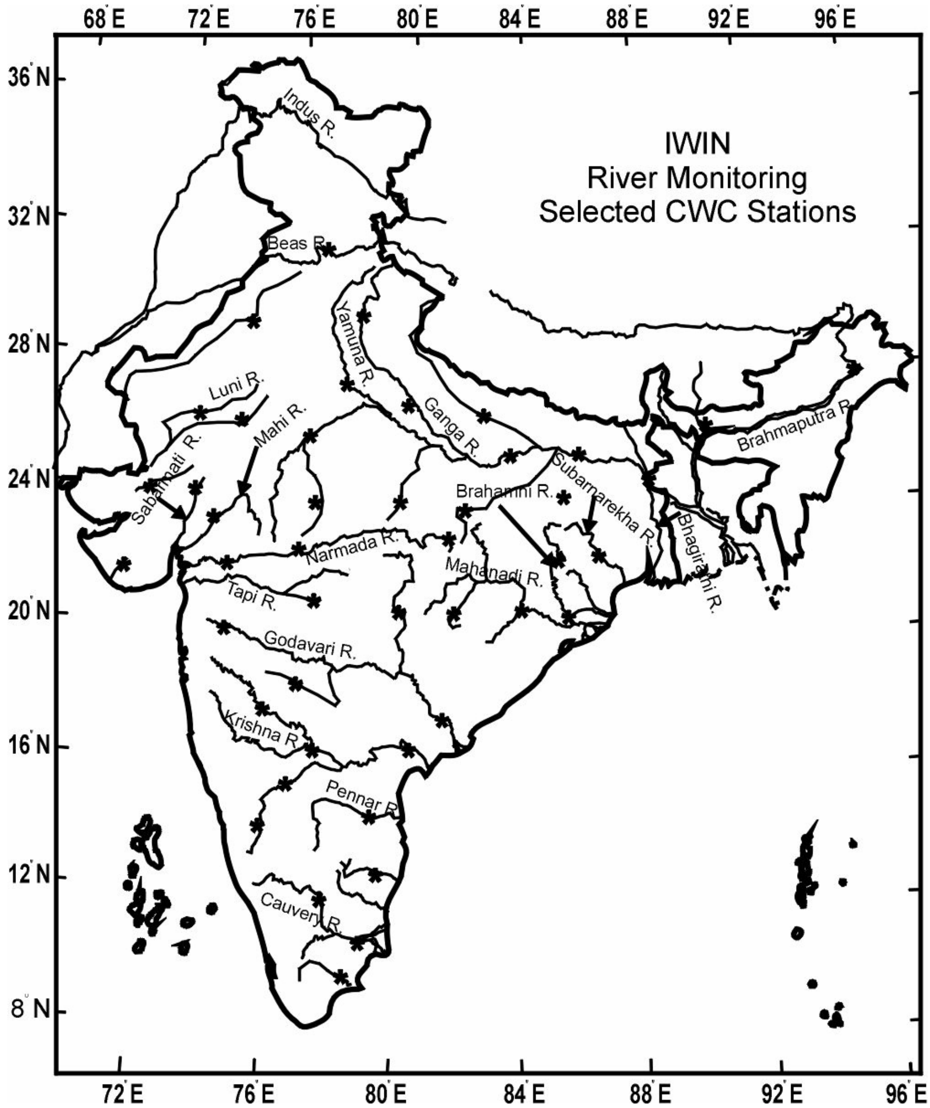

Figure 7

Table 3

Sr. No.	Stn. Name	River Name	Division	Circle
1	Chenimari /khowang	Barhi Deehing of Brahamputra	Upper Brahmaputra, Dibrugarh	Guwahati
2	Kokrajharr /Garang	Brahamputra	Lower Brahmaputra	Jalpaiguri
3	Uttarkashi	Bhagirathi	Himalaya-Ganga	Dehradun
4	Banda	Ken	Lower Yamuna	Agra
5	Chopan	Sone	Middle Ganga	Varanasi
6	Kurldah Bridge	Ganga	Middle Ganga	Varanasi
7	Gandhighat	Ganga	Middle Ganga	Patna
8	Azamabad	Tons	Middle Ganga	Patna

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9	Kanpur	Ganga	Middle Ganga	Lucknow
10	Kuchla Bridge	Ganga	Middle Ganga	Lucknow
11	Varanasi	Ganga	Middle Ganga	Lucknow
12	Ayodhya	Gaghra	Middle Ganga	Patna
13	UDI Chambal	Yamuna	Lower Yamuna	Agra
14	Rajghat	Betwa	Lower Yamuna	Agra
15	Sahijna	Betwa	Lower Yamuna	Agra
16	Tluni	Tons	Upper Yamuna	Delhi
17	Tonk	Banas	Chambal	Jaipur
18	Ganod	Bhadar	Mahi	Ahmedabad
19	Chennur	Pennur	Hyderabad	Chennai
20	Vijay Wada	Krishna	Lower Krishna	Hyderabad
21	Mantralayam	Tungabhadra	Lower Krishna	Hyderabad
22	Hurenhedgi	Krishna	Lower Krishna	Hyderabad
23	Warunji	Koyana	Upper Koyana	Pune
24	Polavaram	Godavari	Lower Godavari	Hyderabad
25	Pathaguden	Indravathi	Lower Godavari	Hyderabad
26	Satrapur	Kanhan Nodi	Wainganga	Nagpur
27	G.R. Bridge	Godavari	Upper Godavari	Hyderabad
28	Pennur	Godavari	Lower Godavari	Hyderabad
29	Musiri	Cauvery	Southern River Division	Coimbattore
30	Kollgal	Cauvery	Cauvery	Bangalore
31	Akkihabbal	Hemavathi	Cauvery	Bangalore
32	Khanpur	Mahi	Mahi Division	Ahmedabad
33	Mataji	Mahi	Mahi Division	Ahmedabad
34	Kunbidi	Bharathpuzha	South Western Rivers	Cochin
35	Tikarpara	Mahanadi	Mahanadi Division	Burla
36	Basantpur	Mahanadi	Mahanadi Division	Burla
37	Gopalkhedor	Purna	Tapi Division	Surat
38	Savkhada	Tapi	Tapi Division	Surat
39	Ghala	Tapi	Tapi Division	Surat
40	Gomlai	Brahmani	Eastern Rivers Division	Bhubaneshwar

Table 4. Segments representing similar hydro-meteorological character

Segment	Hydro-meteorological Character
A	West coast belt comprising of Western Ghats in the southern part, with heavy rainfall due orographic uplift of vapour-laden winds from Arabian Sea during SW summer monsoon (JJAS). Little rain during NE winter monsoon (OND).
B	West coast belt comprising of Western Ghats, with heavy rainfall due orographic uplift of vapour-laden winds from Arabian Sea during SW summer monsoon (JJAS). Some rain also during NE winter monsoon.
C	Arid NW region with some rain during SW summer monsoon (JJAS).
D	Arid rain shadow zone of Western Ghats during SW summer monsoon (JJAS). Little rain during NE winter monsoon (OND).

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E	Area of significant rainfall during both SW and NE monsoon season
F	Area of rain from residual vapour during SW monsoon and largely continental vapour during NE monsoon.
G	Area of rainfall largely from the depressions over the Bay of Bengal during Summer monsoon (JJAS).
H	Area of rain both due to cross over Arabian Sea vapour and the depression arising in the Bay of Bengal during summer monsoon (JJAS). Little rain during winter monsoon (OND).
I	Area of heavy rain from depressions originating over Bay of Bengal. Significant recycling of continental vapour.

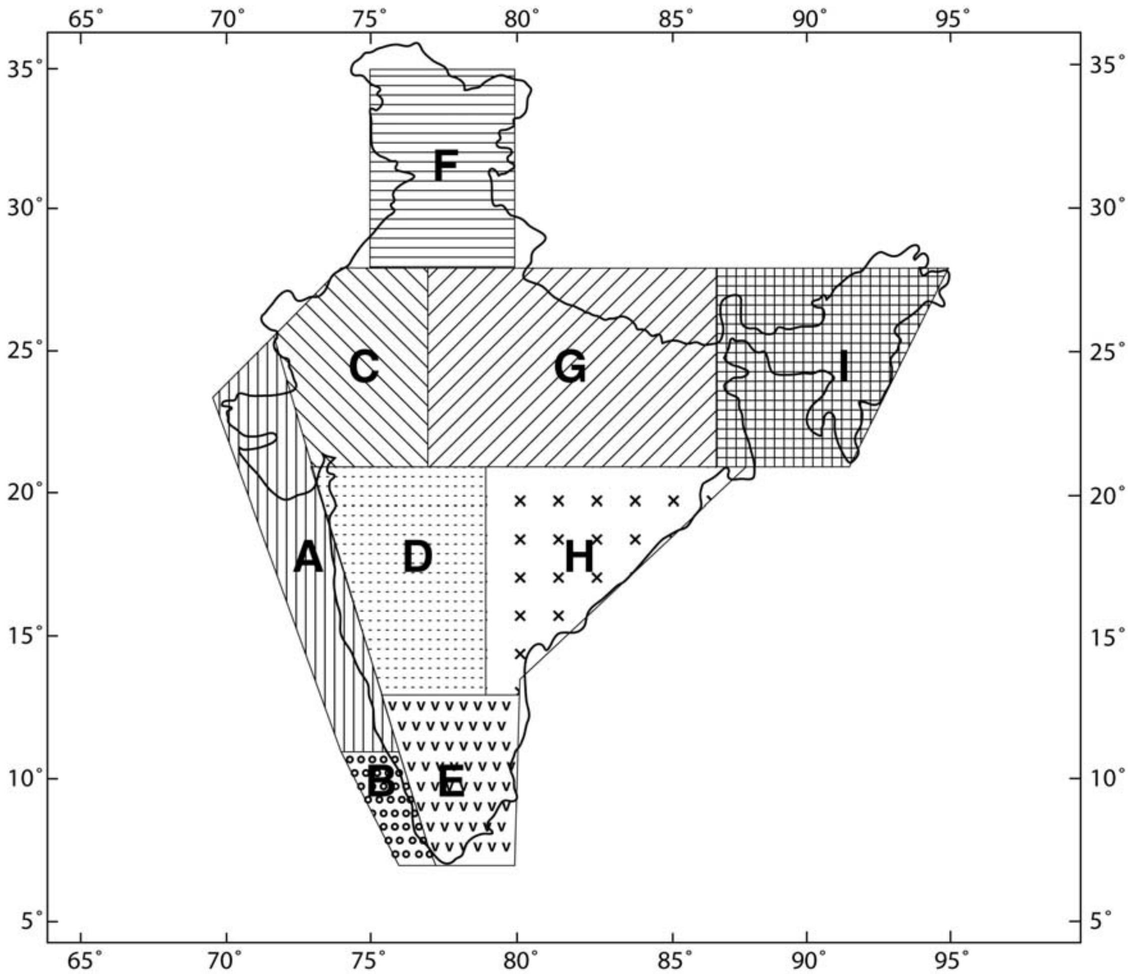

Figure 8. Geographic segments identified for modelling of atmospheric hydrologic processes affecting isotope fractionations. These segments approximately have similar hydro-meteorological characters.

Monthly collection and analyses of samples of the surface waters of the BOB along three sections, namely, (i) Chennai and Port Blair; (ii) Port Blair and Kolkata and (iii) Visakhapattnam to port Blair (Service available only once a month) will form the backbone of the data collection effort. This is because commercial vessels of the Andaman and Nicobar Administration ply regularly along these routes. Approximate locations of the BOB surface water monthly sampling stations are shown in Figure 9.

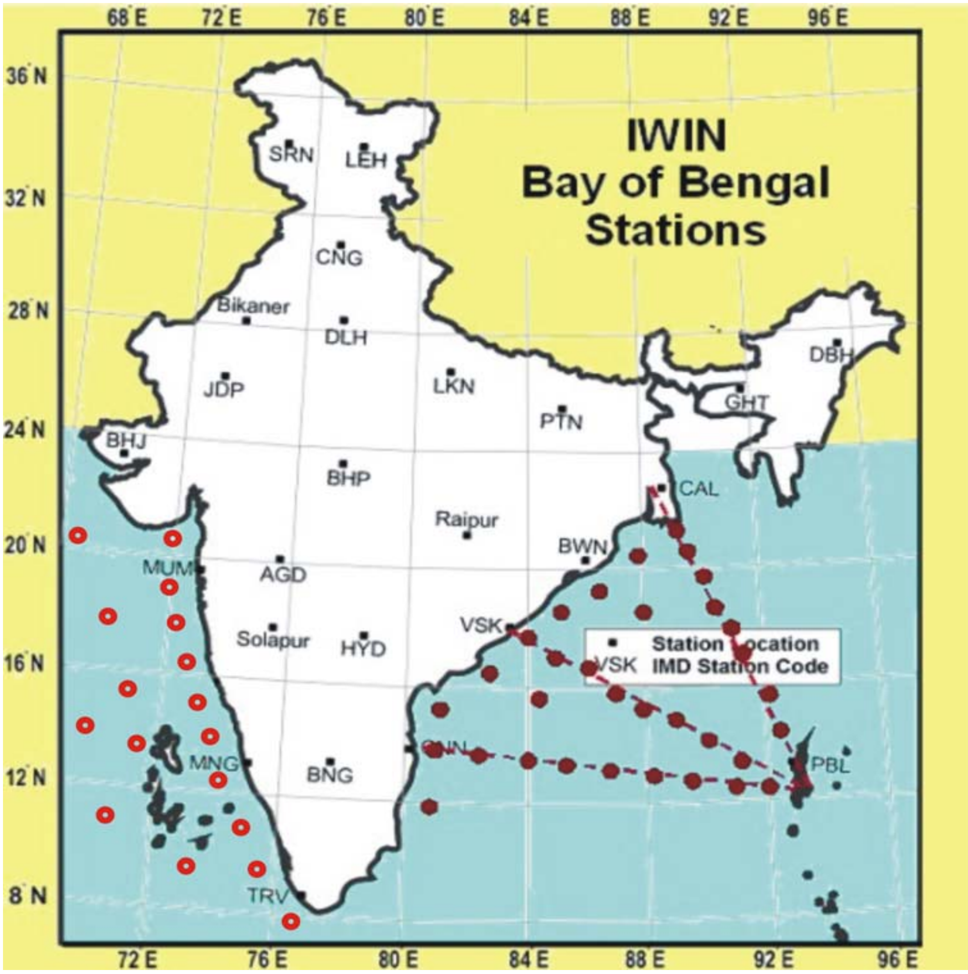

Figure 9. Approximate locations of the AS and BOB surface water monthly sampling stations. Most stations in BOB lie along commercial shipping routes linking Port Blair with Kolkata, Visakhapattnam and Chennai. Locations not lying on these routes will be sampled less frequently depending on the availability of berth on NIO-Tech vessels. AS stations will be sampled using DOD ships of opportunity.

NIO-Tech vessels will be utilised for collection of seawater samples along the East Coast and intermediate section between the coast and the shipping line routes. The surface water temperature and salinity will be measured at the time of sample collection and one litre sample will be collected for isotopic analyses and for repository. Rain water and atmospheric vapour samples during the voyage will also be collected using the rain and vapour sampling devices as shown in Figures 10 & 11. All sample locations will be GPS controlled/recorded. Samples will also be collected for suspended particulate matter by filtering about 50 litres sea water to study turbidity variations induced due to increased runoff. Sea water salinity will be measured on shipboard using Autosal salinometer, calibrated by $AgNO_3$ titration.

For the AS, DOD ships of opportunities will be used for collection of surface water samples and similar procedures and measurements as for BOB sampling will be followed.

232. SAMPLE COLLECTION PROCEDURE

Precipitation:

A specially designed sampling system has been developed (Figure 10) by the International Atomic Energy Agency (IAEA) to collect monthly rain water samples. The system ensures amount weighing and negligible post-precipitation evaporation of the collected sample during the interval between rainfall and collection.

The inflow of the first precipitation prevents further contact of water with the atmosphere. For this purpose the inner tube has to go down to the bottom of the sampler bottle so that only the water surface of the inner diameter of this tube is in contact with the air. It is important that the tube connections with the lower part of the funnel are well welded in order to avoid air exchange through the cap. The external tube is needed for pressure equilibration and it should be long enough to avoid atmospheric air exchange. The system should allow the measurement of total rain amount. The sampler should be installed close to the standard rain gauge. The PVC container should be protected from the sun and if possible from heat.

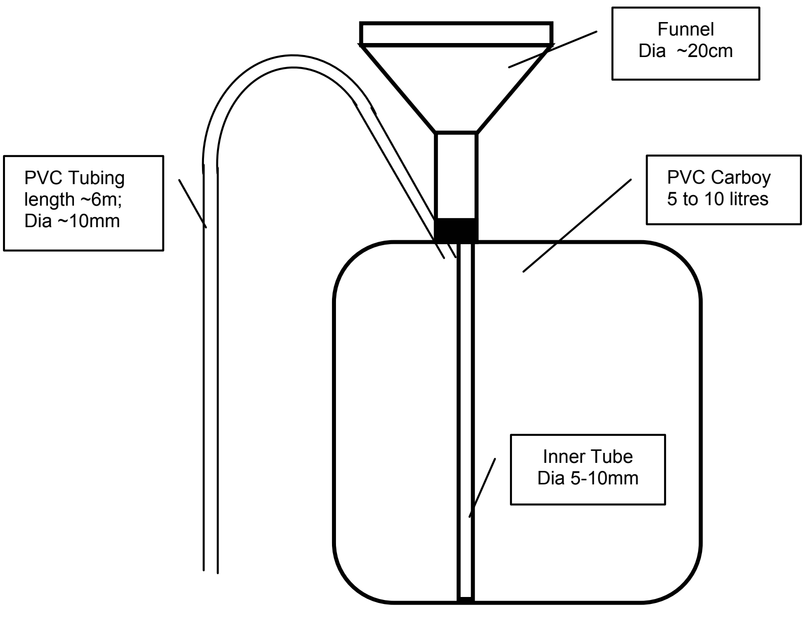

Figure 10. Schematic of the monthly rainfall sampling device.

The size of the container depends on the maximum monthly rain in the region where the sampler is installed.

To account for evaporation from rain drops (if any) data of average monthly/ daily temperature and relative humidity is also required.

Surface Water:

The samples are to be collected from the middle of the flow stream from >30cm below the surface avoiding stagnant pools. In case of shallow flow streams, the sample must be collected from the maximum possible depth.

Groundwater:

Samples must be collected from the first unconfined aquifers from dug wells or hand pumps that are in constant use through out the year. Dug wells/ hand pumps must be pumped before collection to avoid sampling the stagnant water.

Atmospheric vapour:

This is the most difficult sample to collect. It requires cooling a conical shaped metallic vessel using ice to well below dew point and allowing the condensed atmospheric vapour on the outside of the vessel to drip into the collection bottle kept below the cooled vessel (Figure 11).

To ensure equilibrium condensation the condensing surface is well ventilated. To account for isotope fractionation during condensation dry and wet bulb temperatures should be measured at the time of sampling. Approximately 10 ml sample can be collected in about 2 hours.

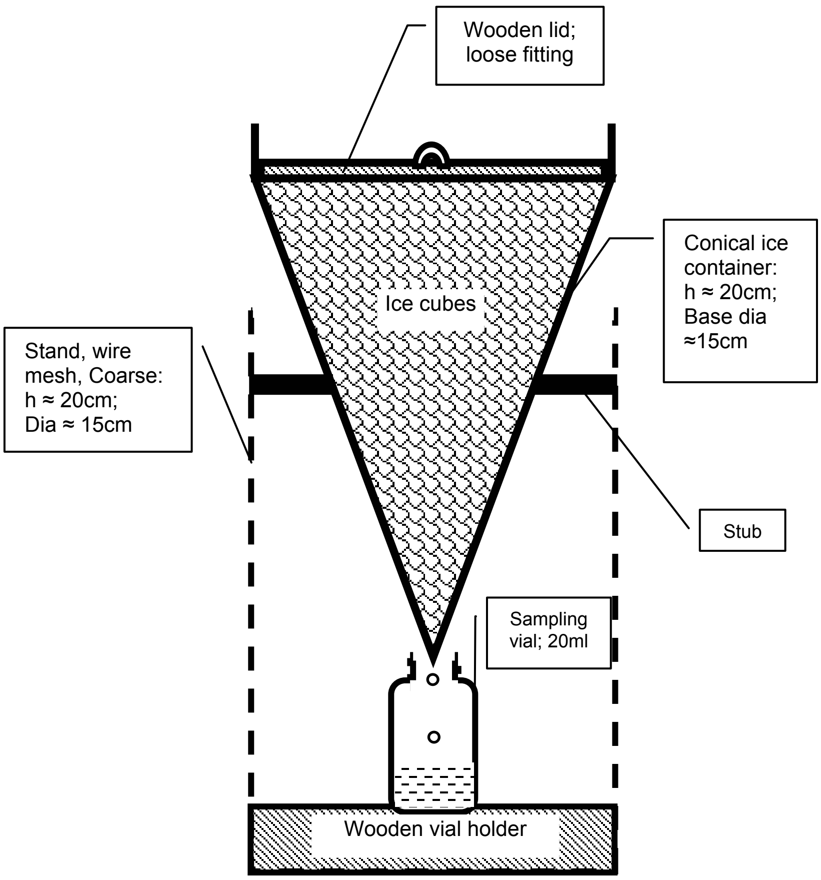

Figure 11. Schematic of the atmospheric moisture sampler.

Further to account for isotopic fractionation during condensation, temperature of the atmosphere, ice and relative humidity need to be measured simultaneously.

Sea Water samples from AS and BOB:

Whereas the DOD vessels are equipped with facilities for surface water sampling, the same will be done by lowering a bucket for collecting the sea water sample in case of commercial shipping. The possibility of being able to lower the bucket for successful sampling has been discussed with SCI.

Common to all types of samples:

In all cases, water samples are to be filled completely (brimming) in high density PVC bottles of appropriate size with screw tight caps and properly labelled, filling in data sheet before shipping/ mailing for analyses.

The size of each sample will be approximately 1 litre, wherever possible (rainfall during monsoon months, surface flows, groundwater). Rain water samples during months with scanty rainfall may be as small as 50-100 ml. Condensed vapour samples may be even smaller (5-10ml). Larger samples would be required to maintain a repository till final completion of project up to publication stage as also for other chemical measurements whenever desired. It may be noted that these analyses in case of precipitation samples may be useful for studying atmospheric washout of particulate matter as also for identification of local sources of chemical and particulate matter in the atmosphere. However, these analyses are secondary to the project and will be made by some other group, if interested.

233. Organisation of Work Elements:

1. Fabrication and procurement of the required number of atmospheric vapour and rainwater samplers.
2. Setting up of atmospheric vapour and rainwater collection stations in consultation with IMD, CRIDA, Universities and other academic Institutions.
3. Setting up of river water collection stations in consultation with CWC, CPCB, Universities and other Academic Institutions.
4. Identifying stations for groundwater sample collection in consultation with CGWB and other agencies for sufficient spatial coverage and specific problems.
5. Development of IWIN web site for interaction among participating scientists and data users.
6. Establishing a protocol for ocean water sample collection in consultation with DOD, NIO-Tech and the SCI.
7. Establishing a system of training the field staff for proper sample collection, storage, labelling with appropriate data sheets and despatch on regular basis.
8. Finalisation of the purchase of the Stable Isotope Ratio Mass Spectrometer (SIRMS) for the National Programme at PRL, Vaisala Radiosonde at NIO and Autosal salinometers at NIO and AU.
9. Setting up of the SIRMS for the National Programme at PRL and operationalising the same.
10. Hiring of the additional academic (PDF) and other staff for the National programme at PRL, NIO, NGRI, NIH and AU.
11. Training of the new staff and establishing a protocol for registering and measuring of the received samples and maintaining a library of samples.
12. Establishing a protocol for inter-laboratory calibration reporting of sample measurements between PRL, IIT-KGP, NIH-Roorkee, NIO Goa, NGRI Hyderabad and NRL-New Delhi.
13. Establishing a protocol for periodic workshop of the Laboratory and field staff

involved in the project and review of progress. These workshops will also be used as forum for encouraging research in specialised areas of isotope hydrology using results of the IWIN programme by inviting research scholars from academic institutions and also providing hand on experience to students.

14. Inter Laboratory Calibration exercise.
15. Isotopic measurements.
16. Adding additional stations/ deleting unworkable stations depending on the periodic review of progress and results of analyses.
17. Preparation of reports and research contributions.
18. Preparation of New research proposals.
19. Arranging annual workshop for discussion of results and wider dissemination of the knowledge gained.
20. Preparation of IWIN programme for next five years for and submission of project proposal

The following operational aspects will guide the working of the project. These are:

The network stations for sample collection will be owned and operated by the respective institutions. The collected samples will be sent along with a copy of sample collection record sheet for isotopic analyses to any of the pre-designated laboratory from among the PRL Ahmedabad/ IIT KGP/ NIH Roorkee/ NRL New Delhi. The results of the analyses will be communicated in standard format to (i) sample providing Institution and (ii) the central data warehouse for the IWIN Programme to be maintained by the PRL. The data will be jointly owned by the particular sample providing Institution, the particular isotope analysis laboratory and the IWIN Programme. The PRL isotope laboratory will organise periodic inter laboratory calibration experiments to ensure that all network data conforms to the same high quality standards. Periodic workshops/group meetings of all participating scientists in the network programme will be held to review the progress and to discuss knowledge increments from the work of the programme. Only those results that have been discussed in these workshops will be cleared for publication. All publications will be jointly issued at the time of first reporting of results. Thereafter, the results will form part of the public domain and will also be communicated to IAEA/GNIP programme.

The isotope laboratories at PRL/ NIH/ IIT-KGP/ NGRI/ BARC/ NIO/ NRL will also act as national facilities for research in stable isotope hydrology by the universities and other academic Institutions. As part of this national facility, yearly training programmes for post graduate students will be conducted with hands on experience in mass spectrometric isotope analysis and sample collection & storage procedures.

Although, the present proposal is for a 5-year period, the National Programme has a 10 years perspective during which several new programmes of local and regional characters will be undertaken in the field of hydrology with several Universities and Academic institutions. Some of these programmes, though not forming part of the present proposal, have been indicated in the detailed project proposal.

234. Time Schedule of Activities Giving Milestones (also append to bar diagram and mark it as Section 410)

1. Most of the proposed organisational work elements (marked 1 to 20 above) will be completed within first 6 months of the final approval and receipt of the 1st instalment of the project grant.
2. Regular measurements are expected to begin in the 2^{nd} 6-month period.

3. 1st project Review workshop will be held during the 3rd 6-month.
4. 1st Review report will be submitted to DST at the beginning of the 3rd 6-month period.
5. Research contributions will regularly be submitted for publication informing results and advancement of knowledge in the subject.
6. Periodic Review workshops will be held and reports submitted every year subsequently.

235. Suggested Plan of Action for Utilization of Research Outcome Expected from the Project.

To fully exploit the potential of the project, it will be necessary to disseminate the results through research publications, conferences & symposia and print and electronic media. In addition, it will be necessary to induce young minds to take up new research project for hydrological modelling at local and regional scale. The setting up of the IWIN web site will encourage interaction between scientists and users of the isotope data and is also expected to be a vehicle for dissemination of hydrological data and science among the technocrats and decision makers.

The impending hydrological changes are unprecedented in the entire geological history and, therefore, need to be studied by a large number of competent scientists. The proposed annual workshops will endeavour to enlist the scientific community in this task. The results will also be discussed with Task Force on interlinking of rivers and other agencies/organisations responsible for management of National water resources.

236. Role of Participating Agencies

India Meteorology Department (IMD)

The Department will identify stations (from those shown in Figure 2 and listed it) where it will possible to setup fortnightly/monthly rainwater and atmospheric condensed vapour collection systems as shown in Figures 6 & 7. Whereas the standardised equipment will be supplied by the National programme, the stations will be manned and operated by the staff of the Department on routine basis once every fortnight. To account for isotope fractionation during condensation temperature of the atmosphere, ice and relative humidity need to be measured simultaneously at the time of sampling. Approximately 10 ml sample can be collected in about 2 hours.

In all cases, water samples are to be filled completely (brimming) in high density PVC bottles of appropriate size with screw tight caps and properly labelled, filling in data sheet before shipping/ mailing for analyses. Every participating station is to keep the record of samples collected and sent for analyses.

As explained above, the required supplemental data for achieving the project objectives are: weather data (precipitation, temperature, relative humidity, pan-evaporation, wind velocities) from the selected stations.

Central Research Institute for Dryland Agriculture (CRIDA)

CRIDA maintains a network of agro-meteorology centres at 25 agricultural Universities in the country.

The sample collection, storage, transportation labelling and record keeping procedures remain the same as in case of IMD.

In addition since CRIDA stations may have a shallow/ deep bore well in the vicinity, half yearly samples of groundwater are also requested from the nearest hand pump/ dug well /bore well as the case may be.

Data requirements are the same as for IMD stations. The known CRIDA agro met stations are located at Akola, Anantapur, Anand, Arjia, Bangalore, Bhubaneshwar, Bijapur, Dapoli, Faizabad, Hisar, Jabalpur, Jorhat, Kanpur, Kovilpatti, Ludhiana, Mohanpur, Palampur, Parbhani, Raipur, Rakh Dhiansar, Ranchi, Ranichauri, Samastipur, Solapur and Trissur. These stations are marked on map in Figure 3.

Central Pollution Control Board (CPCB)

CPCB Maintains a network of stations where flow discharges are routinely measured and water samples collected for water quality monitoring. A selected list of stations from amongst the large number maintained by CPCB is given below Figure 4. The project requires collection of fortnightly /monthly samples from these stations along with data of water flow and standard water quality parameters.

The samples are to be collected from the middle of the flow stream from >30cm below the surface avoiding stagnant pools. In case of shallow flow streams, the sample must be collected from the maximum possible depth. Other than this, there is no special sampling procedure except that for routine water quality sample collection.

Central Water Commission (CWC)

As with CPCB, CWC also maintains a network of monitoring stations for river water quality, flow and sediment discharge of Indian rivers. A select list of river water monitoring stations of CWC is given in Table 3 and plotted on map in Figure 5.

The supplementary data requirements include flow and water quality measurements and sampling frequency is fortnightly/monthly. Sampling procedures remain the same as for standard water quality studies.

Central Ground Water Board (CGWB)

CGWB operates a programme of groundwater quality and water level monitoring at least twice a year, namely, during pre- and post-monsoon period.

Previous studies have shown that in most parts of the country, the seasonal and yearly variations in isotope character present in the rainfall get obliterated during passage of soil water through the unsaturated zone and the groundwater at a given location does not exhibit variations seen in precipitation. But due to highly variable nature of micro-meteorology and geography and the limited horizontal flow velocity of groundwater the spatial variations get accentuated. It is, therefore, essential that IWIN component for groundwater monitoring is designed to provide inputs to study this spatial variability across the (i) ‘atmosphere- groundwater continuum’; (ii) river water-groundwater interactions and (iii) lake or surface reservoir-groundwater interactions. Therefore, initially groundwater samples from shallow unconfined groundwater sources of the country will be monitored as these represent the most active phases involved across hydrologic boundaries. Subsequently, samples from aquifers with palaeo-groundwater and those from special ‘problem areas’ will be taken.

A detailed programme of sampling at watershed level will have to be chalked out keeping in mind limited storage and measurement capabilities. Geohydrological knowledge of aquifers available with CGWB will be fully utilised in this endeavour.

Samples must be collected from the first unconfined aquifers from dug wells or hand pumps that are in constant use through out the year. Dug wells/ hand pumps must be pumped before collection to avoid sampling the stagnant water. Supplementary data requirements include water level fluctuations, basic water quality data and other geohydrologic data as may be available.

National Institute of Hydrology (NIH)

NIH has established their own network of precipitation monitoring stations and is in the process of establishing a Stable Isotope Ratio Mass Spectrometer. Director, NIH very kindly consented to make this facility available for the proposed National Programme samples. NIH will also setup and operate stations for daily collection of precipitation and atmospheric vapour at Roorkee and Sagar (NIH Regional Centre). NIH along with BARC will also be analysing tritium in selected samples that will be available as part of this National Programme.

National Institute of Oceanography (NIO)

NIO will be responsible for collection and analyses of surface water samples from the AS. The Institute will also setup a Vaisala Radiosonde system at and make periodic measurements of atmospheric parameters. Modelling of atmospheric process using ECMWF and the isotope data will also be largely handled by NIO. NIO will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Goa.

National Geophysical Research Institute (NGRI)

NGRI will primarily be responsible for analyses of samples from the southern region. NGRI will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Hyderabad.

Indian Institute of Technology (IIT), Kharagpur

IIT-KGP is also setting up a new Stable Isotope Ratio Mass Spectrometer Laboratory. Director, IIT-KGP very kindly consented to make significant part of the analytical capability this facility available for proposed National Programme samples. IIT-KGP will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Kharagpur.

Bhabha Atomic Research Centre (BARC)

BARC already has an established Stable Isotope Ratio Mass Spectrometer Laboratory. Some part of the analytical capability of this laboratory is expected to be available to the National Programme. BARC will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Mumbai.

BARC along with NIH will also be analysing tritium in selected samples that will be available as part of this National Programme.

Nuclear Research Laboratory (NRL)

NRL has an existing Stable Isotope Ratio Mass Spectrometer Laboratory that is under upgradation. Some part of the analytical capability of this laboratory is expected to be available to the National Programme. NRL will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Delhi.

Physical Research Laboratory (PRL)

PRL already has an established Stable Isotope Ratio Mass Spectrometer Laboratory. As part of the National programme a fully dedicated new Stable Isotope Ratio Mass Spectrometer will additionally be setup at PRL. PRL will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Ahmedabad.

PRL will be the Principal Coordinating Institution for this National programme and will jointly operate the same with NIH, IIT-KGP, BARC and NRL in every respect including construction and maintenance of IWIN website, data organisation, management and dissemination, arranging training and orientation workshops, inter-laboratory calibration programmes etc.

Anna University (AU)

AU will be responsible for collection and analyses of surface water samples from the BOB. AU will also setup and operate a station for daily collection of precipitation and atmospheric vapour at Chennai. It will also setup stations at Visakhapattnam, Kolkata and Port Blair for monthly rainfall and atmospheric vapour sample collection.

Common to all Partners

As mentioned subsequently under item 236 giving details of Application Areas of IWIN for Advanced Practices in Geohydrology, Agro-Ecology, Meteorology and Environmental Pollution, the potentials of isotope techniques are not exploited by the user community. This lag between the research frontiers and the routine applications is due to (a) inadequate dissemination of information across the professional boundaries (b) unfamiliarity with isotope systematics, terminologies and analytical technologies (c) inertia to adopt the newer and non-conventional methods (d) lack of collaborative isotopic research programmes between interdisciplinary organisations. As a result, the professionals other than isotope geochemists fail to recognise the relevance of isotope techniques to their own discipline and deprive themselves of the possible advancement. A very sincere and conscious effort will be made by the Partners of this National programme to encourage applications of Isotope Techniques to their respective fields of activity.

237. Other Practical Applications of Isotopes in Waters of India Network (IWIN) Programme

The IWIN data could have several practical applications of to various related disciplines at smaller regional to local scales. These are enumerated in the following:

Isotopes in Catchment Hydrology

Knowledge of the hydrologic pathways by which water moves over land, percolates and moves underground to re-emerge as streams is important to understand the hydrogeology of a terrain. Stream flow generation (drainage of water to streams and rivers) is a key component of the hydrologic cycle. This fundamental knowledge, perfected by application of isotope technique, can be useful in designing computer models for streamflow prediction, that are important for land use planning, flood contingency planning and dam construction and operation. Another important application of isotope technique is to understand the nature of water storage and drainage on hill slopes. This has important implications for slope stability, erosion and related aspects of geomorphology.

The isotopes of oxygen and hydrogen are among the most effective tools available for delineating and constraining hydrologic flow paths in watersheds. The basis for this application of $\delta^{18}O$ and δD is the temporal variation in the isotopic composition of precipitation. It is well known that the isotopic composition of rainfall varies from storm to storm at a given site. Therefore, the rainfall in any one storm may differ isotopically from the water stored in the subsurface at the start of the storm. This contrast in isotopic composition has proved useful in analysis of stream flow generation on 'storm event' time-scales. The isotopic composition of precipitation also varies with season, leading to a variation of the isotopic composition of stream water on this longer time-scale as well.

Thus, $\delta^{18}O$ and δD measurements can be useful in determining the contribution of rainfall to storm flow, the residence time of water on catchments and other aspects of watershed hydrology. The separation of contributions from event and pre-event (or "new" and "old") waters to storm flow adds a constraint on stream flow generation that hydrometric measurements could never do. The identification of large contribution of pre-event water to storm stream flow (often 70-80% of hydrograph volume and peak flow rate) is entirely consistent with importance of subsurface storm flow as documented by hydrometric studies on forested catchments before isotopes became widely used. In addition, isotopic studies clearly show that, through some combination of mixing and displacement, pre-event water usually makes up the bulk of storm flow, even discharging to streams through macro pores and soil pipes.

In development of lumped-parameter hydrologic models, stable isotopes have provided information that influenced the conceptualisation of stream flow generation mechanisms and improved model calibration. Parameter identifiability was improved with tracers, keeping the model structures quite simple.

Isotopes in Meteorology

In addition to meteorological observations and forecasting, an important mandate for meteorologists is to provide accurate meteorological statistics required for agriculture, water resource management, industries and other nation-building activities.

Some previous detailed studies have interpreted the stable isotopic compositions of meteoric water and their geographic variations primarily in terms of temperature and orographic effects. Recently, investigators have considered all components of the hydrological cycle including the very important component of evapotranspiration. Quantifying evapo-transpirational recycling is critical to the quantification of the hydrologic cycle and is of great importance when considering natural or anthropogenic climate change, or effects of changing vegetation pattern on precipitation. The small geographic depletion (0.075‰ per 100km) of the $\delta^{18}O$ of precipitation in the Amazon basin was shown to be a result of a large contribution of re-evaporated moisture to the basin's water balance. The ratio of evaporation to transpiration in the Amazon Basin have been estimated by using a steady-flux model incorporating *d* values (defined as $d = \delta D - 8.\ \delta^{18}O$). An increase of 3‰ in the *d* of precipitation was reported across the Amazon basin and attributed to an isotopically fractionated evapo-transpirational flux to the water balance. This *d* corresponds to 10-20 % of the precipitation being evaporated, which represents an evaporative component of 20-40% of the total evapo-transpiration flux. A decrease in δD of 3.3‰ per 100 km in winter precipitation and 1.3‰ per 100 km in summer precipitation in central Europe has been observed. This was explained by a ratio of winter precipitation to summer evapo-transpiration.

Isotopes in Pollution Studies

In the rapid pace of urbanisation and industrialisation the pollution watchdogs face the tough task of (i) ensuring appropriate treatment and disposal of industrial and domestic waste, (ii) monitor and prevent the loading of pollutants in atmosphere, soil and water (iii) investigate the movement and mixing of natural (Arsenic, fluoride and salinity etc.) and anthropogenic pollutants from point sources (industrial or urban agglomeration) and most importantly (iv) offer the guidelines and solutions to the nation, that can protect the environment and also sustain the development.

Applying isotopic tracers in conjunction with other chemical analyses and flow path modelling can help determine origin, movement, mixing and flushing of various pollutants particularly in soils and ground waters. Even the limited application of stable isotopes of oxygen and hydrogen can help in accurately estimating the travel time for pollutants through surface and subsurface pathways from the source to surrounding. The tracing the movement of isotopically tagged water offers the insight into the movement of the pollutants that were to travel along with this parcel of water. Offering such information can be vital for planning and setting up the industrial units at appropriate location. Prediction of the chemical impacts of the non-point source pollutants also requires understanding of the different pathways through which water moves on its way to the stream because different pathways provide different opportunities for contact with organic detritus, soil and rock.

Isotopes in Ecology and Agricultural Studies

When water is transported between the roots and the shoots within a plant, its isotopic composition remains unaltered until it reaches tissues or organs such as leaves or young unsuberised stems that are loosing water to the external atmosphere. Evaporative process cause significant enrichment of heavier isotopes (D or ^{18}O) within the xylem-sap. The magnitude of isotopic enrichment is a function of leaf transpiration rate, the humidity gradient between the site of water loss and atmosphere as wells as δD or $\delta^{18}O$ of the atmospheric water. In order to understand and document patterns of water use, uptake and transport by plants, it is important to understand distribution of isotopes within the hydrological components both on temporal and spatial scales. It has been shown that the vegetated land can not be treated as freely evaporating surface. Plants do exert a significant degree of control over the patterns and the rates of evaporative water loss. This has been earlier referred to in the section on studies of catchments.

It has also been well documented that the upper soil layers are commonly enriched in heavier isotopes in water due to evaporative fractionation from the upper soil surface. Below an isotopically unstable zone, the isotopic composition of water changes markedly with depth, often converging to a relatively stable value. When plants are growing in soil, further modification of soil water isotopic composition can result from pattern of water uptakes and water loss from plants rooted at different depths. In the simplest case, we might expect the magnitude of change in isotopic composition of soil water to be different between a tilled and fully planted crop field, or between a forested and deforested catchments.

Plants may utilise many potential water sources depending, first upon the plant and secondly, upon the spatial and temporal properties of soils and climate in a particular region. In order to know which one of these potential sources a plant may be using, it is necessary to collect waters and determine their stable isotope composition (δD and $\delta^{18}O$). These values are then compared with those of water extracted from xylem (water transport) tissues of plants growing in the same environment. This information also provides an indirect method for determining the rooting depth of a plant when clear differences in source water δD and $\delta^{18}O$ can be identified.

Other important components of most catchments are the trees that grow in the variable source area adjacent to streams. These so called riparian trees are important because they sit at the interface between the terrestrial and aquatic portion of the catchment and thus influence the surface and subsurface fluxes of water and other substances linked to water (e.g. nutrients and dissolved organic carbon). It is often assumed that these trees utilise the surface stream waters. Using isotopes, it has been shown that only smaller trees use stream waters while mature trees use little on none of this water. Eucalyptus trees inhabiting the semiarid floodplains along the River Murray in South Eastern Australia have been found to use groundwater and not the surface stream water. Riparian trees have been found to seasonally switch water sources, using water in the surface layers in early growing season and then switching to the deep water during draught period. All these studies demonstrate that regardless of whether plants inhabits arid, semiarid or mesic region, there can be strong relationship between water source and water use pattern. At catchment scale, this information has a number of potential important applications. First it means that more water moves through the 'soil-plant(s)-atmosphere' continuum than would be otherwise expected. Secondly, a hydraulically lifted water source could have a strong influence on the distribution and abundance of all plant species and in turn on the amount of water movement within a catchment or forest stand. Third, estimates of evaporation and transpiration are 1.5 to 3 – fold higher for large trees "mining" deep water sources.

238. Indicative List of Research Projects That Can Utilise Specific Isotope Data:

This is a list of some possible projects that came up during the various project formulation meetings between the collaborating Institutions and some other interested Scientists. No attempt is presently made to give details or to be comprehensive. The purpose is only indicative.

a) Quantifying seasonal variations in reservoir storage from (i) direct precipitation, (ii) surface runoff, (ii) groundwater and (iii) snow melt.

b) Detailed Isotope hydrology of representative basins in different climatic regimes. Priority may be given to Narmada – a water surplus basin, Cauvery – a water deficit basin, Sutlej – a Himalayan river basin.

c) Estimating evaporation from Lakes and Artificial surface water bodies in different climatic regimes and the effect of (i) surface area to depth ratio and (ii) microclimate modifications due to presence of surface water body and seasonal variations thereof.

d) Isotope hydrology of select lake systems.

e) Detailed study of river/groundwater interactions along selected stretches of rivers having pollution load and or interesting geohydrology.

f) Study of soil moisture movement through unsaturated zone in different climatic regimes.

g) Transpiration mechanisms in selected trees/ grasses / shrubs etc.

h) Study of paleao ground waters and thermal waters.

i) Identifying signatures of rock water interactions in high temperature fluids.

j) Mountain hydrology with sinks and springs is separate field and can benefit enormously from use of isotopes due to significant altitude effects from altitude variations, amount effects in the windward/leeward directions. Selection effects due to slope variations, high interception from canopy and evaporation there from, transpiration rates from the large vegetation cover and detention in floor litter and soil zone.

k) Changes in isotope character of rainfall across select sections of Western Ghats due to heavy rainout on windward side and low precipitation on the leeward side.

l) Disappearance and reappearance of water in Himalayan foothill zone.

(300) BUDGET ESTIMATES: SUMMARY

The project has a 10-year perspective but present budget estimates are for the First 5-year Phase.

	Item	BUDGET (in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
A.	Recurring					n	n
	1.Salaries/wages	15,84,000	15,99,600	16,15,200	10,54,800	10,70,400	69,24,000
	2. Consumables Total FEC*.	35,99,000 (US$20,500)	35,52,000 (US$20,000)	26,80,000 Nil	24,15,000 Nil	24,15,000 Nil	1,46,61,000 (US$40,500)
	3. Travel	10,80,000	8,10,000	7,10,000	1,80,000	2,20,000	30,00,000
	4. Other costs	31,63,000 (US$6,500)	8,00,000 (US$2,000)	8,00,000 (US$2,000)	5,00,000	5,00,000	57,63,000 (US$10,500)
B.	Equipments	2,42,10,000 (US$5,29,500)	NIL	NIL	NIL	NIL	2,42,10,000 (US$5,29,500)
C.	Total of all Expenditure Items (A+B) Total FEC*	3,36,36,000 (US$5,56,500)	67,61,600 (US$ 22,000)	58,05,200 (US$2,000)	41,49,800	42,05,400	5,45,58,000 (US$5,46,500)
D.	Administrative Add Institutional Charges @20% expenditure items	67,27,200	13,52,320	11,61,040	8,29,960	8,41,080	1,09,11,600
E.	**Grand total of project budget (C+D)** **Total FEC***	**4,03,63,200** **(US$5,56,500)**	**81,13,920** **(US$ 22,000)**	**69,66,240** **(US$2,000)**	**49,79,760**	**50,46,480**	**6,54,69,600** **(US$5,80,500)**
F.	**PRL Contribution**						
	F1. Salary	4,80,000	4,89,600	4,99,200	5,08,800	5,18,400	24,96,000
	F2. Others	22,00,000	2,00,000	2,00,000	2,00,000	2,00,000	30,00,000
	F3. Equipments	2,00,000	-	-	-	-	2,00,000
	F4. Administrative 20% of (F1+F2+F3)	5,76,000	1,37,920	1,39,840	1,41,760	1,43,680	11,39,200
G.	**Total Contribution From PRL (F1+F2+F3+F4)**	**34,56,000**	**8,27,520**	**8,39,040**	**8,50,560**	**8,62,080**	**68,35,200**
H.	**Net Budget request from DST (E – G)** **Total FEC***	**3,69,07,200** **(US$5,56,500)**	**72,86,400** **(US$ 22,000)**	**61,27,200** **(US$2,000)**	**41,29,200**	**41,84,400**	**5,86,34,400** **(US$5,80,500)**

*FEC- Foreign Exchange Component

Foreign Exchange component (in US$) equivalent of rupee amount at the prevailing rates is furnished.

N.B. Entries here should match with those given in section 310 to 350; justification for each item is to be given in Section following it that is section 311, 321, 331, 341 and 351.

Item No. D is routine required by the Institute.

The Director PRL has agreed to pay full cost of SIRMS Infrastructure listed in items F1, F2, F3 and F4 on approval of the project.

(301) BUDGET ESTIMATES: SUMMARY (Institution-wise)

	Item	BUDGET (in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
	At PRL						
A.	**Recurring**						
A1	Salaries/wages PRL Contribution	4,80,000	4,89,600	4,99,200	5,08,800	5,18,400	24,96,000
A2	Consumables	8,55,000	8,55,000	6,55,000	6,30,000	6,30,000	36,25,000
A3	Travel	2,50,000	1,50,000	1,50,000	1,00,000	1,00,000	7,50,000
A4	Other Costs PRL Contribution	22,00,000	2,00,000	2,00,000	2,00,000	2,00,000	30,00,000
A5	Other Costs DST Contribution	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000	10,00,000
A6	Other Costs Total=(A4+A5)	24,00,000	4,00,000	4,00,000	4,00,000	4,00,000	40,00,000
B.	**Non-Recurring**						
B1	Equipments PRL Contribution	2,00,000					2,00,000
B2	Equipments DST Contribution	1,90,00,000 (US$4,23,000)					1,90,00,000 (US$4,23,000
B3	Equipments Total=(B1+B2)	1,92,00,000 (US$4,23,000)	NIL	NIL	NIL	NIL	1,92,00,000 (US$4,23,000)
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A6+B3 Total FEC*	2,31,85,000 (US$4,23,000)	18,94,600	17,04,200	16,38,800	16,48,400	3,00,71,000 (US$4,23,000)
D.	**Administrative**						
D1	PRL Contribution	5,76,000	1,37,920	1,39,840	1,41,760	1,43,680	11,39,200
D2	DST Contribution	40,61,000	2,41,000	2,01,000	1,86,000	1,86,000	48,75,000
D3	Total=(D1+D2)	46,37,000	3,88,920	3,40,840	3,27,760	3,29,680	60,14,200
E.	**Total Project Budget at PRL (Contributions from PRL and DST)**						
E1	**PRL Contribution** A1+A4+B1+D1	**34,56,000**	**8,27,520**	**8,39,040**	**8,50,560**	**8,62,080**	**68,35,200**
E2	**DST Contribution** A2+A3+A5+B2+D2 **Total FEC***	**2,43,66,000** **(US$4,23,000)**	**14,46,000**	**12,06,000**	**11,16,000**	**11,16,000**	**2,92,50,000** **(US$4,23,000)**
F.	**Total of Project Budget at PRL**						
	Total=(E1+E2) **Total FEC***	**2,78,22,000** **(US$4,23,000)**	**22,73,520**	**20,45,040**	**19,66,560**	**19,78,080**	**3,60,85,200** **(US$4,23,000)**

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	Item	BUDGET (in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
	At NIH						
A.	**Recurring**						
A1	Salaries/wages	3,84,000	3,90,000	3,96,000	4,02,000	4,08,000	19,80,000
A2	Consumables	5,40,000	5,40,000	5,40,000	5,40,000	5,40,000	27,00,000
A3	Travel	30,000	40,000	30,000	20,000	30,000	1,50,000
A4	Other Costs	1,50,000	1,00,000	1,00,000	50,000	50,000	4,50,000
B.	**Non-Recurring**						
	Equipments	60,000					60,000
C.	**Total (Recurring+Non-Recurring)**						
	A1+A2+A3+A4+B	11,64,000	10,70,000	10,66,000	10,12,000	10,28,000	53,40,000
D.	**Administrative**						
	20% of C	2,32,800	2,14,000	2,13,200	2,02,400	2,05,600	10,68,000
F.	**Total Project Budget at NIH**						
	C+D	**13,96,800**	**12,84,000**	**12,79,200**	**12,14,400**	**12,33,600**	**64,08,000**
	At NIO						
A.	**Recurring**						
A1	Salaries/wages	2,88,000	2,88,000	2,88,000			8,64,000
A2	Consumables FEC*	10,49,000 (US$ 20,500)	10,02,000 (US$ 20,000)	3,30,000	1,00,000	1,00,000	25,81,000 (US$ 40,500)
A3	Travel	2,00,000	1,50,000	1,00,000			4,50,000
A4	Other Costs	3,13,000 (US$6,500)	1,00,000 (US$2,000)	1,00,000 (US$2,000)			5,13,000 (US$10,500)
B.	**Non-Recurring**						
	Equipments FEC*	46,50,000 (US$ 1,06,500)					46,50,000 (US$ 1,06,500)
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A4+B Total FEC*	65,00,000 (US$ 1,33,500)	15,40,000 (US$ 22,000)	8,18,000 (US$2,000)	1,00,000	1,00,000	90,58,000 (US$ 1,57,500)
D.	**Administrative**						
	20% of C	13,00,000	3,08,000	1,63,600	20,000	20,000	18,11,600
F.	**Total Project Budget at NIO**						
	C+D Total FEC*	78,00,000 (US$ 1,33,500)	18,48,000 (US$ 22,000)	9,81,600 (US$2,000)	1,20,000	1,20,000	1,08,69,600 (US$ 1,57,500)

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(301) BUDGET ESTIMATES: SUMMARY (Institution-wise)... Continued from previous page

	Item	BUDGET (in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
	At NGRI						
A.	**Recurring**						
A1	Salaries/wages	1,44,000	1,44,000	1,44,000	1,44,000	1,44,000	7,20,000
A2	Consumables	1,45,000	1,45,000	1,45,000	1,45,000	1,45,000	7,25,000
A3	Travel	30,000	40,000	30,000	20,000	30,000	1,50,000
A4	Other Costs	1,50,000	1,00,000	1,00,000	50,000	50,000	4,50,000
B.	**Non-Recurring**						
	Equipments	60,000					60,000
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A4+B Total FEC*	5,29,000	4,29,000	4,19,000	3,59,000	3,69,000	21,05,000
D.	**Administrative**						
	20% of C	1,05,800	85,800	83,800	71,800	73,800	4,21,000
F.	**Total Project Budget at NGRI**						
	C+D	**6,34,800**	**5,14,800**	**5,02,800**	**4,30,800**	**4,42,800**	**25,26,000**
	At AU						
A.	**Recurring**						
A1	Salaries/wages	2,88,000	2,88,000	2,88,000			8,64,000
A2	Consumables	80,000	80,000	80,000	70,000	70,000	3,80,000
A3	Travel	5,10,000	3,50,000	3,40,000			12,00,000
A4	Other Costs	1,50,000	1,00,000	1,00,000			3,50,000
B.	**Non-Recurring**						
	Equipments	2,40,000					2,40,000
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A4+B	12,08,000	7,68,000	768,000	70,000	70,000	28,84,000
D.	**Administrative**						
	20% of C	2,53,600	1,63,600	1,61,600	14,000	14,000	6,06,800
F.	**Total Project Budget at AU**						
	C+D	**15,21,600**	**9,81,600**	**9,69,600**	**84,000**	**84,000**	**36,40,800**

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(301) BUDGET ESTIMATES: SUMMARY (Institution-wise)... Continued from previous page

	Item	BUDGET (in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
	At IIT-KGP						
A.	**Recurring**						
A1	Salaries/wages						
A2	Consumables	1,40,000	1,40,000	1,40,000	1,40,000	1,40,000	7,00,000
A3	Travel	30,000	40,000	30,000	20,000	30,000	1,50,000
A4	Other Costs						
B.	**Non-Recurring**						
	Equipments						
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A4+B	1,70,000	1,80,000	1,70,000	1,60,000	1,70,000	8,50,000
D.	**Administrative**						
	20% of C	34,000	36,000	34,000	32,000	34,000	1,70,000
F.	**Total Project Budget at IIT-KGP**						
	C+D	**2,04,000**	**2,16,000**	**2,04,000**	**1,92,000**	**2,04,000**	**10,20,000**
	At NRL						
A.	**Recurring**						
A1	Salaries/wages						
A2	Consumables	55,000	55,000	55,000	55,000	55,000	2,75,000
A3	Travel	30,000	40,000	30,000	20,000	30,000	1,50,000
A4	Other Costs						
B.	**Non-Recurring**						
	Equipments						
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A4+B	85,000	95,000	85,000	75,000	85,000	4,25,000
D.	**Administrative**						
	20% of C	17,000	19,000	17,000	15,000	17,000	85,000
F.	**Total Project Budget at NRL**						
	C+D	**1,02,000**	**1,14,000**	**1,02,000**	**90,000**	**1,02,000**	**5,10,000**

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(301) BUDGET ESTIMATES: SUMMARY (Institution-wise)... Continued from previous page

	Item	BUDGET (in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
	For (IMD+CRIDA+CPCB+CWC+CGWB)§						
A.	**Recurring**						
A1	Salaries/wages						
A2	Consumables	7,35,000	7,35,000	7,35,000	7,35,000	7,35,000	36,75,000
A3	Travel						
A4	Other Costs						
B.	**Non-Recurring**						
	Equipments						
C.	**Total (Recurring +Non-Recurring)**						
	A1+A2+A3+A4+B	7,35,000	7,35,000	7,35,000	7,35,000	7,35,000	36,75,000
D.	**Administrative**						
	20% of C	1,47,000	1,47,000	1,47,000	1,47,000	1,47,000	7,35,000
F.	**Total Project Budget For (IMD+CRIDA+CPCB+CWC+CGWB)§**						
	C+D	**8,82,000**	**8,82,000**	**8,82,000**	**8,82,000**	**8,82,000**	**44,10,000**
	Combined Budget at All Institutions (PRL+NIH+NIO+NGRI+AU+IIT-KGP+NRL +IMD+CRIDA+CPCB+CWC+CGWB)						
	Grand Total	**4,03,63,200**	**81,13,920**	**69,66,240**	**49,79,760**	**50,46,480**	**6,54,69,600**
	PRL Contribution	**34,56,000**	**8,27,520**	**8,39,040**	**8,50,560**	**8,62,080**	**68,35,200**
	DST Contribution	**3,69,07,200**	**72,86,400**	**61,27,200**	**41,29,200**	**41,84,400**	**5,86,34,400**

§ This budget will be administered from PRL for disbursement to individual agencies.

310. BUDGET FOR SALARIES/WAGES (Institution-wise)

At PRL		SALARIES/WAGES BUDGET(in Rupees)					
Designation & number of persons	Per Month	1st Year (m.m.*)	2nd Year (m.m.)	3rd Year (m.m.)	4th Year (m.m.)	5th Year (m.m.)	Total (m.m.)
#Post Doctoral Fellow/ Project scientist (1)	12,000/=	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(60) 7,20,000
#Scientist 'SC (Tech) (1)	Starting 20,000/=	(12) 2,40,000	(12) 2,46,000	(12) 2,52,000	(12) 2,58,000	(12) 2,64,000	(60) 12,60,000
#Secretarial Assistance (1)	Starting 8,000/=	(12) 96,000	(12) 99,600	(12) 1,03,200	(12) 1,06,800	(12) 1,10,400	(60) 5,16,000
#Total (at PRL)		4,80,000	4,89,600	4,99,200	5,08,800	5,18,400	24,96,000
At NIH							
Post Doctoral Fellow/ Project scientist (1)	Cons. 12,000/=	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(60) 7,20,000
Scientist SB / B (Tech) (1)	Starting 16,000/=	(12) 1,92,000	(12) 1,98,000	(12) 2,04,000	(12) 2,10,000	(12) 2,16,000	(60) 10,20,000
Lab Asst. Skilled/ Unskilled	Cons. 4,000	(12) 48,000	(12) 48,000	(12) 48,000	(12) 48,000	(12) 48,000	(60) 2,40,000
Total (at NIH)		3,84,000	3,90,000	3,96,000	4,02,000	4,08,000	19,80,000
At NIO							
Project scientist (2)	12,000/=	(12) 2,88,000	(12) 2,88,000	(12) 2,88,000	–	–	(36) 8,64,000
Total (at NIO)		2,88,000	2,88,000	2,88,000	–	–	8,64,000
At NGRI							
Project scientist (1)	12,000/=	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(12) 1,44,000	(60) 7,20,000
Total (at NGRI)		1,44,000	1,44,000	1,44,000	1,44,000	1,44,000	7,20,000
At AU							
Project scientist (2)	12,000/=	(12) 2,88,000	(12) 2,88,000	(12) 2,88,000	–	–	(36) 8,64,000
Total (at AU)		2,88,000	2,88,000	2,88,000	–	–	8,64,000
Grand Total SALARIES/WAGES (for all Institutions)		15,84,000	15,99,600	16,15,200	10,54,800	10,70,400	69,24,000

 # The Director PRL has agreed to contribute this amount (total Rs. 24,96,000) as part of PRL's contribution towards project Infrastructure.

311. Justification for the Manpower Requirement:

Seven PDF/Project scientists (one each at PRL, NIH, NGRI and two each at NIO, AU) are required to assist in sample analyses, as also to help PIs at respective institutions in coordinating the sample collection network and result reporting. The incumbents are expected to acquire sufficient training to be able to run independent projects using stable isotope mass-spectrometer at any other institution/ University. A Scientist 'SC/SB (Tech) is required for routine maintenance/ upkeepment and the running of the laboratory each at PRL and at NIO, as these two laboratories will handle most of the sample analyses. These laboratories will have trained and experienced permanent PRL/NIH staff to ensure high level of productivity. Secretarial Assistant is required for Principal Coordinator at PRL for data processing, communication, web-site maintenance and other normal office activities connected with the National Programme.

320. BUDGET FOR CONSUMABLE MATERIALS (Itemwise)

Sr. No.	Item	CONSUMABLE BUDGET(in Rupees)					
		1st Yr	2nd Yr.	3rd Yr.	4th Yr.	5th Yr.	Total
	Sample Collection (Service charge to be paid to operator at field station)						
1a.	Monthly precipitation and atm. vapour. Thirty (30) stns. @Rs. 5000/ year/ stn.	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	7,50,000
1b.	Monthly stream flow. Thirty (30) stns. @ Rs. 5000/ year/ stn	1,50,000	1,50,000	1,50,000	1,50,000	1,50,000	7,50,000
1c.	Monthly shallow groundwater. Thirty (30) New stns/month. @Rs. 500/per stn.	1,80,000	1,80,000	1,80,000	1,80,000	1,80,000	9,00,000
1d.	Daily precipitation and atmospheric vapour. 9 stns @Rs. 5000/ year/ stn.	40,000	40,000	40,000	40,000	40,000	2,00,000
2.	Water sample bottles. 2500 bottles/ yr @ Rs.50/ bottle	1,20,000	1,20,000	1,20,000	1,20,000	1,20,000	6,00,000
3.	Transportation cost of samples (postage/ courier) @ Rs.100/sample	2,50,000	2,50,000	2,50,000	2,50,000	2,50,000	12,50,000
4.	Lab. consumables for stable isotope analyses ($\delta^{18}O$ and δD). @ Rs.250/ analysis	14,00,000	13,75,000	13,75,000	13,55,000	13,55,000	68,60,000
5.	Stationery, diskettes CDs, printer cartridges and other miscellaneous consumables	1,45,000	1,45,000	1,45,000	1,45,000	1,45,000	7,25,000
6.	Salinity Measurements	20,000	20,000	20,000			60,000
7.	Data purchase cost	50,000	50,000	50,000	25,000	25,000	2,00,000
8.	Sonde ascent, Ballons, gases operational support, etc	10,94,000 ($20,500)	10,72,000 ($20,000)	200,000			23,66,000 ($40,500)
Total	**B****	**35,99,000**	**35,52,000**	**26,80,000**	**24,15,000**	**24,15,000**	**1,46,61,000**
	F***	**($20,500)**	**($20,000)**	**Nil**	**Nil**	**Nil**	**($40,500)**

*Q: Quantity or number, B** Budget, ***F: Foreign Exchange Component in US$

(321) BUDGET FOR CONSUMABLE MATERIALS (Institution-wise)

Item								Institution	Total
	PRL	**NIH**	**NIO**	**NGRI**	**AU**	**IIT-KGP**	**NRL**	**(CRIDA/IMD +CPCB/CWC +CGWB)§**	**For all Inst.**
				1st Year					
1a								1,50,000	1,50,000
1b								1,50,000	1,50,000
1c								1,80,000	1,80,000
1d	5,000	10,000	5,000	5,000	5,000	5,000	5,000		40,000
2	10,000	10,000	5,000	5,000	5,000	5,000	5,000	75,000	1,20,000
3	40,000				50,000		10,000	1,50,000	2,50,000
4	5,00,000	5,00,000	1,25,000	1,25,000		1,25,000	25,000		14,00,000
5	50,000	20,000	10,000	10,000	10,000	5,000	10,000	30,000	1,45,000
6			10,000		10,000				20,000
7	50,000								50,000
8	2,00,000		8,94,000						10,94,000
Total	8,55,000	5,40,000	10,49,000	1,45,000	80,000	1,40,000	55,000	7,35,000	35,99,000
FEC			($20,500)						
				2nd Year					
1a								150,000	1,50,000
1b								150,000	1,50,000
1c								180,000	1,80,000
1d	5,000	10,000	5,000	5,000	5,000	5,000	5,000		40,000
2	10,000	10,000	5,000	5,000	5,000	5,000	5,000	75,000	1,20,000
3	40,000				50,000		10,000	1,50,000	2,50,000
4	5,00,000	5,00,000	1,00,000	1,25,000		1,25,000	25,000		13,75,000
5	50,000	20,000	10,000	10,000	10,000	5,000	10,000	30,000	1,45,000
6			10,000		10,000				20,000
7	50,000								50,000
8	2,00,000		8,72,000						10,72,000
Total	8,55,000	5,40,000	10,02,000	1,45,000	80,000	1,40,000	55,000	7,35,000	35,52,000
FEC			($20,000)						
				3rd Year					
1a								1,50,000	1,50,000
1b								1,50,000	1,50,000
1c								1,80,000	1,80,000
1d	5,000	10,000	5,000	5,000	5,000	5,000	5,000		40,000
2	10,000	10,000	5,000	5,000	5,000	5,000	5,000	75,000	1,20,000
3	40,000				50,000		10,000	1,50,000	2,50,000
4	5,00,000	5,00,000	1,00,000	1,25,000		1,25,000	25,000		13,75,000
5	50,000	20,000	10,000	10,000	10,000	5,000	10,000	30,000	1,45,000
6			10,000		10,000				20,000
7	50,000								50,000
8			2,00,000						2,00,000
Total	6,55,000	5,40,000	3,30,000	1,45,000	80,000	1,40,000	55,000	7,35,000	26,80,000
				4th Year					
1a								1,50,000	1,50,000
1b								1,50,000	1,50,000
1c								1,80,000	1,80,000
1d	5,000	10,000	5,000	5,000	5,000	5,000	5,000		40,000
2	10,000	10,000	5,000	5,000	5,000	5,000	5,000	75,000	1,20,000
3	40,000				50,000		10,000	1,50,000	2,50,000
4	5,00,000	5,00,000	80,000	1,25,000		1,25,000	25,000		13,55,000
5	50,000	20,000	10,000	10,000	10,000	5,000	10,000	30,000	1,45,000
6			0						0
7	25,000		0						25,000
8			0						0
Total	6,30,000	5,40,000	1,00,000	1,45,000	70,000	1,40,000	55,000	7,35,000	24,15,000

Table Continued on next page

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Item	**Institution**								**Total**
	PRL	**NIH**	**NIO**	**NGRI**	**AU**	**IIT-KGP**	**NRL**	**(CRIDA/IMD +CPCB/CWC +CGWB)§**	**For all Inst.**
5th Year									
1a								1,50,000	1,50,000
1b								1,50,000	1,50,000
1c								1,80,000	1,80,000
1d	5,000	10,000	5,000	5,000	5,000	5,000	5,000		40,000
2	10,000	10,000	5,000	5,000	5,000	5,000	5,000	75,000	1,20,000
3	40,000				50,000		10,000	1,50,000	2,50,000
4	5,00,000	5,00,000	80,000	1,25,000		1,25,000	25,000		13,55,000
5	50,000	20,000	10,000	10,000	10,000	5,000	10,000	30,000	1,45,000
6									0
7	25,000								25,000
8									0
Total	6,30,000	5,40,000	1,00,000	1,45,000	70,000	1,40,000	55,000	7,35,000	24,15,000
Total for 5 years	**36,25,000**	**27,00,000**	**25,81,000**	**7,25,000**	**3,80,000**	**7,00,000**	**2,75,000**	**36,75,000**	**1,46,61,000**
FEC*			**($40,500)**						**($40,500)**

§ This budget will be administered from PRL for disbursement to individual agencies.

322. Justification for Costly Consumable (if not provided for in Section 231 i.e. Methodology)

Lump sum cost estimates for various activities (Items1a to 1d to 3) have been made based on various requirements for sample collection by different collaborating agencies and shipment to different analytical laboratories. The lump sum cost for laboratory analyses (Item 4) is based on the existing budget spent at PRL for this activity.

Item 6 is for chemicals and glassware required for salinity measurements using $AgNO_3$ titration. Item 7 represents the cost of data from ECMWF reanalysis and also from IMD, CWC, CRIDA, CPCB or from any other national agency as may be required. The cost of a radiosonde ascend (Item 8) is approximately Rs. 15,000/-. It is judiciously planned to have ~150 ascends in first two years which includes alternate days in monsoon months (Jun to Sept) and fortnightly ascends in non monsoon months. It is also planned have daily 4 ascends to understand the diurnal nature of vapour transport during active and break phases of the monsoon. Operational support fee also forms part of this component.

Additionally 30 ascends will be launched from Ahmedabad using the existing Radiosonde at PRL. Separate consumable budget is provided for this.

330. BUDGET FOR TRAVEL

Type of Travel Related activity	BUDGET(in Rupees)					
	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
For sample collection, Training of field staff, and project Coordination **at PRL**	2,50,000	1,50,000	1,50,000	1,00,000	1,00,000	7,50,000
TA/DA for AS sample collection and Vaisala Sonde related work **at NIO**	2,00,000	1,50,000	1,00,000			4,50,000
TA/DA for BOB sample collection **At AU**	4,50,000	3,00,000	3,00,000			10,50,000
Scientific travel for BOB project including Meetings/ conf. **at AU**	60,000	50,000	40,000			1,50,000
Scientific travel for Meetings/ conf. etc **at NIH**	30,000	40,000	30,000	20,000	30,000	1,50,000
Scientific travel for Meetings/ conf. etc **at NGRI**	30,000	40,000	30,000	20,000	30,000	1,50,000
Scientific travel for Meetings/ conf. etc **at NRL**	30,000	40,000	30,000	20,000	30,000	1,50,000
Scientific travel for Meetings/ conf. etc **at IIT-KGP**	30,000	40,000	30,000	20,000	30,000	1,50,000
(All Institutions)						
Total Project Travel Budget	**10,80,000**	**8,10,000**	**7,10,000**	**1,80,000**	**2,20,000**	**30,00,000**

331. Justification for Intensive Travel, If Any:

Intensive travel will be required in the first year of the project for establishing and operationalizing the network of sample collection stations. Subsequently, the travel cost will be largely for inspection to ensure that the samples are being collected following set procedures and/ or to remove bottlenecks / hurdles in the working of the network and to attend the scientific workshop/ seminar for reporting of the results.

In case of AS sampling the costs include DA/TA for staff joining cruises for sample collection almost on monthly basis and land travel plus incidental @ Rs 2,000/= per trip. In case BOB, the costs include ship fare between Chennai to Port Blair/ Visakhapattnam/ Kolkata and the train journey. Every trip fare cost is estimated at Rs. 40,000/=. NIO-Tech ship trips – 5 to 7 trips of 4-5 day each, DA/TA for staff and incidentals @ Rs 2000/= per trip. Scientific travels are for attending meetings, conferences, workshops etc.

340. BUDGET FOR OTHER COSTS/CONTINGENCIES

		BUDGET(in Rupees)					
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
1.	Half yearly Project Coordination meeting costs @ Rs. 1,00,000/- per meeting (lump sum) **at PRL**	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000	10,00,000
2.	# Annual Workshop/ Symposium + hands on training course for University students and research Staff @ Rs.2,00,000/- per course (lump sum) **at PRL**	2,00,000	2,00,000	2,00,000	2,00,000	2,00,000	10,00,000
3.	# Civil work for housing the SIRMS laboratory **at PRL**	15,00,000					15,00,000
4.	# Civil work for Sample Storage facility **at PRL**	5,00,000					5,00,000
5.	Contingencies **at NIO (**Installation and site acceptance test, operational support for Vaisala Sonde and other incidental expenditure)	3,13,000 (US$6500)	1,00,000 (US$2000)	1,00,000 (US$2000)			5,13,000 (US$10,500)
6.	Contingencies **at NIH**	1,50,000	1,00,000	1,00,000	50,000	50,000	4,50,000
7.	Contingencies **at NGRI**	1,50,000	1,00,000	1,00,000	50,000	50,000	4,50,000
8.	Contingencies **at AU**	1,50,000	1,00,000	1,00,000			3,50,000
	Total (at all Institutions)	**31,63,000** (US$6500)	**8,00,000** (US$2000)	**8,00,000** (US$2000)	**5,00,000**	**5,00,000**	**57,63,000** (US$10,500)

 # The Director PRL has agreed to contribute this amount (total Rs. 30, 00,000) as part of PRL's contribution towards project Infrastructure

341. Justification for Specific Costs under Other Costs, If Any:

Item Nos. 1 and 2 in 340 form integral part of the proposed National Programme to ensure proper coordination between the participating laboratories and field sample collection agencies as also for manpower training through hands on experience, developing scientific temper for the field of Isotope Hydrology and societal application of the results.

Contingencies at NIO provide for installation and site acceptance test for Vaisala Radiosonde and the MW21 DigiCORA III sounding System including software. This component represents the operational support costs.

Contingencies at NIH, NGRI, NRL, AU, are intended to provide for unanticipated costs that may be necessary either due to cost escalation, system breakdowns and/or any other emergencies that may arise mostly during sample collection process and/or laboratory operations. These also include costs towards repair/service of the measuring equipments in laboratories and/or field.

350. BUDGET FOR EQUIPMENTS:

Sl. No.	Generic name of the Equipment along with make & model	Imported/ Indigenous	Estimated Costs (in Foreign Currency also)*	Spare time for other users (in %)
1	A new Stable Isotope Ratio Mass Spectrometer system **at PRL*** *	Imported	1,75,00,000 (US$3,89,000)	Nil
2	UPS, Vacuum pumps and other minor equipments **at PRL**	Imported	15,00,000 (US$34,000)	N/A
3	# PC + Printer + Standard Software + Statistical & Mathematical packages **at PRL**	Indigenous	1,00,000	N/A
4	# Fabrication cost of special precipitation sampler 40 Nos. @Rs.1250/ sampler **at PRL**	Indigenous	50,000	N/A
5	# Fabrication cost of atmospheric vapour sampler 40 Nos. @Rs. 1250/ sampler **at PRL**	Indigenous	50,000	N/A
6.	Rain gauges (5 Nos.) **at AU**	Indigenous	50,000	N/A
7.	Hand held GPS (2 Nos.) **at AU**	Locally available	70,000	20%
8.	Digital recording Thermometers (2Nos.) **at AU**	Locally available	10,000	N/A
9	Digital recording salinometers (2Nos.) **at AU**	Locally available	50,000	N/A
10.	PC + accessories **at AU**	Locally available	60,000	20%
11.	MW21 DigiCORA III Vaisala Radiosonde including workstation and software **at NIO**	Imported	46,50,000 (US$1,06,500)	N/A
12.	PC + accessories **at NIH**	Locally available	60,000	20%
13.	PC + accessories **at NGRI**	Locally available	60,000	20%
	Total (at all institutions)		**2,42,10,000 (US$5,29,500)**	

* Includes transport, insurance and installation charges.

** **Specifications of Stable Isotope Ratio Mass Spectrometer System.**
The system consists of two major units:

(1) Dual Inlet IRMS (Gas) consisting of ultra low dead volume dual sample inlet system, extended geometry Ion optics providing high dispersion and near 100% transmission, capable of measuring D/H, $^{13}C/^{12}C$, $^{15}N/^{14}N$, $^{18}O/^{16}O$ and $^{34}S/^{32}S$ with automatic cold finger at the inlet. Computer controlled change over valve, universal Faraday cup collectors, pumping by Turbo molecular and rotary pump combination capable of providing vacuum 10^{-8} mb. Absolute sensitivity of 800 molecules per one CO_2 m/z = 44 ion. Software controlled electromagnet for ion deflection.

(2) Online automated water equilibration system for D/H and $^{18}O/^{16}O$ in water with associated accessories like air compressor, Liquid Nitrogen Dewar, LN2 pump, cryo-cool unit for trapping condensables.

 # The Director, PRL has agreed to contribute this amount (total Rs. 2,00,000) as part of PRL's contribution towards project Infrastructure.

351. Justification for the Proposed Equipment:

About 30,000 isotopic analyses are proposed to be made as part of this project involving both $\delta^{18}O$ and δD. This number will double if temporal and spatial variations of up to 0.5‰ in $\delta^{18}O$ are targeted. In addition, It is hoped, that as the project proceeds several satellite projects will be added as and when interesting problems, interested scientists and institutions can be found to handle a these projects. These satellite programmes will require additional measurement capabilities. Considering that on an average a standard Stable Isotope Ratio Mass Spectrometer (SIRM) laboratory makes about 3,000-4,000 analyses annually, there is a need to have two dedicated machines for this programme. The present proposal, however, incorporates only one new mass spectrometer to supplement the stable isotope laboratory at PRL. Other than PRL, isotope analysis facilities at IIT-KGP, NIH Roorkee, NGRI Hyderabad, NIO Goa and BARC, Mumbai are also planned to be utilised in this National programme. Some of these facilities are already functional or in the process of being installed. However, since all institutions, other than PRL, have already planned other research programmes, they will only be able to analyse a limited number of samples for this Programme. NRL is in the process of upgrading and restarting the existing SIRMS facility with them. It will, therefore, be possible to make some IWIN analyses at NRL also.

The salinometers (item 9) are required for sea water salinity measurements. These will be periodically calibrated against Autosal at NIO Goa and also by $AgNO_3$ titration for chloride estimation.

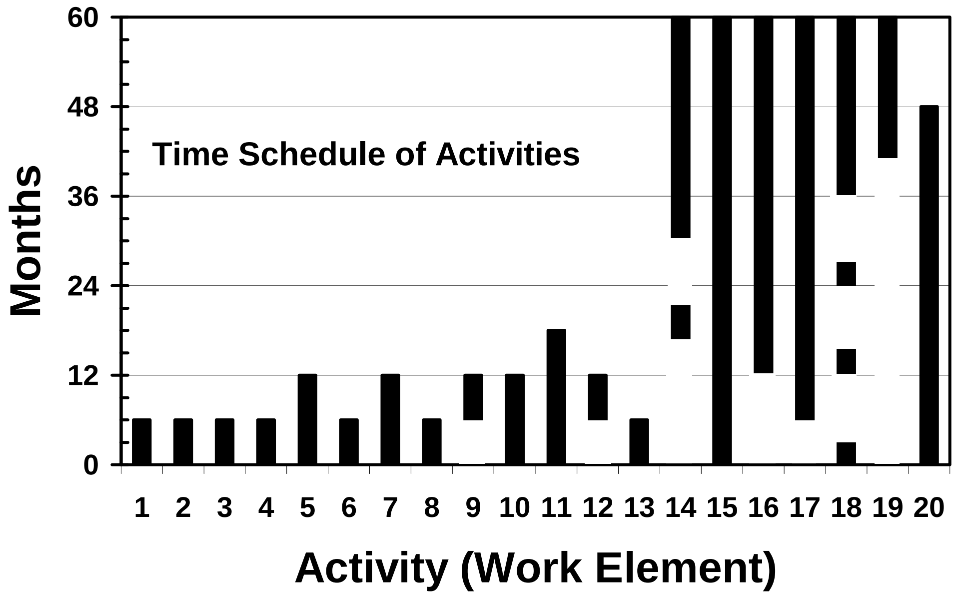
A Vaisala radiosonde (Item 11) will be installed at NIO, Goa. This is necessary for improving the accuracy of computation of moisture transport from the ocean. Even the best available reanalysis upper air data product is not free from uncertainties arising from interpolation and modelling. Hence, a near continuous validation using the technologically advanced upper air sounding unit called MW21 DigiCORA III radio sounding system was recommended by the DST review committee at NIO Goa.

PC's (Items 10, 12 & 13) requested at some of the participating institutions are for data handling, and usual activities such as report preparations etc.

Other items include peripherals to the main equipment and sample collection devices to be placed at field sample collection stations.

The Director, PRL has agreed to contribute Rs. 2,00,000 towards minor equipments as indicated in equipment budget.

410. Time Schedule of Activities through BAR Diagram:



Please see Section 233 for details of work elements numbered 1 to 20.

420. List of Facilities Being Extended by Parent Institution(S) for the Project Implementation:

A) Infrastructural Facilities:

Sr. No.	Infrastructural Facility	Yes/No/ Not required Full or sharing basis
1.	Workshop Facility	Yes
2.	Water & Electricity	Yes
3.	Laboratory Space/ Furniture	Yes
4.	Power Generator	Not required. UPS is required and is being asked as part of equipment budget.
5.	AC Room or AC	Yes
6.	Telecommunication including e-mail & fax	Yes
7.	Transportation	Yes
8.	Administrative/ Secretarial support	Yes
9.	Information facilities like Internet/ Library	Yes
10.	Computational facilities	Yes
11.	Animal/ Glass House	Not Required
12.	Any other special facility being provided	Will be provided if and when needed.

B) Equipment Available with the Institute/ Group/ Department/ Other Institutes for the Project:

Equipment available with	Generic Name of Equipment	Model, Make & year of purchase	Remarks including accessories available and current usage of equipment
Principal Coordinator & his group	Functional Stable Isotope Ratio Mass Spectrometer	PDZ Europa-GEO2020 model	Adequate
Principal Coordinator's Department	Functional Geochemistry Laboratory	Several. Not related to project requirement. But available if a requirement crops up.	

421. Other operational aspects:

The network stations for sample collection will be owned and operated by the respective institutions. The collected samples will be sent along with a copy of sample collection record sheet for isotopic analyses to any of the pre-designated laboratory from among the PRL Ahmedabad/ IIT-KGP/ NIH Roorkee/ NGRI Hyderabad/ NIO Goa/ NRL New Delhi. The results of the analyses will be communicated in standard format to (i) sample providing Institution and (ii) the central data warehouse for the IWIN programme to be maintained by the PRL. The data will be jointly owned by the particular sample providing Institution, the particular isotope analysis laboratory and the IWIN programme. The PRL isotope laboratory will organise periodic inter laboratory calibration experiments to ensure that all network data conforms to the same high quality standards. Periodic workshops/group meetings of all participating scientists in the network programme will be held to review the progress and to discuss knowledge increments from the work of the programme. Only those results that have been discussed in these workshops will be cleared for publication. All publications will be jointly issued at the time of first reporting of results. Thereafter, the results will form part of the public domain and will also be communicated to IAEA/GNIP programme. Efforts will also be made to generate ‘area or problem specific’ detailed investigation satellite projects as and when interesting problems, interested scientists and institutions can be found to handle these projects.

The isotope laboratories at PRL/ NIH/ IIT-KGP/ NGRI/ NIO will also act as national facilities for research in stable isotope hydrology by the universities and other academic Institutions. As part of this national facility, yearly training programmes for post graduate students will be conducted with hands on experience in mass spectrometric isotope analysis and sample collection & storage procedures at these laboratories.

A Project Review Committee will be constituted by the Department of Science and Technology in consultation with the Head of the Nodal Centre and Principal Coordinator to periodically review/ monitor the progress and to guide the IWIN National Programme from time to time.

Although, the present proposal is for a five year period, the National Programme has a 10 years perspective during which several new programmes of local and regional characters will be undertaken in the field of hydrology with several Universities and Academic institutions.

430. Detailed Bio-data of the Principal Coordinator

Name: S.K. Gupta

Address: Scientist 'SG', Room No. 259, Planetary Geosciences Division, Physical Research Laboratory (PRL), P.O. Box 4218. Navrangpura, Ahmedabad
380 009.

Date of Birth: 27th September, 1946.

Institution's Address: Physical Research Laboratory (PRL), P.O. Box 4218. Navrangpura, Ahmedabad 380 009.

Academic Qualifications (University/College from where attained, year of passing, class, Thesis title etc.)

Ph.D.	(Geology) 1974	Indian Institute of Technology Mumbai, India
M.Sc.	(Exploration-Geophysics) 1967	Indian Institute of Technology Kharagpur, India
B.Sc.	(Geological Sciences) 1965	Indian Institute of Technology Kharagpur, India

Professional Societies:

National Academy of Sciences India	Fellow (Life)
Gujarat Science Academy	Fellow (Life)
Indian Water Works Association	Fellow (Life)
Indian Geophysical Union	Fellow (Life)
Geological Society of India	Fellow (Life)
Indian Association of Hydrologists	Fellow (Life)
Indian Physics Association	Life Member
Indian Meteorological Society	Life Member
Indian Society of Engineering Geology	Life Member
Fulbright/EWC Alumni Association	Life Member
Consultancy Development Centre	Associate

Patent list, if any:

U.S. Patent No. 5229005 Issued on July 20, 1993 "Ocean Depth Reverse Osmosis Freshwater Factory"

Publications:

Research Papers:

(a)	Refereed Journals	70.	International (38)
(b)	Proc. Symp., Workshops & Invited	78.	International (32)
Popular Science Articles:		23	
Books:		3	
Editorial Assignments:		2	

Publications list (Last 5 years Only):

Refereed Journal publications (International):

1) **Origin of High Fluoride in Groundwater in the North Gujarat – Cambay Region, India.** S.K. Gupta, R.D. Deshpande, Meetu Agarwal and B.R. Raval.

Hydrogeology Journal, (in press) DOI, doi:*10.1007/s10040-004-0389-2*.

2) **Groundwater $\delta^{18}O$ and δD from Central Indian Peninsula: Influence of Arabian Sea and the Bay of Bengal Branches of Summer Monsoon.** S.K. Gupta, R.D. Deshpande, S.K. Bhattacharya and R.A. Jani. *Journal of Hydrology,* Vol. 303(1-4), pp38-55, 2005*.*

3) **An Insight into the Dynamics of Lake Nainital (Kumaun Himalaya, India) Using Stable Isotope Data.** S.K. Gupta and R.D. Deshpande. *Hydrological Sciences Journal*, Vol. 49(6), pp1099-1113, 2004.

4) **Helium, Radon, and Radiocarbon studies on a Regional Aquifer System of North Gujarat – Cambay Region, India.** M. Agarwal, S.K. Gupta, R.D. Deshpande and M.G. Yadava. *Chemical Geology*, Accepted in press.

5) **Preliminary Studies Concerning SGD in Indian Coastal Regions Using ^{228}Radium and ^{226}Radium.** B.L.K. Somayajulu, V.V. Sharma, S. Nair and S.K. Gupta. *Revista Brasileira de Pesquisa e Desenvolvimento* (2002/2003) (in press).

6) **Origin of Groundwater Helium and Temperature Anomalies in the Cambay region of Gujarat, India.** S.K. Gupta and R.D. Deshpande. *Chemical Geology.* Vol. 198, pp. 33-46. 2003.

7) **Distribution of Oxygen and Hydrogen Isotopes in Shallow Groundwaters from Southern India: Influence of a Dual Monsoon System.** R.D. Deshpande, S.K. Bhattacharya, R.A. Jani, S.K. Gupta. *Journal of Hydrology*, Vol. 271, pp. 226-239. 2003.

8) **Mass Transport Modelling to Assess Contamination to Water Supply Well in Sabarmati River Bed Aquifer, Ahmedabad City, India**. V.V.S. Gurunadha Rao and S.K. Gupta. *Environmental Geology*, Vol. 39(8), pp. 893-900, 2000.

9) **Role of Eustasy, Climate and Tectonics in Late Quaternary Evolution of Nal Cambay Region, NW India.** Sushma Prasad and S.K. Gupta. *Zeitschrift fur Geomorphologie*, Vol. 43(4), pp483-504, 1999.

Refereed Journal publications (National):

10) **The Need and Potential Applications of a Network for Monitoring of Isotopes in Waters of India.** S.K. Gupta and R.D. Deshpande. *Current Science,* Vol. 88, No. 1, pp.107-118, 2005.

11) **Isotopes for Water Resource Management in India.** S.K. Gupta and R.D. Deshpande. *Himalayan Geology,* Vol.26, No.1, pp211-222, 2005.

12) **Water for India in 2050 – First Order Assessment of Available Options.** S.K. Gupta and R.D. Deshpande. *Current Science*, Vol. 86, No. 9, pp.1216-1224*.* 2004.

13) **Synoptic Hydrology of India from the Data of Isotopes in Precipitation.** S.K. Gupta and R.D. Deshpande. *Current Science.* Vol. 85. No. 11, pp. 1591-1595. 2003.

14) **Dissolved Helium and TDS in Groundwater from Bhavnagar in Gujarat: Unrelated to Seismic Events between August 2000 and January 2001.** S.K. Gupta and R.D. Deshpande. Proc. *Indian Acad. Sci (Earth Planet. Sci.).* Vol. 112, No. 1, pp. 51-60. 2003.

15) **On the Origin of the Artesian Groundwater and Escaping Gas at Narveri After the Bhuj Earthquake in 2001.** S.K. Gupta, N. Bhandari, P.S.Thakkar and R. Rengarajan. *Current Science.* Vol.82, No. 4, pp 463-468. 2002.

16) **A 75 ka Record of Palaeoclimatic Changes Inferred from Crystallinity of Illite from Nal Sarovar, Western India.** K. Pandarinath, Sushma Prasad, S.K.

Gupta, *Journal Geological Society of India.* Vol.54, pp 515-522. 1999.

17) **Late Quaternary Sediments from Nal Sarovar, Gujarat, India: Distribution and Provenance.** K. Pandarinath, Sushma Prasad, R.D. Deshpande and S.K. Gupta. *Proc. Ind. Acad. Sci. (Earth & Planet. Sci.),* Vol. 108, No.2, pp107-116, 1999.

Publications in Proceedings of Workshop, Symposia (International):

18) **Contributions of the water isotope studies to hydrology of India.** S.K. Gupta and R.D. Deshpande. Presentation at SCOPE XII GA, 7-11 February 2005, New Delhi.

19) **Sustaining *Akshaydhara,* Pristine Perennial Flow of Water, for Growing India.** S.K. Gupta, Presentation at SCOPE XII GA, 7-11 February 2005, New Delhi.

20) **Isotope Hydrology in India: What Has Been Learned and the Way Forward?** S.K. Gupta and R.D. Deshpande, Hydrological Perspectives for Sustainable Development, 23-25 February 2005, IIT Roorkee, India. (Eds. M. Perumal, D.C. Singhal, B.S. Mathur, D.S. Arya, H. Joshi, D.K. Srivastava, Ranvir Singh, N.K. Goel and M.D. Nautiyal) Allied Publisher Pvt. Ltd. New Delhi. Vol. II, pp. 782-792. (2005).

21) **Hydrology Agenda in Aid of Sustainable Water Resource Development in Gujarat State.** S.K. Gupta and R.D. Deshpande, Hydrological Perspective s for Sustainable Development, 23-25 February 2005, IIT Roorkee, India. (Eds. M. Perumal, D.C. Singhal, B.S. Mathur, D.S. Arya, H. Joshi, D.K. Srivastava, Ranvir Singh, N.K. Goel and M.D. Nautiyal) Allied Publisher Pvt. Ltd. New Delhi. Vol. II, pp. 674-684, (2005).

22) **Water Outlook for India: Quantifying Hydrological Cycle Components and Their Interactions for Sustainable Development Using Isotopic Studies.** S.K. Gupta and R.D. Deshpande, Proc. 2nd APHW Conf. Vol.II, Singapore, 5-9 July 2004. pp.326-325.

23) **Urban Hydrology Issues in India: *Akshaydhara* concept – Some Initiatives in Ahmedabad.** S.K. Gupta and R.D. Deshpande. *Proc. Int. Conf. on Water and Environment, Dec. 16-18, 2003, Bhopal, India.* **Vol. Watershed Management** (Eds. V.P. Singh & R.N. Yadav). Allied Publishers Pvt. Ltd. New Delhi. pp. 316-329. 2003.

24) **High Fluoride in Groundwater of North Gujarat – Cambay Region: Origin, Community Perception and Remediation.** S.K. Gupta and R.D. Deshpande. *Proc. Int. Conf. on Water and Environment, Dec. 16-18, 2003, Bhopal, India.* **Vol. Ground Water Pollution** (Eds. V.P. Singh & R.N. Yadav). Allied Publishers Pvt. Ltd. New Delhi. pp. 368-388. 2003.

25) **Soil-Aquifer-Treatment Systems for Maintaining Water Quality of our Rivers.** S.K. Gupta and R.D. Deshpande. *Proc. Int. Conf. on Water Quality Management, 13-15 Feb. 2003, New Delhi. Pp. KN-72 to KN-82. 2003.*

26) **Modelling Advection–Dispersion Process for Dual Radiotracer Dating of Groundwater with an example of application to a Data Set from Central Australia.** S.K. Gupta. In (Eds. L. Elango and R. Jayakumar) Modelling in Hydrology. Proc. Int. Workshop, Chennai, Nov. 2001. Allied publishers, Mumbai, pp169-190. 2001.

27) **Water Stress in Gujarat, India: Dimensions, Development Plans and**

Peoples' Movement for Sustainable Growth. S.K. Gupta and R.D. Deshpande. Abstract accepted for detailed presentation paper at *Int. Conf. on Water, Environment, Ecology, Social-economics, and Health Engineering*, Oct. 18-21, 1999, Seol, Korea.

28) **Modelling Contamination of a Drinking Water Supply Well in the Sabarmati River Bed Aquifer, Ahmedabad, India.** V.V.S. Gurunadha Rao and S.K. Gupta, In *Impacts of Urban Growth on Surface Water and Groundwater Quality* (ed. J.B. Ellis), Proc. *IUGG 99 Symp HSS, Birmingham, July 1999). IAHS Publ. 259, pp73-81.*

Publications in proceedings of Workshop, Symposia (National):

29) **Mathematical Models for Interpretation of Hydrologic Tracer Data**. S.K. Gupta. In (Eds. A.L. Ramanathan, M. Thangarajan and D.R. Ram) Training Manual on Mathematical Modelling of Groundwater Flow and Mass Transport. Prashant Publishing Co., New Delhi. pp. 176-185, 2004.

30) **Advances in Hydrology and Water Resources in India.** K.D. Sharma, Bhishm Kumar and S.K. Gupta. In (Eds. A.K. Singhvi and A. Bhattacharya) Glimpses of Geoscience Research in India. The Indian Report to IUGS 1999-2004. Indian National Science Academy, New Delhi. pp. 1-4, August 2004.

31) **Hydrological and Engineering Considerations for Artificial Recharge of Ground Water.** S. K. Gupta. In (Eds. B.B. Singhal & O.P. Varma) *DST's Spl. Vol. 3 on 'S&T Inputs for Water Resource Management*, pp. 133-144. Published by India. Geol. Cong. 2003.

32) **Radial collector Wells: Some Insight into Factors Controlling Yield and Capture Zone.** Nipun Kapur and S.K. Gupta. *Proc. Tenth National Symposium on Hydrology*, New Delhi, 18 –19 July, 2000. pp 347-358.

33) **Variations of Some Proxy Palaeoclimatic Indicators in a Core from Nal Sarovar: Implications for Holocene Atmospheric Circulation in NW India.** S.K. Gupta, Sushma Prasad and K. Pandarinath. *Proc. Workshop on "Quaternary Coastal Environments: Records of rapid changes and Responses",* Bhartidasan Univ. Thriruchirappalli, Oct.26-27, 1999.

34) **Emerging Technologies in Groundwater Studies.** S.K. Gupta. *Brainstorming Session on Groundwater Modelling*, CAZRI, Jodhpur. 21-24 Oct. 1999.

List of Projects implemented: Study of Late Quaternary Palaeoclimatic Changes Through Proxy Records of Lake Sediments.

Completed-duration, period: From April 1996 to May 1998

Publications from this:

1. **Holocene Palaeoclimate of NW India.** S.K. Gupta and Sushma Prasad. Invited Review Paper for Encyclopaedia of Quaternary Science. Kluwer Publishers *(in press)*.
2. **Geomorphology, Tectonism and Sedimentation in the Nal Region, Western India.** Sushma Prasad, K. Pandarinath, and S.K. Gupta. *Geomorphology (The*

Netherlands), Vol. 25, pp.207-223, 1998.

3. **Luminescence Dating of a 54m Long Core from Nal Region, Western India - Implications.** Sushma Prasad and S.K. Gupta. *Quaternary Science Review,* Vol. 18, pp 1495-1505,1999.

4. **Role of Eustasy, Climate and Tectonics in Late Quaternary Evolution of Nal Cambay Region, NW India.** Sushma Prasad and S.K. Gupta. Zeitschrift fur Geomorphologie, Vol. 43(4), pp483-504, 1999.

5. **Late Quaternary Sediments from Nal Sarovar, Gujarat, India: Distribution and Provenance.** K. Pandarinath, Sushma Prasad, R.D. Deshpande and S.K. Gupta. *Proc. Ind. Acad. Sci. (Earth & Planet. Sci.),* Vol. 108, No.2, pp107-116, 1999.

6. **A 75 ka Record of Palaeoclimatic Changes Inferred from Crystallinity of Illite from Nal Sarovar, Western India.** K. Pandarinath, Sushma Prasad, S.K. Gupta, *Journal Geological Society of India.* Vol.54, pp 515-522. 1999.

7. **Holocene Climatic Fluctuations in Monsoonal Asia, Arabia & Africa - Review and Possible Causes.** Sushma Prasad and S.K. Gupta. *Modern and Ancient Lakes* (eds. Janet K. Pitman & Alan R. Carroll), Utah Geological Association Guidebook 26. pp.261-275, 1998.

8. **A Mid - Late Holocene Record of Palaeoclimatic Changes from Nal Sarovar: A Palaeo-Desert Margin Lake in Western India.** Sushma Prasad, Sheela Kusumgar and S.K. Gupta. *Journal of Quaternary Science (UK),* Vol. 12, No. 2, pp.153-159, 1997.

9. **Late Quaternary Evolution of the Nal Region, Gujarat, India**. Sushma Prasad, K. Pandarinath and S.K. Gupta., in *Changes in Global Climate due to Natural and Human Activities*, (eds. S.N. Das and R.S. Thakur), Proc. IGBP Symp. (1997). Allied Publishers Ltd, pp 176-179, 1997.

431. Detailed Bio-data of the Co-Principal Coordinator

1. Full Name: SOURENDRA KUMAR BHATTACHARYA
2. Date of Birth: 4 January, 1948
3. Place of Birth: Calcutta, West Bengal, India
4. Office Address: Earth Sciences Division
   Physical Research Laboratory
   Navarangpura
   Ahmedabad 380 009, India
   Ph:079-26314269 (Office)
   079-26742463 (Residence)
   E-mail: bhatta@prl.ernet.in
5. Educational Records:

Qualification	Name of the Institution	Year	Class	(Rank)
School Final	Board of Secondary Education West Bengal	1964	First	First
Pre-University	Calcutta University	1965	First	First
B.Sc.(Physics Honours)	Calcutta University	1968	First	
M.Sc. (Physics)	Calcutta University	1970	First	Third
Advanced Graduate Course	Tata Institute of Fundamental Research	1973	A-Grade	
Ph.D. (Physics)	Physical Research Laboratory (Gujarat University)	1979		

6. Research Appointments:

Visiting Member at Tata Institute of Fundamental Research, Bombay (1971-73).

Mombusho Scholar (Govt. of Japan) in Tokyo University (1976-77).

Co-investigator in Lunar Sample Analysis proposal with NASA (1973-79). Research Associate in Physical Research Laboratory (1973-81).

Indian National Science Academy - Japan Society for Promotion of Science Exchange Fellowship in Japan (1982) for six months.

Fellow in Physical Research Laboratory (1981-88).

Visiting Research Associate in University of California, San Diego, U.S.A. (1987-89). Associate Professor at PRL (1988).

Visiting Scientist At CSIRO, Melbourne, Australia (April-September, 1996).

Visiting Professor at Tokyo Metropolitan University (1997).

Visiting Research Scientist at University of California, San Diego, U.S.A. (February-July, 1998).

Special Consultant at International Atomic Energy Agency, Vienna, August-December, 2002.

Visiting Professor at Laboratory of Glaciology, Geophysics and Environment (LGGE), Grenoble , France under IFCPAR Exchange Program, June, 2005.

7. Present Position:

Sr. Professor, Physical Research Laboratory, Ahmedabad.

8. Past experience:

Cosmic ray effects in Moon and Meteorites; Low activity radiation counting techniques; Neutron activation analysis and radiochemistry.

9. Present areas of interest:

Stable isotope geochemistry; Palaeo-climatology; Isotope ratio mass spectrometry; Anomalous isotopic fractionation in photochemical reactions and dissociations. Application of isotopes in environment and ecology.

10. Academic Activities:

Past guide of five Ph.D. students who did research on various subjects in Stable isotope geochemistry. Teacher of Graduate students in PRL. Principal Investigator of IAEA sponsored co-ordinated Research Project on Trace gases (1992-1999). Past Chairman of Academic Committee, (PRL). Past Editor of "Science Focus" (PRL in-house journal). Chairman of Library Committee. Advisor on several IAEA isotope based programs. Presently guiding two students for Ph.D. in stable isotope based studies. Principal Investigator of IAEA sponsored co-ordinated Research Project on Isotope Tracing in large River basins (2002-2005). Associate Dean at Physical Research Laboratory 2003. Presently guiding two Ph.D. students in PRL. Dean at PRL from February, 2004.

11. Fellowship:

Fellow of Geological Society of India. Fellow of Indian Academy of Sciences, Bangalore. Member of IGCP-303 on Pre-Cambrian/Cambrian Boundary Events. Member of Indian Society of Mass-Spectrometry. Member of National Coordination Committee on Isotope Hydrology. Member of the Selection Committee of Fellows in Earth Sciences for the Indian Academy.

12. Publications: 110 (Total)

List of publications of Prof. S.K. Bhattacharya (from 1998 to 2005)

1) Oxygen isotopic studies of ice, snow and water samples near the Indian station in Antarctica. **S.K. Bhattacharya** and V.N. Nijampurkar. J. Geol. Soc. India, 51, pp.399-404, 1998.
2) ^{12}C enrichment along intraformational unconformities within Proterozoic Bhander limestone, Son Valley, India and its implications. S. Sarkar, P.P. Chakraborty, **S.K. Bhattacharya** and S. Banerjee. Carbonates and Evaporites (13), pp.108-114, 1998.
3) Leonoid Shower and Recovered Objects N. Bhandari, J.N. Goswami, **S.K. Bhattacharya** and others. Current Science, 76, p.619, 1999. Isotopic composition of carbonates and sulphates, potash mineralization and basin architecture of the Nagaur-Ganganagar evaporite basin (north-western India) and their implications on the Neoproterozoic exogenic cycle. D.M. Banerjee, H. Strauss, **S.K. Bhattacharya**, V. Kumar and A. Mazumdar. Mineralogical Magazine, V.62A, pp.106-107, 1998.
4) Isotopic evidence of a rapid cooling and continuous sedimentation across the Eocene-Oligocene boundary of Wagapadher and Waior, Kutch. S. Sarangi, A. Sarkar, **S.K. Bhattacharya** and A.K. Ray. J. Geol. Soc. Ind., vol. 51, pp. 245-248, 1998.
5) Groundwater NO_3 and F contamination processes in Pushkar Valley, Rajasthan as reflected from ^{18}O isotopic signature and ^{3}H recharge studies. P.S. Datta, S.K. Tyagi, P. Mookerjee, **S.K. Bhattacharya**, N. Gupta and P.D. Bhatnagar. Environmental Monitoring and Assessment 56: 209-219, 1999.
6) Paleomonsoon and Paleoproductivity records in $\delta^{13}O$, $\delta^{13}C$ and $CaCO_3$ variations in the Northern Indian Ocean sediments. Sarkar, R. Ramesh, **S.K. Bhattacharya** and N.B. Prize. Proc. Ind. Acad. Sci., v. 109, pp. 157-169, 2000.
7) A new class of oxygen isotopic fractionation in photo dissociation of carbon dioxide potential implications for atmospheres of Mars and Earth. **S.K.**

Bhattacharya, J. Savarino and M.H. Thiemens. Geophysical Research Letters, v. 27, pp.1459-1462, 2000.

8) Precise determination of $^{196}Hg/^{202}Hg$ ratio in meteorites and terrestrial standard rocks by radiochemical neutron Activation. P. Kumar, M. Ebihara, H. Nakahara and **S.K. Bhattacharya** Geochemical Journal, v.35, pp. 101-116, 2001.
9) CO_2 levels in the late Palaeozoic and Mesozoic atmosphere from soil carbonate and organic matter, Satpura Basin, Central India. Prosenjit Ghosh, P. Ghosh, and **S.K. Bhattacharya**. Palaeo. Palaeo. Palaeo., v. 170, pp. 219-236, 2001.
10) Stable isotopic studies of microbial carbonates from Talchir sediments of East-Central India. Prosenjit Ghosh, **S.K. Bhattacharya** and A. Chakrabarti. Current Science, v. 80, 1326-1330, 2001.
11) Growth rate and life span of Eocene-Oligocene Nummulites tests: inferences from Sr/Ca ratio. S. Sarangi, A. Sarkar, M.M. Sarin, **S.K. Bhattacharya**, M. Ebihara and A.K. Ray. Terra Nova, v 13, no 4, 264-269, 2001.
12) Monsoonal signature in trace gases from Cape Rama, India. **S.K. Bhattacharya**, R.J. Francey, D.V. Borole, C.E. Allison, P. Steele and Ken Masarie. *In* Isotope aided studies of atmospheric carbon dioxide and other greenhouse gases: Phase II, Technical Document of International Atomic Energy Agency, IAEA-TECDOC-1269, pp. 81-89, 2002.
13) Trace element and isotopic studies of Talchir carbonate nodules: environmental and provenance Implications. Prosenjit Ghosh, **S.K. Bhattacharya**, A.M. Dayal, J.R. Trivedi, M. Ebihara, M.M. Sarin and Chakrabarti. Proceedings of Indian Academy of Sciences, v.111, 1-15, 2002.
14) Pressure dependence of isotopic enrichment in ozone formed by photolysis of oxygen. **S.K. Bhattacharya**, S. Chakraborty, J. Savarino and M.H. Thiemens. Proceedings of International Symposium on Isotopomers, ISI-2001-15.pdf, Yokohama, Japan, 2002.
15) Oxygen isotope anomaly in ozone dissociation on glass surface. S. Chakraborty, **S.K. Bhattacharya**. Proceedings of International Symposium on Isotopomers, ISI-2001-P9.pdf, Yokohama, Japan, 2002.
16) Isotopic analysis of Permo-Carboniferous Talchir sediments from East-Central India: signature of glacial melt-water lakes. **S.K. Bhattacharya**, P. Ghosh, and A.K. Chakrabarti. Chemical Geology, 188, 261-274, 2002.
17) Carbon and oxygen isotopic compositions of carbonate concretions of the Talchir Formation and their palaeoenvironmental implications. **S.K. Bhattacharya**, P. Ghosh and A. Chakrabarti. Journal of Geological Society of India, 60, 677, 2002.
18) Stable isotopes in the source waters of the Yamuna and its tributaries: Seasonal and altitudinal variations and relation to major cations. T.K. Dalai, **S.K. Bhattacharya** and S. Krishnaswami. Hydrological Processes, 16, 3345-3364, 2002.
19) Negative δ13C excursion and anoxia at the Permo-Triassic boundary in the Tethys Sea. P. Ghosh, **S.K. Bhattacharya**, A.D. Shukla, P.N. Shukla, N. Bhandari, G. Parthasarathy and A.C. Kunwar. Current Science, 83, 498, 2002.
20) Isotopic and sedimentological clues to productivity change in a late Riphean sea: A case study from two intracratonic basins of India. P.P. Chakrabarty, A. Sarkar, **S.K. Bhattacharya** and P. Sanyal. Proc. Ind. Acad. Sci., Earth Planet. Sc., 111(4), 379, 2002.
21) Low pressure dependency of the isotopic enrichment in ozone: Stratospheric implications. **S.K. Bhattacharya**, Subrata Chakraborty, J. Savarino and M.H. Thiemens. J. Geophysical Research, 107 (D23), 4675, doi:10.1029/2002JD002508, 2002.
22) Distribution of oxygen and hydrogen isotopes in shallow groundwater from south India: geographical Influence of a dual monsoon system. R.D. Deshpande, **S.K. Bhattacharya**, R.A. Jani and S.K. Gupta. Journal of Hydrology, 271, 226, 2003.
23) Carbon isotope studies across the Eocene-Oligocene boundary sequence of

Kutch, western India. A. Sarkar, S. Sarangi, **S.K. Bhattacharya** and A.K. Ray. Geophys. Res. Lett., vol. 30, no. 11, 42-1, 2003.

24) Oxygen isotopic anomaly in surface induced ozone dissociation. S. Chakraborty and **S.K. Bhattacharya**. Chemical Phys. Letters, 369, 662, 2003.
25) Mass independent isotopic fractionation: Recent development. S. Chakraborty and **S.K. Bhattacharya**. Current Science, 84(6), 766, 2003.
26) Oxygen isotopic fractionation during UV and visible light photo-dissociation of ozone. S. Chakraborty and **S.K. Bhattacharya**. J. Chem. Phys., 118, 2164, 2003.
27) Investigation on oxygen isotopic exchange between CO2 and O (1D): Experimental demonstration of stratospheric results. S. Chakraborty and **S.K. Bhattacharya**. J. Geophys. Res., 108, No. D23, 4724, 2003.
28) CO2 level in the ancient atmosphere: new estimates from the Late Palaeozoic and Mesozoic soils from central India. Prosenjit Ghosh, **S.K. Bhattacharya**, and Parthasarathi Ghosh. (To appear as a chapter in "A history of atmospheric CO2 and its effects on plants, animals, and ecosystems" to be published by Springer-Verlag, 2003).
29) Dinosaur dung mass from the late Cretaceous (Maastrichtian) Lameta Formation: Isotopic and other markers for a fluid and solid intake suggesting a C3 plant diet. Ghosh, **S.K. Bhattacharya**, R.K. Kar, D.M. Mohabey, K. Ambwani, and A. Sahni. Cretaceous Research, 24, 743-750, 2003.
30) Sudden warming epochs during 42 to 28 ky BP in the Himalayan region from Stable isotope record of sediment from a relict lake in Goting, Garhwal, North India. Prosenjit Ghosh and **S.K. Bhattacharya**. Proc. Ind. Acad. Sci. (Earth and Planet. Sci.), vol. 85, No.1, 101-108, 2003.
31) Stable isotope investigations of a late Neoproterozoic-early Cambrian succession from western India: signatures of global and regional C-isotope events. Aninda Mazumdar and S.K**. Bhattacharya**. (Accepted in Geochemical Journal, 2003).
32) Variations in denitrification and surface productivity with SW-Monsoon during the Holocene In eastern Arabian Sea. R. Agnihotri, **S.K. Bhattacharya**, B.L.K. Somayajulu. Holocene, 13, 5, 701-713, 2003.
33) Sedimentology, faunal, isotopic and geochemical studies of Kutch basin, western India: Implications to the palaeoenvironmental evolution during the Palaeogene. A. Sarkar, S. Sarangi, A.K. Ray, M. Ebihara and **S.K. Bhattacharya**. (To appear in "Warm Early Palaeogene" to be published by Geological Society of America, 2003).
34) Isotope studies in large river basins: A new global research focus. John J. Gibson, **S.K. Bhattacharya** and others. EOS, vol. 83, no.52, 24 Dec., 2002.
35) Isotopic variations in Indian monsoon precipitation: Records from Bombay and New Delhi. **S.K. Bhattacharya**, K. Froehlich, P.K. Aggarwal and K.M. Kulkarni. Geophys. Res. Lett., vol. 30, No. 24, 2285, doi: 10.1029/2003GL018453, 2003.
36) Carbonate geochemistry across the Eocene/Oligocene boundary of Kutch, western India: implications to oceanic O2-poor condition and foraminiferal extinction. Sarkar, S. Sarangi, M. Ebihara, **S.K. Bhattacharya** and A.K. Ray. Chemical Geology, 201, 281-293, 2003.
37) Mio-Pliocene monsoonal record from Himalayan Foreland Basin (Indian Siwalik) and its relation to the vegetational change. Sanyal, **S. K. Bhattacharya**, R. Kumar, S.K. Ghosh and S.J. Sangode. Paleo-3 (in Press), 2003.
38) Low pressure dependency of the isotopic enrichment in ozone: Stratospheric implications. **S.K. Bhattacharya**, Subrata Chakraborty, J. Savarino and M.H. Thiemens, J. Geophysical Research, 107 (D23), 4675, doi:10.1029/2002JD002508, 2002.
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40) Carbon isotope studies across the Eocene-Oligocene boundary sequence of Kutch, western India. A. Sarkar, S. Sarangi, **S.K. Bhattacharya** and A.K. Ray, Geophys. Res. Lett., vol. 30, no. 11, 42-1, 2003.
41) Oxygen isotopic anomaly in surface induced ozone dissociation. S. Chakraborty and **S.K. Bhattacharya,** Chemical Phys. Letters, 369, 662, 2003.
42) Mass independent isotopic fractionation: Recent development. S. Chakraborty and **S.K. Bhattacharya,** Current Science, 84(6), 766, 2003.
43) Oxygen isotopic fractionation during UV and visible light photo-dissociation of ozone. S. Chakraborty and **S.K. Bhattacharya,** J. Chem Phys., 118, 2164, 2003.
44) Investigation on oxygen isotopic exchange between CO_2 and $O(^1D)$: Experimental demonstration of stratospheric results. S. Chakraborty and **S.K. Bhattacharya,** J. Geophys. Res., 108, No. D23, 4724, 2003.
45) Dinosaur coprolites from the Late Cretaceous (Maastrichtian) Lameta Formation: Isotopic and other markers suggesting a C_3 plant diet. Ghosh, **S.K. Bhattacharya**, A. Sahni, R.K. Kar, D.M. Mohabey, and K. Ambwani. Cretaceous Research, 24, 743-750, 2003.
46) Sudden warming epochs during 42 to 28 ky BP in the Himalayan region from Stable isotope record of sediment from a relict lake in Goting, Garhwal, North India. Prosenjit Ghosh and **S.K. Bhattacharya**, Proc. Ind. Acad. Sci.(Earth and Planet. Sci.), vol. 85, No.1, 101-108, 2003.
47) Changes in surface productivity and sub-surface denitrification during the Holocene: a multiproxy study from the eastern Arabian Sea. R. Agnihotri, **S.K. Bhattacharya**, M.M. Sarin , and B.L.K. Somayajulu, Holocene, 13,5, 701-713,2003.
48) Isotopic variations in Indian monsoon precipitation: Records from Bombay and New Delhi, **S.K. Bhattacharya**, K. Froehlich, P.K. Aggarwal and K.M. Kulkarni, Geophys. Res. Lett., vol. 30, No. 24, 2285, doi: 10.1029/2003GL018453, 2003.
49) Carbonate geochemistry across the Eocene/Oligocene boundary of Kutch, western India: implications to oceanic O2-poor condition and foraminiferal extinction. A. Sarkar, S. Sarangi, M. Ebihara, **S.K. Bhattacharya** and A.K. Ray, Chemical Geology, 201, 281-293, 2003.
50) Mio-Pliocene monsoonal record from Himalayan Foreland Basin (Indian Siwalik) and its relation to the vegetational change. P. Sanyal, **S. K. Bhattacharya**, R. Kumar, S.K. Ghosh and S.J. Sangode, Palaeo-Palaeo-Palaeo, 205, 23-41, 2004.
51) Stable isotopic study of late Neoproterozoic-early Cambrian(?) sediments from Nagaur-Ganganagar basin, western India: Possible signatures of global and regional C-isotope events. Aninda Mazumdar and **S.K. Bhattacharya**, Geochemical Journal, vol 38, 163-175, 2004.
52) Groundwater $d^{18}O$ and dD from Central Indian Peninsula: Influence of the Arabian Sea and the Bay of Bengal branches of the summer monsoon, S.K. Gupta, R.D. Deshpande**, S.K. Bhattacharya** and R.A. Jani, Journal of Hydrology, vol XX, 1-18, 2004.
53) Atmospheric CO2 during the late Paleozoic and Mesozoic: Estimates from Indian soils Prosenjit Ghosh, **S.K. Bhattacharya** and Parthasarathi Ghosh. In A History of Atmospheric CO2 and its effects o plants, animals and ecosystems Edited by J.R. Ehleringer, T. Cerling and M.D. Dearing, Ecological Studies vol. 177, pp. 8-34, Springer 2005.
54) Facies, dissolution seams and stable isotope compositions of the Rohtas Limestone (Vindhyan Supergroup) in the Son Valley area, central India. S. Banerjee, **S.K. Bhattacharya** and S. Sarkar, J. Earth System Science, vol 114, pp 87-96, 2005.
55) Carbon isotope ratio of dissolved inorganic carbon (DIC) in rivers draining the Deccan Traps, India: Sources of DIC and their magnitudes. Anirban Das, S. Krishnaswami and **S.K. Bhattacharya**, Earth and Planet. Sci. Lett., vol XX, 1-11, 2005.
56) Chemical diagenesis of Siwalik sandstone: Isotopic and mineralogical proxies from Surai Khola section, Nepal. Prasanta Sanyal, S.K. Bhattacharya and M. Prasad

Sedimentary Geology, vol. XX, 1-18, 2005.

57) Palaeovegetational reconstruction in Late Miocene: A case study based on early diagenetic carbonate cement from the Indian Siwalik. Prasanta Sanyal, **S.K. Bhattacharya,** Rohtas Kumar, S.K. Ghosh and S.J. Sangode, Palaeo-Palaeo-Palaeo., vol XX, 1-15, 2005.
58) Seasonal variations in the isotopes of oxygen and hydrogen in geothermal waters from Bakreswar and Tantloi, Eastern India: implications for groundwater characterization. N. Majumdar, R.K. Majumdar, A.L. Mukherjee, **S.K. Bhattacharya** and R.A. Jani, Journal of Asian Earth Sciences, June, 2005 (available online in www. Elsevier.com).
59) Characterization of recharge processes and groundwater flow mechanism in weathered-fractured granites using isotopes. B.S. Sukhija, D.V. Reddy, P. Nagabhushanam, **S.K. Bhattacharya**, R.A. Jani and Devender Kumar, Hydrogeology Journal (accepted for publication).

432. Detailed Bio-data of the Co-Principal Coordinator

1. Name : Rengaswamy Ramesh
2. Date of birth : 02 June 1956
3. Place of birth : Alwarthirunagari, Tamil Nadu, India.
4. Office Address : 265, Physical Research Laboratory
   Navrangpura, Ahmedabad 380 009.
   Ph: 079-26314265
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   e-mail: r.ramesh@prl.ernet.in
5. Residential Address: B 501, Suryavanshi Towers,
   Vastrapur, Ahmedabad 380 015.
   Ph: 079-26763980

6. Educational records :

S. No.	Degree	Subjects	Class/ Marks	Year	Univ.	Additional Particulars
1.	S.S.L.C	Science Mathematics	First / 83% 100%	1972	Madras Board	Merit Certificate
2.	P.U.C.	Physics Mathematics Chemistry	First / 70% 100% 86.5%	1973	Madras	Distinction in Maths & Chemistry
3.	B.Sc.	Physics(Main) Mathematics Chemistry	First / 83.8% 100% 84%	1976	Madras	Second rank
4.	M.Sc.	Physics	First GPA 5.96/6	1978	Madras	First rank
5.	Ph. D	Physics	NA	1984*	Gujarat	----------

** Thesis was submitted in Dec. 1984; degree certificated awarded in March 1986, as convocation was delayed by a year due to riots in 1985.*

7. Awards and Recognitions:

(a) National merit certificate from the Ministry of Education and Social Welfare, 1972, for excellent performance in the school final examination.
(b) All India Bengali Literary Conference medal, 1973, for outstanding performance in the pre- University examination.
(c) The Jawaharlal Nehru Memorial Fund Award, 1976, for excelling in the B.Sc examination.
(d) The Jagirdar of Arni Medal, Prof. P.E. Subrahmanya Ayyar Medal, Dr. K. S. Krishnan Gold Medal and Dr. K. S. Krishnan Memorial Prize, 1978 for securing the top position in the M.Sc. examination.
(e) **INSA Young Scientist Medal**, 1987.
(f) **SS Bhatnagar Award** for Earth, Atmosphere, Ocean and Planetary Sciences, 1998 (for Contributions to **Paleoceanography and climate change studies**).
(g) Best paper award for the papers presented in several National and International

Conferences:
(i) National Space Science Symposium, Nagpur, 1990.
(ii) Fifth national Mass spectrometry Conference, Ahmedabad, 1991.
(iii) Sixth National Mass spectrometry conference, Dehradun, 1993.
(iv) International Conference on Global Analysis, Interpretation and Modelling, Garmisch-Partenkirchen, Germany, 1995.
(v) One of the five papers selected in the Poster competition for developing Country Scientists, IGBP Open Science meeting, London, UK, 1998.
(vi) ISMAS Silver Jubilee Symposium, Goa, 2003.
(vii)11th ISMAS workshop, Shimla, 2004
(viii) First Ananthakrishnan memorial conference, IITM, Pune, 2005.

8. Research appointments:

Visiting Member at Physical Research Laboratory (PRL), Ahmedabad (1978-1984); Post Doctoral Fellow, PRL (1985-86); Research Associate, PRL (1987); Scientist-D, PRL (1987-94); Visiting Research Associate, Scripps Institution of Oceanography, San Diego, USA (3 months in 1992, 2 months in 1994); Reader, PRL (1994-1999); Associate Professor (999-2001);
currently Professor in the Planetary Geosciences Division at PRL (Grade Rs.16400-450-20000).

9. Present areas of interest:

Stable isotope mass spectrometry, paleoclimate , paleoceanography, isotopic tracers in earth system, climate modelling, satellite and biological oceanography (productivity measurements in the ocean using nitrogen isotopes).

10. Fellowship/Membership of Professional bodies:
Fellow of the Indian National Science Academy, the Indian Academy of ciences, and the National Academy of Sciences.

Life member of the Indian Society for Mass spectrometry, member for the paleoclimate part of the Indian Climate Research Program, ISRO- GBP working group Chairman and has served as member of SCOR/IMAGES working groups, sponsored by Scientific Committee for Ocean Research: WG 113: Evolution of the Indian monsoon in Marine records: comparison between Indian and East Asian subsystems WG 177: Synthesis of Decadal to millennial climate records of the last 80ky.

Member of INSA-SCAR committee for the second term.

Life member of the Gondwana Geological Society and the Indian Meteorological Society.

Lead author for the Paleoclimate chapter in the forthcoming IPCC Assessment Report 4 (WMO and UNEP).

List of publications of Dr R Ramesh during 1995-2005

1. S. Bartarya, S.K. Bhattacharya, **R. Ramesh** & B. L. K. Somayajulu (1995) $\delta^{18}O$ and δD systematics in the surficial waters of the Gaula river catchment area, Kumaun Himalaya *J. Hydrol.* **167,** 369-379.
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6. S.Chakraborty & **R. Ramesh** (1997) Environmental significance of carbon and oxygen isotope ratios of banded corals from Lakshadweep, India. *Quaternary International* **37:1,** 55-65.
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9. **R. Ramesh** & R.V. Krishnamurthy (1998) $\delta^{13}C$ of marine organic matter and ocean pH. *Geochem. Journal*, **32,1,** 65-69.
10. S.K. Singh, J.R. Trivedi, K. Pande, **R.Ramesh** & S.Krishnaswami (1998) Chemical and Sr, O, C isotopic compositions of carbonates from the Lesser - Himalaya: Implications to the Sr isotopic composition of the source waters of the Ganga, Ghaghara and the Indus rivers. *Geochim. Cosmochim Acta* **62,5,** 743-755.
11. J. S. Ray & **R. Ramesh** (1998) Stable carbon and oxygen isotope analysis of natural calcite and dolomite mixtures using selective acid extraction *J. Geol. Soc. Ind.* **52.,** 23-332.
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17. M. G. Yadava & **R. Ramesh** (1999) Speleothems – useful proxies for past monsoon rainfall, *J. Sci. Ind. Res.*, **58**, 339-348.
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34. D. Jagadheesha & **R. Ramesh** (2001) Past monsoons: A review of proxy data and modelling, *Mausam*, special issue on Global and Regional Climate Change (ed. G. B. Pant) **52**, 275-284.
35. M. G. Yadava & **R. Ramesh** (2001) Past rainfall and trace element variations in a tropical speleothem from India, *Mausam*, special issue on Global and Regional Climate Change (ed. G. B. Pant) **52**, 307-316.
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38. R. Korisettar and **R. Ramesh**, (2002) The Indian Monsoon: Roots, relations and relevance, in: Archaeology and Interactive Disciplines, Indian Archaeology in

retrospect, Vol. III, ed. s S. Settar and R. Korisettar, Indian Council of Historical Research, Manohar Publications, pp.23-59.

39. M. G. Yadava, **R.Ramesh** and G B Pant (2004) Past monsoon rainfall variations in peninsular India, recorded in a 331 year old speleothem, *Holocene*, **14**, 4, 517-524.
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41. R. P. Dhir, S. K. Tandon, B. K. Sareen, **R. Ramesh**, T K G Rao, A Kailath and N Sharma (2004) Calcretes in the Thar Desert: Genesis, Chronology and Paleoenvironment, *Proc. Ind. Acad. Sci. (Earth & Planet. Sci.)*, **113, 3**, 473-515.
42. Sanjeev Kumar, **R. Ramesh**, N. B. Bhosle, S. Sardesai and M S Seshshayee (2004) Natural isotopic composition of nitrogen in suspended particulate matter in the Bay of Bengal, *Biogeosciences* (EGU journal), **1**, 63-70.
43. **R. Ramesh** and M. G. Yadava (2004) Significance of stable isotopes and radiocarbon dating in fluvial environments, In: Lecture notes, DST Programme on Fluvial systems (ed. L. S. Chamyal), Dept. of Geology, M.S. University of Baroda, Vadodara, India, pp.107-149.
44. M. G. Yadava and **R. Ramesh** (2005) Monsoon reconstruction from radiocarbon dated tropical Indian speleothems, *Holocene*, **15**, 1, 48-59.
45. M. G. Yadava and **R. Ramesh** (2005) Decadal variability in the Indo-Gangetic monsoon rainfall during the last ~2800 years: Speleothem $\delta^{18}O$ evidence from the Sota cave, Uttar Pradesh, S*pecial publication of NCAOR, Goa*, in the press.
46. Sanjeev Kumar, **R. Ramesh**, M S Seshshayee, S. Sardesai and P. P. Patel (2005) Signature of terrestrial influence on nitrogen isotopic composition of suspended particulate matter in the Bay of Bengal, *Curr. Sci.* **88**(5) 770- 774.
47. Sanjeev Kumar and **R. Ramesh** (2005), Productivity measurements in the Bay of Bengal using the ^{15}N tracer: implications to the global carbon cycle, *Ind. J. Mar. Sci*.,**34(2)**, 153-162.
48. **R. Ramesh** and M. G. Yadava (2005), Climate and water resources of India, *Curr. Sci*. (in the press).
49. J. S. Ray and **R. Ramesh** (2005) Stable carbon and oxygen isotopic compositions of Indian carbonatites, *International. Geology reviews*, (in the press).
50. **R. Ramesh**, and M. Tiwari (2005), Significance of stable oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic compositions of individual foraminifera (*O. universa*) in a sediment core from the Eastern Arabian Sea, in "*Oceanic Micropaleontology, Paleoceanography and Paleoclimate*", edited by D. K. Sinha, M/s Narosa Publ. (representing Springer-Verlag), New Delhi, India. (in the press)
51. N. Sharma, R.A. Jani and **R. Ramesh** (2005) Oxygen isotope studies in an Ice wall near Maitri, Indian Antarctic Station, S*pecial publication of NCAOR, Goa* (in the press).

Other publications (news/ popular articles/reports)

52. M.K. Hughes & **R. Ramesh** (1982) Dendroclimatology in India *Tree-ring Society Newletter*, 20, 3-4.
53. **R. Ramesh** (1990) Carbon dioxide cycles, *Science Focus*, 1(4), 12-18.
54. **R. Ramesh** (1991) Past atmospheric CO_2 variations: a new approach, *Science Focus*, 2(1), 5-6.
55. **R. Ramesh** (1993) Corals as proxy indicators of past environmental changes, *Indian Meteorological Society Ahmedabad Newsletter,* 10, 5-7.
56. **R. Ramesh** (1999) Oceanic data for global change research, *IGBP in Action-**ISRO** GBP Newsletter*, 4, 8-11.

57. **R. Ramesh** (2000) A 300 year old δD record from a silver fir tree (*Abies pindrow*), from Pahalgam, Kashmir: Evidence for little ice age in India, In: IGBP in India 2000, A status report on projects, Indian National Science Academy, New Delhi, (ed. R Narasimha et al.), 314-318.
58. **R. Ramesh** (2000) Paleomonsoonal records from marine and land-based geological deposits in the Indian Region, In: IGBP in India 2000, A status report on projects, Indian National Science Academy, New Delhi, (ed. R Narasimha et al.), 319-323.
59. **R. Ramesh** (2000) Evaluation of the paleoclimatic potential of High resolution proxies (corals and speleothems) from the Indian region, In: IGBP in India 2000, A status report on projects, Indian National Science Academy, New Delhi, (ed. R Narasimha et al.), 314-318.

433. Detailed Bio-data of the Principal Investigator

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Sex	Male
Nationality:	Indian
Contact address:	
Official:	Scientist F and Head Hydrological Investigations Division National Institute of Hydrology, Roorkee-247 667 (Uttaranchal) Phone: 0091-1332-276414 Fax: 0091-1332-72123; Email: bk@nih.ernet.in
Residential:	135/1 Solanipuram Roorkee-247 667 (Uttaranchal) Phone: 0091-1332-70846 ; 272111 Mobile: 09897080846

Education:

1983	Ph. D. (Physics)	University of Roorkee, Roorkee
1976	M. Sc. (Physics)	Agra University, Agra
1974	B. Sc. (PCM)	Agra University, Agra

Professional Training

1993	Application of Environmental Isotopes in Hydrology (Under UNDP Training Program)	University of Paris, France
1990	Isotope Techniques in Hydrology (IAEA Regional Training Course)	BARC, Mumbai

Experience:

1978		Hydrologist, Uttar Pradesh Ground Water Department, Lucknow
1990	Scientist C, Nuclear Hydrology Div.	National Institute of Hydrology
1993	Scientist E & Head N. H. Div.	National Institute of Hydrology
Scientist F and Head**, H. I. Div**		National Institute of Hydrology

Summary of Work Experience

Worked as Hydrologist in the field of Isotope Hydrology for 12 years in a govt. organisation (U.P. Ground Water Department, Lucknow, India), where intense use of isotope techniques for the study of canal seepage, groundwater flow velocity and in the estimation of natural recharge to groundwater were initiated by the investigator.

Working as Scientist and Head of N.H./H.I. Division at National Institute of Hydrology, Roorkee, India for the last 13 years, initiated isotope applications studies including establishment of a standard laboratory. Developed various sample preparation lines for isotopic analyses including benzene synthesizer, tritium enrichment unit and several other instruments. The experience in instrumentation was fully utilized in developing new hydrological equipment such as depth water sampler, automatic hydrologic station for sediment, flow and hydromet measurements for watershed studies. Several Isotope Hydrological studies and consultancy projects have been completed/in progress. In addition the following scientific / administrative responsibilities were / are being shouldered:

Served as Head of the Regional Centre of the National Institute of Hydrology at Sagar (MP) for two years.
Served as a examiner for several M.Sc./M. Tech/Ph. D. thesis at the Indian Institute of Technology Roorkee and at Gurukuk Gangri Vishwa vidyalaya, Hardwar.
Guided several Ph. D. thesis, M. Sc., M. Tech, and M. E. thesis at IIT-R, Roorkee.
Organised one International Conference and several training courses/workshops in the field of Hydrology and Water Resources.
Guiding, helping and collaborating with a number of State/central govt. organisations for Isotope hydrological studies.
Serving as a member representing Asia-Pacific region in the Steering Committee of the Joint International Isotopes in Hydrology Program of IAEA/UNESCO.

Research Experience:

1 Soil moisture variation and movement through unsaturated soil strata and estimation of recharge to aquifers using isotope techniques. Carried out column experiments in laboratory and field for fluid flow through porous media using tracer (isotope) techniques.
2 Use of isotopes chemical approaches to establishes interconnections in water bodies and source of salinity in different geological settings.
3 Identification of recharge sources and location of recharge zones for deeper aquifers using isotope techniques.
4 Geohydrological and surface water and groundwater interaction studies in the Ganga basin using isotope techniques.
5 Dating of groundwater and Watershed studies
6 Groundwater pollution / salinization and sea water intrusion using environmental isotopes
7 Evaluation of artificial recharge measures, Seepage / leakage from water bodies and soil erosion from catchments using isotopes.
8 Limnological studies (completed a number of hydrological studies on lake sedimentation, water balance and pollution aspects and several are in progress) using isotope techniques.

Membership in professional societies and activities in civic, public or international affairs.

1. Life Member of Indian Association of Hydrologists (IAH)
2. Life member of Indian Association for Application of radioisotopes and radiations in industry.
3. Life member of Indian Water Resources Society (IWRS).
4. Life member of Indian Society for Mass Spectrometry (ISMS).
5. Member of International Association for Hydrological Sciences (IAHS).

List of research publications

I <u>Technical papers in Refereed Journals</u>

1. Nachiappan, Rm. P., Bhishm Kumar, Rm. Manickavasagam and S. Balakrishnan (2003) Hydrochemical characteristics of groundwater in Nainital lake basin: Implication on the landslide hazards. *J. of Geological Society of India* **(accepted for publication)***.*
2. Nachiappan, Rm. P., Bhishm Kumar and Rm. Manickavasagam (2002) Estimation of sub-surface components of water balance of lake Nainital (Kumaun Himalaya, India) using environmental isotopes. *Hydrol. Sciences J.* **47SI**:

3. Saravanakumar, N. Jacob, S. V. Navada, S. M. Rao, Rm. P. Nachiappan, Bhishm Kumar, and J. S. R. Murthy (2001) Study of lake hydrodynamics using environmental isotopes. *Hydrological Processes* **15:**425-439.
4. Bhishm Kumar and Rm. P. Nachiappan (1999) On the sensitivity of Craig and Gordon model for the estimation of isotopic composition of lake evaporates. *Water Resources Research* **35(5)**:1689-1691.

5. Saravanakumar, S. V. Navada, S. M. Rao, Rm. P. Nachiappan, Bhishm Kumar, T. M. Krishnamoorthy, S. K. Jha and V. K. Shukla (1999) Determination of recent sedimentation rates and pattern in Lake Naini, India by ^{210}Pb and ^{137}Cs dating techniques. *Int. J. Applied Radiation and Isotopes* **51**:97-105
6. Bhishm Kumar, S. P. Rai, Rm. P. Nachiappan, Saravanakumar and S. V. Navada (1999) Improved prediction of life expectancy for a Himalayan Lake: Nainital, U.P., India. *Mountain Research and Development* **19(2)**:113-121

II <u>Technical papers in Conferences</u>

1. *Nachiappan, Rm. P., M. Someshwar Rao, Bhishm Kumar, S. V. Navada and P. Satyanarayana (2003) Chemical and isotopic techniques for development of groundwater management strategies in a coastal aquifer: Krishna river delta, South India.* ***Accepted for oral presentation*** *in the International Symposium on Isotope Hydrology and Integrated Water Resources Management, International Atomic Energy Agency, 19 - 23 May 2003 Vienna, Austria*
2. Bhishm Kumar, P. P. Berde, Rm. P. Nachiappan, Himansu Joshi, S. V. Navada and K. M. Kulkarni, (2003) Isotopic and hydrochemical approaches to Study the Salinity Affected Areas in Amarawati Districts of Maharastra State in India. **Accepted for poster presentation** in the International Symposium on Isotope Hydrology and Integrated Water Resources Management, International Atomic Energy Agency, 19 - 23 May 2003 Vienna, Austria
3. Nachiappan, Rm. P. and Bhishm Kumar (2002) Water Quality Aspects of Lake Nainital, Kumaun Himalayas, Uttaranchal. In:(AL. Ramanathan and R. Ramesh, Editors) *Recent Trends in Hydrogeochemistry*. Proceedings of an International workshop, Jawaharlal Nehru University, Delhi. Capital publishing company, New Delhi. pp. 103-113.
4. Bhishm Kumar and Rm. P. Nachiappan (2002) Comprehensive hydrological investigations of Nainital lake using multiple tracer techniques. Presented in The International Conference on Quarternary Climate, Tectonics and Environment of the Himalaya: Comparison with other regions, Kumaun University, 11-15 March, 2002, Nainital, India
5. Bhishm Kumar and Rm. P. Nachiappan (2002) Hydrological findings crucial for the effective management of Lake Nainital in Kumaun Lesser Himalaya, Uttaranchal. Presented in the National Seminar on Natural Wealth of Uttaranchal, Lucknow University Alumni Asociation, 14-15 March, 2002, Dehradun, India.
6. Bhishm Kumar and Rm. P. Nachiappan (2002) Isotopic investigations for lakes: A case study of lake Nainital in Kumaun Lesser Himalaya, India. Presented in the International Conference on Water Resources Management in Arid Regions (WaRMAR) Kuwait Institute for Scientific Research, 23-27 March, 2002, Kuwait.
7. Rao, M. S., Bhishm Kumar, U. K. Singh, Rm. P. Nachiappan and Jagmohan (2002) Exploring recharge sources and zones for deeper aquifers using environmental isotopes: A case study. Proc. of The International Conference on Water Resources Management in Arid Regions (WaRMAR) Kuwait Institute for Scientific Research, 23-27 March, 2002, Kuwait. Vol. 2: 61-75.
8. *Nachiappan, Rm. P.* and Bhishm Kumar (2001) Integrated use of isotopic and

conventional techniques to study water balance of lake Nainital. Presented in The International Workshop on Integrated Water Management, Bangalore University, 21-23 June, 2001, Bangalore, India.

9. Bhishm Kumar, *Rm. P. Nachiappan* and Pankaj Mani (2001) Estimation of sedimentation rates and life expectancy of Umiam Barapani reservoir in Meghalaya using sediment dating techniques. Proc. National Seminar on Water and Land Management including CAD for Socio Economic Upliftment of NE Region, NERIWALM, 22-23 December, 2001, Guwahati, India. Volume III:19-28.
10. Bhishm Kumar and Rm. P. Nachiappan (2000) Estimation of alluvial aquifer parameter by single-well dilution technique using isotopic and chemical tracers - A comparison. In: (A. Dassargues, editor) *Tracers and Modelling in Hydrogeology*. Proc. of a Liege Conference, **IAHS Pub. No. 262**:215-218
11. Nachiappan, Rm. P., Bhishm Kumar, U. Saravanakumar, Noble Jacob, T. Baby Joseph, Suman Sharma, S. V. Navada and Rm. Manickavasagam (2000) Estimation of sub-surface components of water balance of lake Nainital (Kumaun Himalaya, India) using environmental isotopes. Proc. of an Int. Conference on Integrated Water Resources Management for Sustainable Development (ICIWRM-2000), Roorkee, India.
12. Rao, M. S., Bhishm Kumar, Rm. P. Nachiappan and Jagmohan (2000) Identification of aquifer recharge sources and zones in Ganga - Yamuna Doab using isotope techniques. Proc. of an Int. Conference on Integrated Water Resources Management for Sustainable Development (ICIWRM-2000), Roorkee, India.
13. Nachiappan, Rm. P. and Bhishm Kumar (1999) Study of the interconnection between a lake and surrounding springs using environmental tracers in Kumaun Lesser Himalayas. In (Ch. Leighbundgut, editor) *Integrated methods in catchment hydrology - Tracer, Remote Sensing and New Hydrometric Techniques*. Proc. of a Birmingham Symposium, **IAHS Pub. No. 258**:53-56
14. Bhishm Kumar, Rm. P. Nachiappan and S. P. Rai (1999) Water Balance and impact of sedimentation on the hydrology of a Himalayan Lake. *Proc. of Int. Conference on Water, Environment, Ecology, Socio-economic and Health Engineering* (WEESHE), October 18-20, Seoul, Korea.
15. Bhishm Kumar and Rm. P. Nachiappan (1999) Application of radiometric dating techniques to study the impact of sedimentation on the life and hydrology of a Himalayan lake. *Proc. of the National Workshop on Hydrologic and Hydraulic Routing in Alluvial Streams* (NWHHRAS-99), Indian Association of Hydrologists, 26-27 November, Roorkee.
16. Bhishm Kumar, Rm. P. Nachiappan, S. P. Rai and U. Saravanakumar (1997), Radiometric dating techniques for the estimation of sedimentation rate and lake life - A case study. Proc. Intl. Symp. Emerging Trends in Hydrology, 25-27 September, University of Roorkee, Roorkee, India

III. <u>Research reports</u>

1. Bhishm Kumar and Rm. P. Nachiappan (1998) ‘Water Quality Studies on Lake Nainital and Surroundings’, Case Study Report, CS(AR)-1/1999-2000. National Institute of Hydrology.

2. Bhishm Kumar and Rm. P. Nachiappan (1998) 'Estimation of Sedimentation Rates and Pattern and useful life of Lake Nainital, in Kumaun Himalayas, U. P., using radiometric dating techniques’, Case Study Report, CS(AR)-1/98-99. National Institute of Hydrology.
3. Bhishm Kumar and Rm. P. Nachiappan (1998) 'Water Balance of Lake Nainital, Kumaun Himalayas, UP', Case Study Report, CS(AR)-6/98-99. National

Institute of Hydrology.

4. Bhishm Kumar and Rm. P. Nachiappan (2000) 'Estimation of rates and pattern of sedimentation and useful life of Dal-Nagin lake, Jammu and Kashmir using natural fallout of Cs-137 and Pb-210 radioisotopes', Case Study Report, TR/BR-11/1999-2000. National Institute of Hydrology.
5. Bhishm Kumar and Rm. P. Nachiappan (2000) 'Study of Lake Nainital - groundwater interaction using isotope techniques', Case Study Report, CS/AR-37/98-99. National Institute of Hydrology.
6. Bhishm Kumar, M. Someshwar Rao, Rm. P. Nachiappan and Jagmohan (2002) 'Identification of sources and zones of recharge to groundwater in Hardwar and Saharanpur Districts', Case Study Report, National Institute of Hydrology.
7. Jain, S. K., S. P. Rai, Bhishm Kumar and Rm. P. Nachiappan (2000) 'Sedimentation study of Mansar lake, District Udhampur (J&K)', CS/AR-11/1999-2000. National Institute of Hydrology.

IV Information Brochures

1. Bhishm Kumar and Rm. P. Nachiappan (1997) 'Use of Isotope Techniques in Hydrology'. National Institute of Hydrology. Target readers: Field Engineers, Common public and Non-Government Organisations
2. Bhishm Kumar and Rm. P. Nachiappan (1999) 'High-lights of the Project on Hydrological Studies of Lake Nainital, Kumaun Himalayas, Uttar Pradesh'. National Institute of Hydrology. Target readers: Senior Level Government Executives and Non-Government Organisations

434. Detailed Bio-data of the Principal Investigator

1. **Name :** DR. P. S. DATTA
2. **Date of Birth**: 3rd June, 1950
3. **Current Position:** Project Director & Professor, Nuclear Research Laboratory, Indian Agricultural Research Institute, New Delhi-110012.
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6. **E-mail:** dattapsdsd@rediffmail.com or psdatta@iari.res.in
7. **Academic Record:** Ph. D. (I. I.T, Kanpur) 1975; M. Sc. (I. I.T, Kanpur) 1970
8. **Experience:** Thirty four years experience on application and development of isotope tracers approaches and nuclear techniques for investigations on crop production linked assessment and management of water resources in river basins and agro-ecosystems of semi arid and arid regions; processes controlling nutrients leaching; modelling of soil moisture movement; plants water-use efficiency; soil-water plant relationships; groundwater provenance, recharge characteristics, flow-pathways of intermixing, groundwater-surface water interactions; influent and effluent seepage; delineation of aquifer recharging zones and hydrodynamic zones; groundwater pollution characteristics; irradiation for post-harvest preservation and environmental impact assessment.
9. **Publications**:
   (a) Research Papers - Hundred and six (b) Books/Book Chapters - Three

10. Award / Recognition / Invitations

* CPCB, NRDC, ASSOCHAM Award for best research work on Sustainable Water Supply, Rechargeability and Contamination Related Groundwater Protection Strategies.
* Golden Jubilee Honour 'Outstanding Talent' for research contributions on Nuclear Physics applications, by Bundelkhand University, Jhansi and D.V.College, Orai.
* Zayed International Prize for Environment, UAE, honour for research contribution on desrtification and groundwater contamination in arid region.
* Invited Consultant, IAEA, Vienna Coordinated Reasearch Project on Isotope Hydrology.
* Invited Faculty Member on Isotope Hydrology, Department of Hydrology, I.I.T., Roorkee and on Groundwater Hydrology, Deptt. of Environmental Biology, University of Delhi.
* Invited Consultant on Clean Water Campeign, Centre for Science and Environment, New Delhi.
* Invited Consultant on Water Supply Programmes and Groundwater Hydrology, Fluorosis Research and Rural Development Foundation, New Delhi.
* Invited Member, New York Academy of Sciences, USA.
* Invited Member, Research Board of Advisors, American Biographical Institute, USA.
* Invited Key Speaker on Water Resources Assessment, Protection and Management, in many International/National Conferences/Seminars/Workshops/Training Courses.
* Nominated for 'Blaskar Award' for Environmental Sciences and Engineering, by

San Diego Foundation, USA.

* Nominated for Fellow, National Academy of Agricultural Sciences.
* Member, Academic Council, Indian Agricultural Research Institute, New Delhi.
* Member, National Coordination Committee for Isotope Hydrology, Department of Atomic Energy, Govt. of India.
* Member, ISI Panel (BDC46:p6) for Glossary of Terms on Hydrology.
* Member, Research Advisory Board, Sri Ram Institute of Industrial Research, New Delhi
* Member, Water Quality Control Authority, Min. of Water Resources, Govt. of India

11. Special Assignments:

1 Member-Secretary, High level Technical Committee on Hydrology (Min. of Water Resources, Govt. of India) and Experts panels on Groundwater, Hydro-meterology, Water Quality, Erosion and Sedimentation, Education and Training. (1984-85).

2 Member-Secretary, ARCCOH/UNESCO Steering Committee on Hydrology. (1983-84).

3 Member/Scientist-In-Charge, ARCCOH/UNESCO Working Group on Major Regional Project for Conservation and Utilization of Water Resources for the Rural Communities in the Asian Region. (1983-84)

4 Member-Secretary, Expert Review Group to identify International Hydrological Programme (UNESCO) phase-III Projects/Plans. (1983-85).

12. Travel Abroad: USSR, Austria, UAE, Netherlands, Finland, Hungary, Nepal.

LIST OF THE PROJECT THEME RELATED PUBLICATIONS OF DR. P.S. DATTA

(a) Journal Research Papers

1) P.S.Datta and P.S.Goel (1977). Groundwater recharge in Punjab state (India) using tritium tracer. Nordic Hydrology, 8, 225-236.
2) P.S.Goel, P.S.Datta, and B.S.Tanwar (1977). Measurement of vertical recharge to groundwater in Haryana state (India) using tritium tracer. Nordic Hydrology, 8, 211-224.
3) P.S.Datta, S.K.Gupta, A.Jayasurya, V.N.Nijampurkar, P.Sharma and M.I.Pulsnin (1980). A survey of Helium in groundwater in parts of Sabarmati basin in Gujarat state and in Jaisalmer District, Rajasthan. Hydrological Sciences Bulletin, IAHS Publn., 25, 2, 6/(1980), pp.183-193.
4) P.S.Datta, S.K.Tyagi and H.Chandrasekharan (1991). Factors controlling stable isotope composition of rainfall in New Delhi, India. J. Hydrol., 128: 223-236.
5) P.S.Datta, S.K.Bhattacharya and S.K.Tyagi (1996). ^{18}O studies on recharge of phreatic aquifers and groundwater flow paths of mixing in Delhi area. J. Hydrol., vol.176, pp.25-36.
6) P.S.Datta, D.L.Deb and S.K.Tyagi (1996). Stable isotope (^{18}O) investigations of the processes controlling fluoride contamination of groundwater. J. Contaminant Hydrology, 24(1): 85-96.
7) P.S.Datta, D.L.Deb and S.K.Tyagi (1997). Assessment of groundwater contamination from fertilizers in Delhi area based on ^{18}O, NO_3- and K^+ composition. J. Contaminant Hydrology, 27(3-4):249-262.
8) P.S.Datta, S.K.Tyagi, S.K.Bhattacharya, P.Mookerjee, N.Gupta & P.D.Bhatnagar (1999). Groundwater NO_3 and F contamination processes in Pushkar Valley, Rajasthan as reflected from ^{18}O isotopic signature and ^{3}H recharge studies. J. of Environemntal Monitoring and Assessment, vol.56: 209-219.
9) D.V.Borole, S.K.Gupta, S.Krishanswami, P.S.Datta and B.I.Desai (1979). Uranium isotopic investigations and radiocarbon measurement of river-groundwater systems, Sabarmati Basin, Gujarat, India. Isotope Hydrology,

1978, Vol.1, IAEA-SM-228/11, 118-201, IAEA, Vienna.
10) P.S.Datta, P.S.Goel, Rama and S.P.Sangal (1973). Groundwater recharge in western Utter Pradesh. Proc. Ind. Acd. Sci., 78, Sec. A, pp. 1-12.
11) P.S.Datta, B.I.Desai and S.K.Gupta (1979). Comparative study of groundwater recharge rates in parts of Indo-Gangetic and Sabarmati alluvium plains. Mausam, 30,1, 129-133.
12) P.S.Datta, B.I.Desai and S.K.Gupta (1980). Hydrological investigations in Sabarmati basin-I. groundwater recharge estimation using tritium tagging method. Proc. Ind. Natn. Sci. Acad., Phys. Sci., 46, No.1, p. 84-98.
13) P.S.Datta, S.K.Gupta and S.C.Sharma (1980). A conceptual model of water transport through the unsaturated soil zone. Mausam, 31(1): 9-18.
14) D.P.Agarwal, P.S.Datta, Zahid Husain, R.V.Krishanmurthy, V.N.Mishra, S.N.Rajaguru and P.K.Thomas (1980). Paleoclimate, stratigraphy and prehistory in north and west Rajasthan. Proc. Ind. Acd. Sci. (Earth Planet Sci.), Vol.89, No.1, pp.51-66.
15) P.S.Datta and V.B.Lal (1987). Indian laws for water pollution control. Economics and Political Weekly, pp.1-14.
16) P.S.Datta and V.B.Lal (1988). Protection for air pollution control. Economics and Political Weekly, pp.1-12.
17) P.S.Datta, S.K.Bhattacharya, P.Mookerjee and S.K.Tyagi (1994). Study of groundwater occurence and mixing in Pushkar (Ajmer) Valley, Rajasthan with ^{18}O and hydrochemical data. J. Geol. Soc. India. 43: 446-456.
18) P.C.Pande, P.S.Datta and S.K.Bhattacharya (1994). Biphasic enrichment of ^{18}O in developing wheat grain water. Indian J. Plant Physiol., Vol.XXXVII, No.1, pp. 30-31.
19) P.S.Datta (1995). Meteorological synoptic situation in relation to ^{18}O of New Delhi rainfall. J. Nuclear Agric. Biol. 24(1): 8-12.
20) P.S.Datta, S.K.Bhattacharya, S.K.Tyagi and R.A.Jani. (1995). Vegetative growth and ecophysiological significance of ^{13}C and ^{18}O composition of air-CO_2. Plant Physiol. and Biochem., Vol.22(1), pp. 64-67.
21) S.K.Tyagi and P.S.Datta (1995). Stable isotopic and hydrochemical study on groundwater contamination at IARI farm. J. Nuclear Agric. Biol. 24(4): 248-252.
22) P.S.Datta and S.K.Tyagi (1996). Major ion chemistry of groundwater in Delhi area: Chemical weathering processes and groundwater flow regime. J.Geol.Soc.India., vol.47, pp.179-188.
23) P.S.Datta, P.Mookerjee and S.K.Tyagi (1997). Significance of ^{18}O-analyses in identification of rainfall moisture source and potential groundwater zones. Proc. International Seminar on Monsoon Meteorology and Water Resources Hydrology, Journal of Applied Hydrology, Vol X, No.3,4: 46-53.
24) P.S.Datta, P.Mookerjee, H.Chandrasekharan, and T.K.Mukherjee (1990). Variability in groundwater recharge through the unsaturated zone. Bulletin of Radiation Protection. Vol.13, No.1, pp.127-130.
25) P.S.Datta, S.K.Bhattacharya and S.K.Tyagi (1995). Seasonal variability of ^{13}C and ^{18}O in atmospheric CO_2 and biosphere-hydrosphere interactions. Annales Geophysicae Supplement. Vol.13, European Geophysical Society Publn., pp.3-7.
26) P.S.Datta and S.K.Tyagi (1995). Impact of changing land use and urbanisation on groundwater hydrology in Delhi area. Annales Geophysicae Supplement. Vol.13, European Geophysical Society Publn., pp.8-12.
27) P.C.Pande, P.S.Datta, S.K.Bhattacharya, and S.K.Tyagi. (1995).Post-anthesis metabolic enrichment of $H_2{}^{18}O$ in wheat grain. Indian J. of Exp. Biology. Vol.33, pp.394-396.
28) S.K.Tyagi, P.S.Datta and P.Mookerjee (1997). Groundwater quality fluctuations in

the IARI farm New Delhi. J. Indian Water Res. Soc. Vol.17(3):41-43.

29) H.Chandrasekharan, P.S.Datta, T.K.Mukherjee and S.K.Tyagi (1990). Temporal variation of Deuterium and oxygen-18 in groundwater in IARI farm, New Delhi. J. Nuclear Agric. Biol., 19: 137-139.
30) P.S.Datta (1990). Deuterium and oxygen-18 studies in groundwater of Delhi area, India - comments. J. Hydrol., 113: 385-389.
31) P.S.Datta, and S.K.Gupta (1978). Soil moisture movement and groundwater recharge by tritium tagging method- discussion, Current Science, Vol.47, No.2, Jan. 20, pp.51.
32) P.S.Datta and Ashok Jain (1987). FICCI-CSIR National Conference on technology for self-reliance and growth. J. Scientific & Industrial Research. Vol.46, 429-432.

(b) Research Papers in Proceedings Seminars/ Symposia/ Conferences

International:

33) P.S.Goel, P.S.Datta, Rama, S.P.Sangal, Hans Kumar, Prakash Bahadur, R.K.Sabharwal and B.S.Tanwar (1978). Tritium tracers studies on groundwater recharge in the alluvial deposits of Indo-gangetic plains of Western U.P.,Punjab and Haryana. Proc.Indo-German Workshop on "Approaches and methodologies for development of groundwater resources", Hyderabad, pp.309-322.
34) P.S.Datta, B.I.Desai, S.K.Gupta and A.Jayasurya (1978). Soil moisture movement through vadose zones in alluvial plains of Sabarmati basin. Current Trends in Arid Zone Hydrology, Proc. International Symp. on "Study and Management of Water Resources in Arid and Semi-arid Regions", Ahmedabad, pp. 12-27.
35) N.Bhandari, P.S.Datta, and S.K.Guapta (1978). Groundwater velocity around Pokharan and confinement of radioactivity produced by the Nuclear Explosion. Current Trends in Arid Zone Hydrology, Proc. International Symp. on "Study and Management of Water Resources in Arid and Semi-arid Regions", Ahmedabad, pp. 127-135.
36) D.P.Agarwal, P.S.Datta, S.Kusumugar, N.C.Mehrotra, V.Nautiyal, R.K.Pant and S.L.Shali (1979). Preliminary sedimentological studies on the Quaternary deposits of Kashmir. Proc. '9th International Seminar on "Himalayan Geology", Dehradun. Himalayan Geology. Vol.9, Part-II, pp.631-637.
37) P.S.Datta, P.S.Goel, B.C.Raymahashay and Yudhbir (1973). Tracer investigation of groundwater flow in gangetic alluvium near Kanpur. Proc. Indo-Soviet Symposium on "Recent Trends in exploration of minerals, oil and groundwater", New Delhi. pp.1-12.
38) P.S.Datta and S.Banerji (1981). Fluctuations of groundwater quality in shallow aquifers of Kanpur Metropolis, India. Abstract: Proc. International Symp. on "Quality of groundwater", ISQW'81, Amsterdam. pp.1-3.
39) P.S.Datta (1983). Trend analysis of the Sabarmati river quality at Ahmedabad for decade (1969-78). IAHS Publn. No.141, Proc. IAHS Symp. on "Dissolved load of rivers and surface water quality/quantity relationship", XVIII General Assembly of the IUGG, Hamburg, Federal Republic of Germany. pp. 71-77.
40) P.S.Datta, S.K.Bhattacharya and S.K.Tyagi (1994). Assessment of groundwater flow conditions and hydrodynamic zones in phreatic aquifers of Delhi area using oxygen-18. Proc. International Workshop on Groundwater Monitoring and Recharge in Semi-arid Areas, Hyderabad IAH/UNESCO Publn. pp. S IV12 - S IV24.
41) P.S.Datta and S.K.Tyagi (1995). Isotopic investigations on groundwater recharge conditions and flow regime in Delhi region - a review. Proc. International Conf. Water & Energy 2001, CBIP Diamond Jubilee R&D Session, New Delhi. Oxford and IBH Publn., Vol-II, pp. 629-642.
42) P.S.Datta and S.K.Tyagi (1995). Groundwater resource management alternatives

with changing landuse and urbanisation in Delhi area. Proc. International Conf. Water & Energy 2001, CBIP Diamond Jubilee R&D Session, New Delhi. Oxford and IBH Publn., pp.41-44.

43) P.S.Datta and S.K.Tyagi (1995). Geochemical processes controlling groundwater quality in Pushkar Valley, Rajasthan, India. Proc. IGCP-349 International Conf. on Quaternary Deserts and Climatic change, Al Ain, UAE. Balkema Publishing Co. (Netherlands). pp.397-401.

44) P.S.Datta and S.K.Tyagi (1995). Groundwater intermixing model and recharge conditions in Delhi area as derived from oxygen-18 and Deuterium. Sub-surface water Hydrology, Kluwar Academic Publication, Netherlands, pp. 103-119.

45) S.K.Tyagi, P.S.Datta, P.Mookerjee and S.K.Bhattacharya (1997). Delineation of groundwater zones and contamina-tion characteristics based on ^{18}O-isotopic and SO-ion data. Proc. 2nd International R&D Conference on Water and Energy, 21-24 Oct. 1997, Vadodara, Organised by Central Board of Irrigation and Power, New Delhi, pp.112-122.

46) S.K.Tyagi, P.S.Datta, and S.K.Bhattacharya (1997). ^{18}O-isotope imaging of groundwater in Najafgarh block, Delhi to assess availability under changing recharge conditions. Proc. International Symp. on 'Emerging Trends in Hydrology', September 25-27, 1997, S8, pp.711-718.

47) P.S.Datta, S.K.Tyagi and P. Mookerjee (1997). Estimating contributions to groundwater from rainfall and lateral flow in urbanised area based on ^{18}O-Cl relationship. Proc. International Conference on 'Isotopes in the Solar System', 11-14, Nov. 1997, Ahmedabad, pp.177-178.

48) P.S.Datta, S.K.Bhattacharya, S.K.Tyagi, R.A.Jani (1997). $^{1}3C/^{1}2C$ studies on assessment of water-use-efficiency of vegetation in an agroecosystem. Proc. International Symposium on 'Isotopes in the Solar system'. 11-14, Nov. 1997. Ahmedabad, pp.175-176.

49) P.S.Datta and S.K.Tyagi (1998). An approach for assessment of risk from groundwater contamination in Delhi area. IHP/UNESCO Proc. 2nd Internatinal Symposium on Assessing and Managing Health Risks for Drinking Water Contamination: Approaches and Applications, September 7-10, 1998, Santiego, Chile, pp.12-15.

50) P.S.Datta, K.M.Manjaiah and S.K.Tyagi (1999). ^{18}O isotopic characterisation of non-point source contributed heavy metal (Zn and Cu) contamination of groundwater. Proc. International Symposium on Isotope Techniques in Water Resources Development and Management, May 10-14, 1999, Vienna, IAEA-SM-361/35, p. 190-198.

51) P.S.Datta and S.K.Tyagi (2000) Evaluation and management of groundwater resources in fluorosis endemic areas in Rajasthan State, India. Proc. Dubai International Conference on Desertification, 12-15 February, 2000. Zayed International Prize, UAE Publn., p. 162-164.

52) P.S.Datta (1998). (Invited Lead paper). An overview of chemical contamination of groundwater in India. Proc. International Conference on Environment and Health, July 7-9, 1998, New Delhi. Centre for Science and Environment, New Delhi, Publn. (In press)

53) P.S.Datta, K.M.Manjaiah and S.K.Tyagi (1999). Irrigation water management strategies as derived from $^{18}O/^{16}O$ and $^{13}C/^{12}C$ isotope signatures in water-plant-air interface. Proc. International Conference on Managing Natural Resources, February 14-18, 2000, New Delhi. p. 564-565.

54) K.M.Manjaiah, P.S.Datta and U.Sen (1999). Soil organic matter stocks and turnover under different crop management practices in an agricultural ecosystem. Proc. International Conference on Managing Natural Resources, February 14-18, 2000, New Delhi. p. 564.

55) P.S.Datta (2000) Groundwater pollution and over exploitation linked environmental issues for land resources management. Proc. International Conf. on Land Resources Management for Food, Employment and Environmental Security, New Delhi, 7-13 November, 2000. In "Advances in Land Resource Management for 21st Century", Soil Conservation Society of India, Publn., p. 471-479.
56) P.S.Datta and S.K. Tyagi (2000) Advances in groundwater research for integrated management and sustainable development. Proc. International Conf. on Integrated Water Resources Management for Sustainable Development, New Delhi, 19-21 December, 2000. p. 623-632.
57) P.S.Datta, S.K. Rohilla and S.K. Tyagi (2001) Integrated approach for water resoueces management in Delhi region: Problems and perspectives. Proc. International Symposium on Regional Water Resources Mangement, 6th Scientific Assembly of the IAHS, Maastricht, Netherlands, 18-27 July, 2001. IAHS Publn. "Regional Management of Water Resources", No. 268, p. 1-8.
58) P.S.Datta, S.K.Rohilla and S.K.Tyagi (1999). Sustainable supply, rechargeability and fluoride pollution related groundwater issues in urbanised areas. Proc. Xth World Water Congress, March 11-17, 2000, Melbourne, Australia. (In press).
59) P.S.Datta and S.K. Tyagi (2001) Climatic significance of stable isotopes charateristics of air-CO2 and rainfall in Delhi area water-plant-air system. Proc. International Conference on Study of Environmental Changes Using Isotope Techniques, Vienna, Austria, 23-27 April, 2001. (In press).
60) D.K. Joshi, A.P.S. Verma and P.S. Datta (2001) Isotopomer distributions linked determination of oil, dry rubber and water contents in seeds, latex and crop plants using pulsed NMR spectroscopy. First International Symposium on Isotopomers, 23-26 July, 2001, Yokohama, Japan. (Abstract accepted).
61) P.S. Datta, S.K. Tyagi, S.K. Bhattacharya, R.A. Jani, S.K. Mohiddin and D.K. Chadha (2001) Isotopic characterization of groundwater vulnerability to pollution from industrial activities. Proc. International Conference on Industrial Pollution and Control Technologies (ICIPACT) - 2001, December 7-10, 2001, Hyderabad. (Accepted).
62) P.S. Datta and S.K. Tyagi and S.K. Mohiddin (2002) Isotopic approaches for groundwater assessment, development and management in semi-arid regions, International Conference on Water Resources and Integrated Management in the Third Millenium, 2-6 February, 2002, Dubai, United Arab Emirates. (Abstract accepted).
63) P.S. Datta, S.K. Bhattacharya, S.K. Tyagi and R.A. Jani (2002) Applications of ^{2}H, ^{13}C, ^{18}O stable isotopes for sustainable management of overexploited groundwater aquifers. International Conference on Isotopes, 10-14 March, 2002, Cape Town, South Africa. (Abstarct accepted).
64) S.K. Tyagi, P.S. Datta, S.K. Bhattacharya, R.A. Jani, S.K. Mohiddin and D.K. Chadha (2002) Isotopic characterisation of Delhi area groundwater pollution. International Conference on Isotopes, 10-14 March, 2002, Cape Town, South Africa. (Abstract accepted).
65) P.S. Datta, S.K. Tyagi, S.K. Bhattacharya, R.A. Jani, and S.K. Mohiddin, Isotope tracer studies significance for calibration of pollutants transport model in alluvial groundwater systems, 4th International Conference on Calibration and Reliability in Groundwater Modelling, 17-20 June, 2002, Prague, Czech Republic. (Abstract accepted).
66) P.S. Datta, S.K. Tyagi, S.K. Bhattacharya, R.A. Jani and S.K. Mohiddin (2002) Isotopic assessment of groundwater vulnerability to depletion and pollution from environmental changes, International Workshop on Vulnerability of Water Resources to Environmental Change, 16-19 September, 2002, Beijing, China. (Abstract accepted).

67) P.S. Datta and S.K. Tyagi (2003) Consequences of human activities in semi-arid regions of India. International Conference on Hydrology of Mediterranean and Semi-Arid Regions, 7-10 April, 2003. Montepellier, France. (Paper accepted).

National:

68) P.S.Datta (1980). Indian contributions to applications of artificially injected tritium in hydrological investigations. NGRI/DAE, Monograph, Proc. Workshop on "Nuclear Techniques on Hydrology", Hyderabad, pp. 145-163.
69) P.S.Datta and S.Banerji (1981). Advances in groundwater investigation pertinent of planning and managment. Proc. Seminar on "Developement and management of groundwater resources", New Delhi. pp. 1-7.
70) P.S.Datta (1987). Technological self-reliance and R&D capabilities in the Tungsten industry in India. Proc. National Workshop in Tungsten Resources Developement, Dec.24, 1987, Bhubaneshwar, pp.16-38.
71) P.S.Datta (1987). Status of Tungsten beneficiation technology and research needs. Proc. National Workshop in Tungsten Resources Developement, Dec.24, 1987, Bhubaneshwar, pp.1-15.
72) P.S.Datta (1987). Public participation in watershed management- A case study of the Damodar Valley Corporation. Proc. UGC Retreat on State of World Environment Series- Indian Environment, New Delhi, pp.1-11.
73) P.Mookerjee, P.S.Datta, T.K.Mukherjee and H.Chandrasekharan (1990). Groundwater recharge estimates of Najafgarh Block in Delhi by tracing soil moisture movement. Proc. National Seminar on Soil Moisture Processes and Modelling, Kharagpur, pp.79-85.
74) P.S.Datta (2000) Isotope tracer studies on groundwater for environmentally Sustainable resource management. Proc. Workshop on grounwater development and management "Past achievements and future strategies" Organised by Central Grondwater Authority, New Delhi, 14th January, 2000.
75) P.S.Datta, P.Mookerjee and S.K.Tyagi (1998). Isotope signature based groundwater investigations for environmentally sustainable agriculture. Proc. National Seminar on Water Management for Sustainable Agriculture - Problems and Perspectives for the 21st Century, April 15-17, 1998, New Delhi, 420-426.
76) P.S.Datta and S.K.Tyagi (1998). Isotopic evidences on causes of falling water table in Delhi region and remedial measures. Proc. INCOH/UNESCO Ninth National Symposium on Hydrology, Nov. 26-27, Amritsar, pp.286-294.
77) P.Mookerjee, P.S.Datta, N.V.K.Chkravarty, H.Pathak, R.V.Singh and S.K.Tyagi (1998).Groundwater sustainability in Delhi region viewed through groundwater recharge studies employing nuclear techniques towards better crop productivity. Seminar on Artificial Recharge of Groundwater, December 15-16, 1998, New Delhi, pp.II-97 to II-105.
78) P.S.Datta (1999). (Invited Key-Note Address). Fluoride contamination of groundwater in India: Hydrogeological perspectives and issues. Proc. National Seminar on Health and Environment'99, February 25-27, Udaipur, pp.1-7.
79) P.S.Datta (1989). Industrialisation or sustainable environment or both. Proc. Workshop Industrialisation or Sustainable Environment. New Delhi, pp.1-4
80) P.S.Datta, P.S.Goel, Rama and S.P.Sangal (1974). Determination of recharge to groundwater in the plains of northern India. Proc. Natn. Symp. on "Application of Isotope Techniques in Hydrology and Hydraulics, Poona, p. 106.
81) P.S.Goel, P.S.Datta, and Rama (1974). Factors affecting recharge in alluvium plains. Proc. Natn. Symp. on "Application of Isotope Techniques in Hydrology and Hydraulics, Poona, p. 176.
82) P.Mookerjee, P.S.Datta, H.Chandrasekharan and S.K.Tyagi (1992). Sustaining groundwater potential of Delhi under changing environmental conditions. Proc. Symposium on Maximizing and Sustaining Crop and Animal Productivity by Modern Techniques, 1992, Varanasi.

83) P.Mookerjee, P.S.Datta, H.Chandrasekharan and S.K.Tyagi (1994). Groundwater in Delhi area, problem and prospects under fast urbanisation - a nuclear aided study. Proc. DAE-BRNS Symposium on Nuclear Applications in Agriculture, Animal Husbandry and Food Preservation, New Delhi, pp.61-63.
84) P.Mookerjee, P.S.Datta, H.Chandrasekharan, S.K.Tyagi and R.V.Singh (1994). Ground water in Delhi area, problems and prospects under fast urbanisation -- a nuclear aided study. Proc. DAE-BRNS Symp. on Nuclear Application in Agriculture, Animal Husbandry and Food preservation. New Delhi, March 16-18, 1994. pp. 61-63.
85) P.S.Datta, S.K.Bhattacharya and S.K.Tyagi (1996). Delineation of groundwater recharging zones with high resolution based on ^{18}O-elevation relationships. Ext.Abs. Proc. DAE-BRNS Symposium on Nuclear Techniques in Increasing Crop and Animal Productivity, Bombay,pp.44-45.
86) S.K.Tyagi, P.S.Datta and S.K.Bhattacharya (1996). Stable isotope (^{18}O) imaging of regional groundwater sulphate composition, flow pattern and systems analysis. Ext.Abs. Proc. DAE-BRNS Symposium on Nuclear Techniques in Increasing Crop and Animal Productivity, Bombay,pp.45-46.
87) P.Mookerjee, P.S.Datta, R.V.Singh and S.K.Tyagi (1996). Systems approach for soil moisture process at a dry land farm with natural flora at IARI, New Delhi - A nuclear aided study. Ext.Abs. Proc. DAE-BRNS Symposium on Nuclear Techniques in Increasing Crop and Animal Productivity, Bombay, pp.46-47.
88) K.M.Manjaiah, P.S.Datta and S.K.Tyagi(1997). Significance of soil C/N ratio and groundwater contamination characteristcs in nitrogen and water management strategies. Proc. National Seminar on Developments in Soil Science, 62nd Annual Convention of Indian Society of Soil Science, Oct.18-20, 1997, Calcutta, pp.65-69.
89) P.S.Datta (2000) Isotopic characterisation of groundwater pollution dynamics in Delhi. Proc. National Seminar on Groundwater Quality, JNU, New Delhi, 22nd July, 2000. p. 9-10.
90) P.S.Datta (2000) Advances in evaluation of the processes controlling groundwater quality in arid regions. Proc. National Seminar on Groundwater Quality, Organised by the JNU, New Delhi, 22nd July, 2000. p. 20-21.
91) S.K.Rohilla, P.S.Datta and Venkatesh Dutta (2000) Urban sprawling induced landuse changes and its impact on groundwater resources of NCT Delhi. Proc. National Seminar on Groundwater Quality, Organised by the JNU, New Delhi, 22nd July, 2000. p. 16-17.
92) P.S.Datta (1999). Sustainable water supply, rechargeability and contamination related groundwater issues and protection strategies. Proc. New Millenium Conference 'Retrospect of Indian Research on Environmental Pollution: Focus 21st Century', November 22, 1999, New Delhi, pp.21-23.
93) S.K.Rohilla and P.S.Datta (1998). Delhi's Water: Emerging Scenario. Proc. Thirty Sixth AIHDA Policy Seminar on 'Integrated Water Management in Human Settlements, December 22-25, 1999, Pune. (In press).
94) P.S.Datta (1998). (Invited Lead Paper). Advances in isotope techniques for environmentally sustainable resource management and crop production. Proc. National Seminar on Advances in the Studies of Physical Environment for Resource Management and Crop Production, March 23-25, 1998, New Delhi. (In press).
95) P.S.Datta (1998). (Invited Lead Paper). Sustainable Development of Mountain Environment. Proc. National Seminar on Sustainable Development of Mountain Environment, March 27-28, 1998, New Delhi. (In press).
96) P.S.Datta (1999). (Invited Lead paper). Groundwater issues for sustainable water supply in Delhi Area. Proc. ICSSR-IDPAD Project Cluster Meeting and National Seminar on Urban Issues, January 29-30, New Delhi. (In press).

97) P.S.Datta (2001) Safe water supply linked groundwater issues in Delhi region. Proc. Seminar "How Safe is Safe Water ", Univ. of Delhi, 2nd February, 2001. (In press).
98) P.S.Datta (2002) Groundwater quality issues and protection strategies in the National Capital Region, National Seminar on 'Water in the NCR', May, 2002, New Delhi.

(c) Book Chapters

99) P.S.Datta (1994). Management of Groundwater for Sustainable Agriculture and Environment. In (Ed. Prof. D.L.Deb) Natural Resources Managment for Sustainable Agriculture and Environment, Angkor Publishers Ltd., pp.220-236. (Contributed an invited article).
100) H.Chandrasekharan, P.S.Datta and P.Mookerjee (1994). Hydrological investigations - an integrated approach. Published in 'Twentyfive Years of Nuclear Applications in Agricultural Research', NRL/IARI Publication, pp.158-174. (Contributed a chapter).
101) P.S.Datta (1996) Crop Productivity Linked Significance of Isotope Hydrology - an Indian Perspective. In "Isotopes and Radiations in Agriculture and Environment Research" Published by ISNA, New Delhi, pp. 156-175. (Contributed an invited article).
102) P.S.Datta (2000) Hand-Book on "Planning and Implementation of Water Supply Programmmes in Fluorosis Endemic Areas". (Ed:A.K.Susheela) UNICEF Publication. (Contributed two chapters).

(d) Books/Bulletins

103) P.S.Datta (1997). Stable Isotopic Investigations for Groundwater Management and Sustainable Environment (Search for Alternatives): A Case Study of Delhi Region. NRL/IARI Publication.
104) S.K.Rohilla, P.S.Datta and S.P.Bansal (1998). Delhi's Water and Solid Waste Management, Environmental Hot Spot Series. Vigyan Prasar Publication, New Delhi.
105) P.S.Datta (1999). Groundwater Situation in Delhi: Red Alert. NRL/IARI Publication.

(e) Popular Articles

106) P.S.Datta (1984). Meteorology and Water Resources in India. Bhagirath, Jul-Sept., pp.5-7.
107) P.S.Datta (1986). Towards a Safer Environment. Science Age, December Issue, pp.11-13.

435. Detailed Bio-data of the Principal Investigator

NAME	:	Dr. Mrs. Hema Achyuthan
Place and Date of Birth	:	*Srirangam, Trichy Dist., Tamil Nadu 24.ll.1956.*
Nationality	:	Indian
Professional Address	:	Centre for Geoscience and Engineering, Anna University, Chennai -600 025.
Residence Address	:	H-36/A, Parvathi Street, Kalakshetra Colony, Besant Nagar, Chennai -90.
Present Position	:	Assistant Professor (since Dec 2000) Centre for Geoscience and Engineering, Anna University, Chennai -25.

Educational Qualification :

B.Sc.	1978	Geology, POONA University, Pune.	70%
M.Sc.	1980	Geology, POONA University, Pune.	64.4%
Ph.D.	1987	Geology, POONA University, Pune	

Title of the Thesis: Quaternary Geology of Nagaur District, Rajasthan.
Teaching: 10 yrs.
Research experience : 22 years.
Date of Joining : Anna University as Lecturer : 4.12.1991.

Specialization:
** Arid and fluvial geomorphology with special reference to soil formation and understanding palaeoclimate.
* Radiometric dating and Geochronology of recent sediments.

Research/Teaching positions:
UGC Project Assistant June 1980-1982 under the UGC Sponsored project on Man Land relationship in the Thar desert, Rajasthan.
CSIR JRF Fellow - 1982-1985.
CSIR SRF Fellow - 1985-1987.
DST sponsored project Principal Investigator Young Scientist Programme 1988-1990.
CSIR 1991 July- Nov 1991 Research Associate.
Anna University, Dec 3.12.1991. Lecturer
Anna University Sr. lecturer from 4.12.96.
Assistant professor from 4.12.2000.

Awards and prize(s) Won:

- ISCA Young Scientist Award in January 1985.
- CIES travel fellowship for a period of three months at the Insitut of Agronomique, Paris, France May-Aug. 1985.
- Certificate of Award 1994, Anna University, Chennai-25. Quality Circle Endowment- Member of the Best Quality Circle for the year 1993-94.
- Fulbright Post Doctoral Fellowship for a period of six months at the University of Arizona, Tucson, 1995
- NSF grant as Research Associate for a period of three months June to September 1998 at the University of Arizona, Tucson and Central Washington University, Ellensburg, USA. As Research Associate.
- INSA Visiting fellowship for a period of two months June-July 1999 at the Central arid Zone Research Institute, Jodhpur.

- Recipient of the TAMIL NADU SCIENTIST AWARD (TANSA) in the field of Environmental Sciences for the year 1999 awarded by Tamil Nadu State Council for Science and Technology.

Member of Professional Societies and Editorial Positions:

* Life Member of the Journal Geological Society of India, Bangalore (F 1666).
* Life member of International Society of Prehistory and Quaternary Science, Deccan College, Pune.
* Life Member of the Palaeontological Society of India, Lucknow.
* Associate Member Third world Academy of Women Scientists, Trieste, Italy.
* International Association of Geomorphologists.USA.
* Member Indo prehistoric and Protohistoric Society, Canberra, Australia
* Member of the IGCP 341- Desert margins and Paleoclimate.
* Member of the Journal of Sedimentary Research, USA.
- Associate editor of the Journal of Geological Society of Sri Lanka.
- Member of the CSIR, New Delhi, Committee member for Earth and Environmental Sciences) :

<u>List of publications published in refereed journals and Seminar Proceedings.</u>

1) Hema Achyuthan (2003): Bedrock incision in the arid tracts of Jaisalmer, Rajasthan. Indian National Science Academy (accepted)
2) Hema Achyuthan (2003): Petrologic analysis and geochemistry of the late Neogene-Early Quaternary Hardpan calcretes of western Rajasthan Region, India. Quaternary International, 102-103.
3) Hema Achyuthan, V. Baker (2002): Radiocarbon dates and Quaternary geomorphology of the east coast, Tamil Nadu. Radiocarbon, 44, 137-144.
4) Hema Achyuthan, V.R. Baker, L. Machargue, T. Jull and J. Donahue (2002): Concentration of ^{10}Be in ferricretes of Jaisalmer basin. (in preparation).
5) Z.Cooper and Hema Achyuthan (2002). Holocene sea level changes in the Andaman Islands submitted for publication in Radiocarbon.
6) Ellen Wohl and Hema Achyuthan (2002). Substrate Influences on Incised-Channel Morphology. <u>Journal of Geology</u>, v.110, 115-120.
7) Hema Achyuthan, D. Richardmohan and S. Srinivasalu (2002): Trace metals concentrations in the sediment cores of estuary and tidal zones between Chennai and Pondicherry, along the east coast of India. Indian Journal of Marine Sciences, V.31 (2), 141-149.
8) Hema Achyuthan (2002): Late Neogene-Early Quaternary ferricretes of Jaisalmer basin, Rajasthan, India- with special reference to its formation. (submitted to Catena for publication).
9) Hema Achyuthan, Ramasubramanian, and S.Nagalakshmi, T. (2002). Late Neogene-Quaternary ferricretes and red soils around Chennai. (accepted Indian Journal of Geographical Union).
10) Hema Achyuthan (2000). Geomorphology and occurrence of ferricretes as marker horizons in an Arid environment, Jaisalmer Basin, Rajasthan- A Review. In Sunando Bandyopadhyay, D.C. Goswami, S.R. Jog, M. Bhattacharji, Amal Kar, A.B. Mukerji (eds.) Landforms Processes and Environment management (Prof. M.K.Bandyopadhyay Felicitation Volume). In press.
11) Hema Achyuthan, J. Quade and L. Roe. (2001). Stable isotopes of Pedogenic carbonates from the eastern margins of the Thar desert, Rajasthan. Submitted for publication to Quaternary Research.
12) Hema Achyuthan (1999). Ferricretes of Jaisalmer basin, their origin and palaeoenvironment. <u>Man and Environment</u>, 24 (1), 77-90.
13) Hema Achyuthan and C.Eastoe (1999). Mineralogy and Isotopic composition of

pyrite bearing ejects from a Mud vulcano, Baratang , Andaman Islands. Journal of Geological Society of India, V. 53, 329-334.

14) M. Stiner, Hema Achyuthan, G.Arsebuk, F.C.Howell, S.C. Josephson, K.E.Juell, J. Pigati and J. Quade (1998). Reconstructing cave bear palaeocology from skeletons: a cross disciplinary study of Middle Pleistocene bears from Yarimburgaz cave, Turkey. Palaeobiology, 24(1), 74-98.
15) Hema Achyuthan and S.N.Rajaguru (1998). Micromorphology of Quaternary calcretes around Didwana in Thar desert of Rajasthan. Journal of Arid Zone, 37(1), 25-35.
16) Hema Achyuthan and Z.Cooper (1997). Mineralogy and Micromorphological studies of lateritic soils around Port Blair, Andaman Islands. Geoscience Journal, 18(2), 141-148.
17) Hema Achyuthan (1997). Age and formation of Oyster beds in Muthukadu tidal flat zone, Chennai. Current Science, 73(5), 451-453. .
18) Hema Achyuthan and S.Pappu (1997). Observation on the geomorphology and Archaeology of Erumaivattipalayam, Red Hills, Tamil Nadu. Man and Environment, 22(1), 87-90.
19) Hema Achyuthan, S.N.Ghate and S.N.Rajaguru (1997). Mineral replacement of plant roots influvial sediments of the link channel of Krishna river, Near Yedurwadi, Belgaum District, Karnataka. Journal of Geological Society of India, 50, 765-768.
20) Hema Achyuthan (1997). Late Neogene - Quaternary palaeoenvironmental changes along the east coast of Madras, Tamil Nadu, India. In: Wijayananda,N.P., Cooray, P.G. and Mosley,P. (eds.). Geology in South Asia-II,Geological Survey and Mines Bureau, Sri Lanka, Professional Paper 7, 197-203.
21) Hema Achyuthan and S.N.Rajaguru (1997). Genesis of ferricretes and calcretes of the Jayal gravel ridge: a micromorphological approach. In: Wijayananda,N.P., Cooray, P.G. and Mosley,P. (eds.). Geology in South Asia-II,Geological Survey and Mines Bureau, Sri Lanka, Professional Paper 7, 51-59.
22) Hema Achyuthan (1996). Geomorphic evolution and genesis of laterites from the east coast of Madras, Tamil Nadu. Geomorphology, 16, 71-76.
23) R.K. Ganjoo and Hema Achyuthan (1995). Geomorphic evolution of the High level gravels in the upland region of western Maharashtra. In Datta, A., Ghosh A.K.and Margabandhu, C.(eds.) India at the Dawn of History. Essays in Memory of Sh.V.D. Krishnaswami. Agam kala Prakashan, Delhi. 9-16.
24) Hema Achyuthan, R. Nagendra and C. Mohana Doss. (1994). Heteropigmentation of Karai clays, Tamil Nadu. Current Science, 67(8), 606-608.
25) Hema Achyuthan and B. Rukmangada Reddi. (1993). Geomorphic evolution of the Talchappar salt lake, Churu Dist., Rajasthan. Jour. of Arid Environment, 25,109-116.
26) Hema Achyuthan and S.N.Rajaguru (1993). Reddening of dune sands from Didwana and Budha Pushkar - micromorphological approach. Man and Environment, 18(1), 21-34.
27) Hema Achyuthan, C.Gaillard and S.N.Rajaguru. (1991). Geoarchaeology of Acheulian calc pan site, Singi Talav, Didwana, Nagaur Dist., Rajasthan. Geoarchaeology, 6, 151-168.
28) S.N.Ghate, Hema Achyuthan and S.N.Rajaguru (1989). Micromorphological studies of Karal from the western coast of Maharashtra. Jour. Geological Soc. of India. 36, 624-633.
29) Hema Achyuthan, S.N.Rajaguru and V.N.Misra (1989). Radiometric dating of the 16R dune section, Didwana, Rajasthan. Man and Environment,12, 67-74.
30) Zarine Cooper and Hema Achyuthan (1989). Petrographic features of Andamanese pottery. Bull. Indo-Pacific Prehistory Association, 9, 22-32.
31) Zarine Cooper and Hema Achyuthan (1988). Analyses of sediments from a cave in the Andaman Islands. Man and Environment, 12, 67-74.

32) Hema Achyuthan (1988). On problem of reddening of Quaternary dune sands around Didwana: A Palaeolithic site in Thar desert. In K.L.Bhowmik (ed.). Current Anthropological and Archaeological perspectives. Inter. India Publications. 21-32.
33) Hema Raghavan, and M.A.Courty, (1987). Holocene pedosedimentary and Pleistocene pedo-sedimentary environments in the Thar desert (Didwana, India). In Proceedings VII Soil Micromorphology (Eds.) N. Federoff, L.M. Bresson and M.A.Courty) pp. 639-646. Assoc. Francaise pour l'etude du sol, Paris.
34) M.A. Courty, R.P. Dhir and Hema Raghavan (1987). Morphology, genesis and evolution of calcitic features in Rajasthan soils (India). same volume. 227-234. In Proceedings VII Soil Micromorphology (Eds.) N. Federoff, L.M. Bresson and M.A.Courty) pp. 227-234. Assoc. Francaise pour l'etude du sol, Paris.
35) Hema Raghavan, S.N.Rajaguru, V.N.Misra, D.R.Raju and G.Parashar (1986). A note on the mineralogical study of some sand dunes from the Thar desert. Bull.Deccan College, 45, 37-46.
36) R. K. Ganjoo, Hema Raghavan, S.N. Rajaguru and C. Gaillard (1984). Late Neogene fossil wood from the Bikaner gravel beds, Rajasthan. Current Science, 53, 1207-1208.
37) V.N.Misra, S.N.Rajaguru, D.R.Raju, Hema Achyuthan, C.Gaillard (1982). Acheulian occupation and evolving landscape around Didwana in the Thar desert of India. Man and Environment, 6,72-86.
38) Hema Raghavan, V.G. Phansalkar, V.V.Peshwa and A.G.Dessai. (1982). Geology and drainage analysis of the area between Perambalur and Padalur in the Trichy dist., Tamil Nadu. Photonirvachak, Jour.Ind.Soc., Photo-Int. and Remote Sensing. 2(1).

Publication of Popular articles:

39) India Magazine: Kishengarh fort. 1997 with Srimathi Venkatalakshmi.
40) Sananda (Bengali) Deserted villages of Rajasthan. With Srimathi Venkatalakshmi.Dept. of science and humanities, Anna university, Chennai 600 025.
41) Jour. Geological Society of India, Aug. 1998. Reminiscence M.S.Krishnan.

436. Detailed Bio-data of the Principal Investigator

A. Name : P.M. Muraleedharan
B. Date of Birth : 08-10-1955
C. Institution : National Institute of Oceanography, Goa
D. SC/ST : No
E. Academic career:

1. Ph.D. 1985; Cochin University of Science and Technology
2. M.Sc; 1979; Cochin University of Science and Technology
3. B.Sc; 1076; University of Kerala

Professional career:

1. Scientist, E II; since 2001, NIO
2. Scientist, E I: since 1997, NIO
3. Scientist, C : since 1992, NIO
4. Scientist, B : since 1987, NIO
5. Post doctoral fellow: 1986 – 1987, PRL
6. Post doctoral fellow: 1985 – 1986, Cochin University
7. JRF (UGC): 1983 –1985, Cochin University.

F. Awards won : Nil
G. Publications:

1. Books: Nil
2. Research papers: 19 (referred journals)
3. Reports: 3
4. Conference papers: 11
5. General articles: Nil
6. Patents: Nil

H. (Selected) list of publications:

1) P.M.Muraleedharan and S. Prasannakumar (1992) Equatorial Jet-A case study. Indian *J. Marine Sci*., 4211., 35- 45.
2) P.M. Muraleedharan (1993) Intermonsoonal Equatorial Jets. *Indian J. Marine*
3) *Sci., 22*, 1-7.
4) P.M. Muraleedharan, M.R. Ramesh Kumar and L.V.G. Rao (1995) A note on pole-ward undercurrent along the southwest coast of India. *Continental Shelf Res.,* 15, 165-184.
5) P.M. Muraleedharan and S. Prasannakumar (1996) Arabian Sea up welling - A comparison between coastal and open ocean regions. *Currents Science, Special section: JGOFS (INDIA*), 71 (11), 842-846.
6) M.R. Ramesh Kumar, P.M. Muraleedharan and P.V. Sathe (1993) Precipitable water over the tropical Indian Ocean derived from Nimbus 7 Satellite Data - A case study. *Boundary Layer Meteorology,* 466, 325-330.
7) M.R. Ramesh Kumar, P.M.Muraleedharan and P.V. Sathe (1999) On the role of sea Surface temperature variability over the tropical Indian Ocean in relation to Summer Monsoon using satellite data. *Remote Sensing of Environment, 70, 238 – 244.*
8) P.V. Sathe and P.M. Muraleedharan (1998) Retrieval and processing of atmospheric parameters from satellite data. *Computers & Geosciences, 24* (8). 797 - 803.
9) P.M. Muraleedharan, T. Pankajakshan and Suchitra Sundaram. 2002. Air sea exchange of fluxes and Indian monsoon from satellite data. Proceedings, Pan Ocean Remote Sensing Conference (PORSEC) 2002, Vol. I, p.320 –330.
10) P.M. Muraleedharan and T. Pankajakshan (2003). Latent heat – rainfall relationship over the tropical Indian ocean during three contrasting years.

Communicated to Journal of Indian Society of Remote Sensing (Photonirvachak).

11) P.M. Muraleedharan, T. Pankajakshan and M. Harikrishnan (2003). Validation of Multi-channel Scanning Microwave Radiometer onboard Oceansat-I. Communicated to current science (sent revised version).

437. Detailed Bio-data of the Principal Investigator

1. Name: P. Nagabhushanam
2. Designation: Scientist- E-II
3. Department: Groundwater / Tritium & Radiocarbon Lab
4. Institute Name: National Geophysical Research Institute (NGRI)
5. Address: Room No. 009 (Main Building), National Geophysical Research Institute, Uppal Road, Hyderabad – 500 007.
6. Date of Birth: 6th August 1952
7. Telephone / fax/ email: (0) 040-23434700 extn. 2497 / Fax: 040-23434651 / (R) 27203251, nagpasupu@rediffmail.com
8. Educational qualification: M. Sc. (Tech., Applied Electronics)
9. Experience: 25 years of experience in the field of isotope hydrology covering the topics of groundwater recharge, groundwater flow direction and velocity, identification of recharge area / discharge areas, mine seepage, paleoclimate, early-breakthrough of injection water in oil fields, interaction between surface water and groundwater, artificial recharge etc.
10. Publications: ~50 publications (includes SCI & Non-SCI journals, and symp/semi./workshop proceedings)
11. Technical reports: 12 technical reports

438. Detailed Bio-data of the Co- Investigator

Name : Dr. Shyam Lal

Date of Birth : Dec. 25, 1951

Designation : Professor

Address : Space and Atmospheric Sciences Div.
Physical Research Laboratory
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Tel.: 079 2631 4671 (O)
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Specialization : Atmospheric Science

Educational Qualifications : Ph. D. Gujarat University 1982

Recognition: Fellow - Indian Academy of Sciences, Bangalore
Fellow - Indian National Science Academy, New Delhi

Member of international and national commissions and committees:

(i) International Ozone Commission (IOC)
(ii) Programme Advisory Committee on Atmospheric Science of DST, New Delhi
(iii) Earth and Environmental Sciences Research Committee of CSIR, New Delhi

Publications :

Publications in national and international journals : 73

Publications list (last 5years only)

1. Lal, S., Naja, M. and Subbaraya, B.H. Seasonal variations in surface ozone and its precursors over an urban site in India. Atmospheric Environment , 2000, Vol. 34, p.2713-2724.
2. Lal, S., Acharya, Y.B., Chand, D., P. Rajaratnam, and Subbaraya, B.H. Changes in the vertical distribution of trace gases over Hyderabad. In 'Long term changes and trends in the atmosphere', 2000, Ed. G. Beig, New Age international publisher, New Delhi, p.320-334.
3. Sheel, V. and Lal, S. Long term trends in sulfur hexafluoride. In 'Long term changes and trends in the atmosphere', 2000, Ed. G. Beig, New Age international publisher, New Delhi, p.351-366.
4. Patra, P.K., Lal, S., Sheel, V., Subbaraya, B.H., C. Bruehl, R. B. Borchers, and Fabian, P., Chlorine partitioning in the stratosphere based on insitu measurements. Tellus, 2000, Vol. 52B, p.934-946
5. Lal, S. and Sheel, V. A study of the atmospheric photochemical loss of N_2O based on trace gas measurements. Chemosphere – Global Change Science, 2000, Vol. 2, p.455-463.
6. Subbaraya, B.H., Lal, S. and Naja, M. Tropical tropospheric chemistry and climate change. Mausam, 2001, 52, p. 97-108.
7. Lelieveld, J. et al. The Indian Ocean Experiment: widespread air pollution from south and southeast Asia. Science, 2001, Vol. 291, p.1031-1036.

8. Chand, D., Modh, K.S., Naja, M., Venkataramani, S., and Lal, S. Latitudinal trends in O_3, CO, CH_4 and SF_6 over the Indian Ocean during the IFP INDOEX-1999 ship cruise. Current Science, 2001, 80, p.101-105.
9. Lal, S., and Lawrence, M.G. Elevated mixing ratios of surface ozone over the Arabian Sea.Geophys Res. Letters, 2001, 28, p.1487-90.
10. Bange, H.W., Andreae, M.O., Lal, S., Law, C.S., Naqvi, S.W.A., Patra, P.K., Rixen, T. and Upstill-Goddard, R. C.Nitrous oxide emissions from the Arabian Sea: A synthesis Atmos. Chem. and Phys. 2001, Vol.1, p.61-71, 2001
11. Nair, P.R., Chand, D., Lal, S., Modh, K.S., Naja, M., K. Parameswaran, M.K., Ravindran, S. and Venkataramani, S. Temporal variations in surface ozone at Thumba (8.6N, 77E)- a tropical coastal site in India. Atmos. Env., 2002, 36, p.603-610, 2002.
12. Naja, M. and Lal, S. Surface ozone and precursor gases at Gadanki (13.5N, 79.2E), a tropical rural site in India. J. Geophys. Res. 2002, Vol. 107, p. **8**-1 to **8**-13.
13. Lal, S. Global warming- Kyoto Protocol. In 'Energy and food security : Advances in science for sustainable environment and development in India during the next decade', Editors: S. K. Malik and S. Varadarajan, Indian National Science Academy, New Delhi, India, 2003, p57-73.
14. 66. Chand D., Lal S., Naja M. Variations of ozone in the marine boundary layer over the Arabian Sea and the Indian Ocean during the 1998 and 1999 INDOEX campaigns. J. Geophys. Res. 2003, Vol. 108, p.doi:10.1029/2001JD001589.
15. Lal, S., Sheel, V. and Patra, P.K. Satellite techniques for trace gas measurements. Mausam, 2003, Vol. 54, p315-326.
16. Patra, P.K., Lal, S., Venkataramani, S. and Chand, D. Halogen Occultation Experiment (HALOE) and balloon-borne in situ measurements of methane in stratosphere and their relation to quasi-biennial oscillation (QBO). Atmos. Chem. Phys., 2003, Vol. 3 ,p1051-1062.
17. Naja, M., Lal, S. and Chand, D. Diurnal and seasonal variabilities in surface ozone at a high altitude site Mt Abu (24.6N, 72.7E, 1680 m asl) in India. Atmos. Env. 2003, Vol.37, p.4205-4215.
18. Naja, M., D. Chand, L. Sahu and S. Lal, Trace gases over the marine region around India, Ind, J. Marine Science, 2004, Vol.33, 95-106
19. Lal S., D. Chand, S. Venkataramani, K. S. Appu, M. Naja, and P. K. Patra, Trends in methane and sulfur hexafluoride at a tropical coastal site, Thumba (8.6N,77E), in India, Atmos. Env. 2004, Vol. 38, p.1145-1151
20. Sheel V., S. Lal and C. Bruel, Validation of a 2D model using observed profiles of SF_6 with main focus on the tropics, Atmospheric Environment, 2005, Vol. 39, p.1255-1261
21. Tripathi, S.N.,S. Dey, V. Tare, S.K. Satheesh, S. Lal and S. Venkataramni, Enhanced layer of balck carbon in a north indian industrial city, Geophys. Res. Lett., 2005, 32, L12802, doi:10.1029/2005GL022564

439. Detailed Bio-data of the Co- Investigator

Name	:	Dr. S.V.Navada
Date of Birth	:	25th July 1948
Designation	:	Head Isotope Hydrology Section
Division	:	Isotope Application Division, BARC
Phone No.	:	+91-22- 25593854
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Qualification	:	Ph.D (1988) Mumbai University

Dr. S.V. Navada is presently head of the Isotope hydrology section of BARC, Mumbai. He has over 30 years of experience in the application of isotope techniques in water resources development and management. Some of his current interests are:

-surface water and groundwater pollution
-surface water- groundwater interactions
-groundwater recharge studies in arid and semi arid areas
-origin of geothermal waters
-dynamics and sedimentation in lakes and reservoirs
-seepage in dams and reservoirs
-origin of springs in hilly areas in the Himalayas

Publications

Journals

1) "Determination of recent sedimentation rates and pattern in lake Naini by ^{210}Pb and ^{137}Cs dating techniques." U.Saravana Kumar, S.V.Navada, S.M.Rao, Rm Nachiappan, B.Kumar, T.M.K. Krishnamurthy, S.K.Jha, and V.C.Shukla, Applied Radiation and Isotopes 51, 97-105,1999.
2) "Improved prediction of life expectancy for a Himalayan lake, Nainital, Uttar pradesh,
3) India." Bhishm Kumar, Rm Nachiappan, S.P.Rai, U.Saravana Kumar, and S.V.Navada, Mountain Research and Development, USA, 11(2),113-121,1999.
4) "Hydrogen and Oxygen isotopic analysis of Antartic lake waters." R.Sinha, S.V.Navada, Asim Chatterjee, U.Saravana Kumar, A.Mitra, A.R.Nair, Current Science 78(8), 992-995.2000.
5) "Environmental isotope study on hydrodynamics of lake Naini, U.P.,India", U.Saravana Kumar, Noble Jacob, S.V.Navada,S.M.Rao, Rm Nachiappan, B.Kumar, and J.S.R.Murthy, Hydrological processes (U.K.),15, 425-439, 2001.
6) "Field isotope investigations and numerical simulation of lake hydrodynamics" J.S.R.Murthy, U.Saravana Kumar, S.V.Navada and S.M.Rao, Hydrological Processes (U.K.), 16, 1703-1723, 2002.
7) "Contribution of storms to groundwater recharge in the semi-arid region of Karnataka, India" K.Shivanna, U.P.Kularni, T.B.Joseph, and S.V.Navada, Hydrological Processes (U.K.), 18,473 –485, (2004)

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8) "Radiotracer study on dispersion of sewage off Mumbai coast in Western India." U.Saravana Kumar,V.N.Yelgaonkar, and S.V.Navada, Proc. 2nd int. Conf.on Isotopes,Oct.1997,Sydney,Australia.
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23) “Isotope hydrogeochemistry of groundwater in Purna river basin, Maharastra, India”, Suman Sharma, K.M.Kulkarni, U.P.Kulkarni, A.S.Deodhar, S.V.Navada, P.K.Jain, Proc. Int. Symp. On Isotope Hydrology and Integrated Water Resource Management, 19 –23 May 2003, IAEA, Vienna

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Degree	Subject	University	Year	% Of Marks
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- **Service Profile at Physical Research Laboratory**

Position	Duration
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Scientist-D (Tech)	July 1996 – Jan 2004
Scientist-’SC’	July 1990 - July 1996
Scientist-’SB’	April 1989 - July 1990
Scientific Assistant - ‘C’	February 1989 - April 1989

- **Membership of Scientific Associations and Organisation**

Life membership of:
Nuclear track society of India
Indian Physics Association
Indian Meteorological Society

List of Publications – R.D. Deshpande

International Journals

1) **Origin of High Fluoride in Groundwater in the North Gujarat – Cambay Region, India.** S.K. Gupta, R.D. Deshpande, Meetu Agarwal and B.R. Raval. *Hydrogeology Journal,* (in press) DOI, doi:*10.1007/s10040-004-0389-2*.
2) **Groundwater δ^{18}O and δD from Central Indian Peninsula: Influence of Arabian Sea and the Bay of Bengal Branches of Summer Monsoon.** S.K. Gupta, R.D. Deshpande, S.K. Bhattacharya and R.A. Jani. *Journal of Hydrology,* Vol. 303(1-4), pp38-55, 2005.
3) **An Insight into the Dynamics of Lake Nainital (Kumaun Himalaya, India) Using Stable Isotope Data.** S.K. Gupta and R.D. Deshpande. *Hydrological*

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5) **Origin of Groundwater Helium and Temperature Anomalies in the Cambay region of Gujarat, India.** S.K. Gupta and R.D. Deshpande. *Chemical Geology*. Vol. 198, pp. 33-46. 2003.
6) **Distribution of Oxygen and Hydrogen Isotopes in Shallow Groundwaters from Southern India: Influence of a Dual Monsoon System.** R.D. Deshpande, S.K. Bhattacharya, R.A. Jani, S.K. Gupta. *Journal of Hydrology*, Vol. 271, pp. 226-239. 2003.
7) **A Comparative study of monsoon and non-monsoon Himalayan lakes,** India. S. Kusumgar, D. P. Agrawal, **R.D. Deshpande**, R. Ramesh, C. Sharma and M.G. Yadava. Radiocarbon, 191-195, (1995).
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9) **The Need and Potential Applications of a Network for Monitoring of Isotopes in Waters of India.** S.K. Gupta and R.D. Deshpande. *Current Science,* Vol. 88, No. 1, pp.107-118, 2005.
10) **Isotopes for Water Resource Management in India.** S.K. Gupta and R.D. Deshpande. *Himalayan Geology,* Vol.26, No.1, pp211-222, 2005.
11) **Water for India in 2050 – First Order Assessment of Available Options.** S.K. Gupta and R.D. Deshpande. *Current Science*, Vol. 86, No. 9, pp.1216-1224. 2004.
12) **Synoptic Hydrology of India from the Data of Isotopes in Precipitation.** S.K. Gupta and R.D. Deshpande. *Current Science.* Vol. 85. No. 11, pp. 1591-1595. 2003.
13) **Dissolved Helium and TDS in Groundwater from Bhavnagar in Gujarat: Unrelated to Seismic Events between August 2000 and January 2001.** S.K. Gupta and R.D. Deshpande. Proc. *Indian Acad. Sci (Earth Planet. Sci.).* Vol. 112, No. 1, pp. 51-60. 2003.

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14) **Contributions of the water isotope studies to hydrology of India.** S.K. Gupta and R.D. Deshpande. Presentation at SCOPE XII GA, 7-11 February 2005, New Delhi.
15) **Isotope Hydrology in India: What Has Been Learned and the Way Forward?** S.K. Gupta and R.D. Deshpande, Hydrological Perspectives for Sustainable Development, 23-25 February 2005, IIT Roorkee, India. (Eds. M. Perumal, D.C. Singhal, B.S. Mathur, D.S. Arya, H. Joshi, D.K. Srivastava, Ranvir Singh, N.K. Goel and M.D. Nautiyal) Allied Publisher Pvt. Ltd. New Delhi. Vol. II, pp. 782-792. (2005).
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17) **Water Outlook for India: Quantifying Hydrological Cycle Components and Their Interactions for Sustainable Development Using Isotopic Studies.** S.K. Gupta and R.D. Deshpande, Proc. 2nd APHW Conf. Vol.II, Singapore, 5-9 July 2004. pp.326-325.

18) **Urban Hydrology Issues in India: *Akshaydhara* concept – Some Initiatives in Ahmedabad.** S.K. Gupta and R.D. Deshpande. *Proc. Int. Conf. on Water and Environment, Dec. 16-18, 2003, Bhopal, India.* **Vol. Watershed Management** (Eds. V.P. Singh & R.N. Yadav). Allied Publishers Pvt. Ltd. New Delhi. pp. 316-329. 2003.
19) **High Fluoride in Groundwater of North Gujarat – Cambay Region: Origin, Community Perception and Remediation.** S.K. Gupta and R.D. Deshpande. *Proc. Int. Conf. on Water and Environment, Dec. 16-18, 2003, Bhopal, India.* **Vol. Ground Water Pollution** (Eds. V.P. Singh & R.N. Yadav). Allied Publishers Pvt. Ltd. New Delhi. pp. 368-388. 2003.
20) **Soil-Aquifer-Treatment Systems for Maintaining Water Quality of our Rivers.** S.K. Gupta and R.D. Deshpande. *Proc. Int. Conf. on Water Quality Management, 13-15 Feb. 2003, New Delhi. Pp. KN-72 to KN-82. 2003.*
21) **Palaeoclimatic Evidence from the Kashmir Karewas updated.** D.P. Agrawal, **R.D. Deshpande**, S. Kusumgar and C. Sharma. Proceedings of XIII INQUA Congress Beijing, China. 1991.

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22) **A hydrology research agenda in aid of sustainable and self-reliant water resource development in Gujarat State.** S.K. Gupta, **R.D. Deshpande** and M.G. Yadava. Proceedings of National Symposium on Palaeodrainage and water resources in Gujarat. Sarasvati Nadi Shodh Sansthan, Rajkot, India. November 26-28, 2001.

International Report

A report on Depleting Groundwater Levels and Increasing Fluoride Concentration in Villages of Mehsana District, Gujarat, India: Cost to Economy and Health. S.K. Gupta and **R.D. Deshpande**, Water Resources Research Foundation (WRRF), 74p, 1998. Sponsored by Habitat and Environment Committee (HEC) of the Habitat International Coalition (HIC), Dakar-Senegal.

Presentations at Conferences and Workshops

1. International Workshop on earth system processes related to Gujarat earthquake using space technology. IIT Kanpur, India. 55-56, January 27-29, **2003**. Presented a paper entitled “Release of helium associated with Bhuj Earthquake 2001”.

2. National Symposium on Palaeodrainage and water resources in Gujarat. Organized by Sarasvati Nadi Shodh Sansthan at Rajkot during November 26th-28th, **2001**. Presented a paper entitled “A hydrology research agenda in aid of sustainable and self reliant water resource development in Gujarat state”

3. National Workshop on Radon/Helium Precursors for Earthquake Studies. Organised by Guru Nanak Dev University under Himalayan Seismicity Programme of DST, at Amritsar during October 12-17, **1998**. Presented a lecture on “Measurement Technique for Natural Helium in Groundwater and Preliminary results from Cambay Basin”.

4. Training Workshop on Geomatics ‘96 - Data Standardisation and GIS Application. Organised by Indian Society of Geomatics at Ahmedabad during April 10-13, **1996**.

5. Training Workshop on Environmental Isotope Techniques in Hydrology. Organised by NIH at Roorkee during December 4-8, **1995**. Presented a Tutorial lecture on “Stable Isotopes of Oxygen and Hydrogen in groundwater studies”.

6. Thematic Workshop on Major Stratigraphic Boundaries. Organised by DST at

Jammu during October **1994**. Presented an invited lecture on "Pleistocene - Holocene Boundary - An Indian Perspective".

7. IGBP National Symposium organised by Indian Committee on IGBP at Madras during April 21-24, **1993**. Presented a paper entitled "Mineral Magnetic Studies of the Himalayan Lake Core and their Palaeo-environmental implication".

500. Any Other Relevant Matter:

The proposal in its present form is based on the recommendations of the two meetings of the DST Review Committee. The original proposal was formulated based on three Project formulation and finalisation meetings of Project scientists, collaborating institutions and other interested Scientists who have contributed to giving this shape to the present National Programme. The minutes of the three Project formulation and finalisation meetings are given below;

Minutes and recommendations of the One-day workshop on Isotopes in Waters of India Network (IWIN) held at Nuclear Research Laboratory, Indian Agriculture Research Institute (IARI), New Delhi on Nov. 14, 2003.

A One-day workshop was held to discuss in detail the proposal of the Physical Research Laboratory (PRL) on Isotopes in Waters of India Network (IWIN). The participants included scientists of the Indian Agriculture Research Institute (IARI), representatives of other collaborating agencies, interested researchers and other earth scientists involved in isotopes studies in the hydrosphere.

A list of participants to the meeting is given in Appendix -1.

The primary objective of the workshop was to deliberate on the pre-circulated draft proposal in terms of scientific rationale, proposed methodology, role of participating agencies and to recommend suitable modification to avoid duplication and to try and remove the bottlenecks to ensure effective implementation.

Prof. P.S. Datta, Project Director, NRL welcomed the participants and Prof. A.V Moharir, Head, Division of Agriculture physics, IARI gave the introductory remarks.

The workshop started with an overview presentation of the mechanism of oxygen and hydrogen isotope fractionations during phase change of water and applications in hydrology by Dr. P.S. Datta. This was followed by an overview presentation of the IWIN project by Dr. S.K. Gupta. He indicated that the theme of the IWIN project is to fingerprint the different water sources of India in terms of their oxygen and hydrogen isotope characters for quantifying the factors (geographical, climate etc) controlling spatial distribution of water during rainy season and its re-distribution within the hydrological cycle during the dry period. The objective of this exercise is to:

(i) Identify dominant seasonal vapour sources over the Indian landmass in quantitative terms vis-á-vis Arabian Sea (AS), Bay of Bengal (BOB) and continental.

(ii) Estimate partitioning into rain and sub-partitioning into, stream flow, groundwater, evapo-transpiration and soil moisture.

(iii) Determine the degree of control that geographical and climatic factors exercise over the entire hydrological cycle both temporally and spatially.

The motivation was to understand and describe the continental scale hydrological cycle and Land-Ocean-Atmosphere interaction over and around India.

Dr. Gupta expressed that the project was not only expected to provide an improved understanding of various basic hydrological issues concerning water sources of India, but also provide data to model through-flow rates, residence time distributions through different components in a spatially and temporally distributed manner. These data will be useful as the country moves to rapidly develop its water resources over the next few decades to meet the water demand for increasing population and improving quality of life.

This overview presentation was followed by a demonstration of the apparatuses/ devices for collection of samples of rainfall, atmospheric vapour, stream water and groundwater. It was pointed out that sampling techniques for surface and groundwater sampling were similar to that being followed by Central Water Commission (CWC), Central Pollution Control Board (CPCB) and Central Ground Water Board (CGWB) for common chemical quality monitoring programmes. Clarifications were sought by Dr. B. Mukhopadhyay of India Meteorology Department (IMD) and Dr. G.G.S.N. Rao, Principal Scientist, Central Research Institute for Dryland Agriculture (CRIDA) with respect to rain water and atmospheric vapour sampling. It was pointed out by Dr. B. Mukhopadhyay that the IMD setup at some of the proposed sampling locations was rudimentary and ice needed for moisture sampling was unlikely to be available. Therefore, IMD would initially participate in sampling at metro-stations only. Dr. G.G.S.N. Rao said that since their stations were located with academic institutions such problems could be overcome. And some of their stations could fill-in the gap in the network to provide samples. It was also pointed out that National Institute of Hydrology (NIH) has already set up 8 rainfall collection stations at their regional centres as part of their Indian Network for Isotopes in Precipitation (INIP). It was agreed that the two networks, INIP and IWIN, will be integrated and duplication avoided.

In the post-lunch session, the various components of the IWIN programme, namely, the atmospheric component, the surface water component, the groundwater component and the Bay of Bengal component were discussed in detail.

The specific objectives of the atmospheric component of the IWIN project were identified as (i) resolving conflicting views on identification of the principal oceanic sources of vapour inflow; and estimating (ii) redistribution of this vapour in terms of fraction precipitating over different land areas of the country; (iii) fraction of AS vapour crossing over to the BOB; (iv) amount and fraction re-entering as BOB branch; (v) fractions of precipitated water being recycled as evaporation and plant transpiration; (vi) identifying and quantifying geographic controls on precipitation and recycling; (vii) similar details regarding the NE winter precipitation; (viii) estimating the amount of moisture picked up from the BOB by the relatively dry winds of East Asian origin before contributing to NE monsoon rainfall. It was pointed out that Dr. Muraleedharan of National Institute of Oceanography (NIO) is the PI of the atmospheric component of the IWIN project. In addition to the isotope data, NCEP/ NCAR reanalysis data is to be used for this. Dr. B. Mukhopadhyay suggested establishing linkages with NWP and NCMRF programmes and also suggested the names of Dr. L.S. Rathod, Dr. Akhilesh Gupta, Dr. S.R. Kalsi and Dr. B.K. Basu of IMD for further contact.

The specific objectives of the surface water component of the IWIN programme were identified as: (i) isotope hydrograph separation for major streams to identify and partition flow into rainwater runoff and groundwater components temporally and spatially; (ii) in case of Himalayan rivers, separation of rainwater runoff, snowmelt and groundwater drainage components both temporally and spatially; (iii) estimation of seasonal evaporation from major reservoirs located in different climatic regimes in the country. The results of these studies are expected to be directly applicable to predicting hydrological change due to inter-basin transfer of waters. Dr. D.P. Singh, Director, Hydrology (RS), CWC pointed out that his organisation maintains and routinely monitors 650 stations for river water quality and discharge measurements across the country. He suggested contacting CWC Member (River Monitoring) for further discussions.

In case of groundwater, it was pointed out that studies so far done in different parts of the country have not shown any significant isotopic changes in groundwater over timescales of few years. Therefore, rather than temporal variations it is the spatial variation of isotopic composition that is important as it depends on isotopic characters to vapour source of the local rain, geography, surface geology, irrigation source water etc. The specific objectives of the groundwater component of the IWIN programme were therefore identified as: (i) characterising base level contemporary groundwater isotopic signature and its dependence on hydrological, meteorological, topographical and other factors; (ii) estimating evapo-transpiration, prior to groundwater recharge; (iii) establishing long term stability of groundwater isotopic composition by comparing new measurements with those taken more than 10-20 years ago in some parts of the country; (iv) confirming/ refuting theories linking groundwater fluoride to inherent aridity in many parts of India. To get country-wide coverage, samples from ~1,000 stations will be collected and analysed. The collection criteria will be (a) shallow unconfined groundwater; (b) ~0.5 km away from known surface water sources such as ponds, streams and reservoirs; (c) wide and near uniform spatial coverage on basin scale; (d) adjustments will be made to address local/ regional groundwater issues such as: identifying palaeo-waters, mixing between aquifers, surface - groundwater interactions etc. Dr. Uma Kapoor of CGWB assured that their network of periodic sample collection could be utilised for IWIN programme.

The specific objectives of the Bay of Bengal component of the IWIN programme were identified as studying seasonal water balance and mixing in the Bay of Bengal using salinity and isotopic variations of surface water. This was considered important as the BOB is an important source of monsoon rain primarily over Himalayan Mountains and much of North India during June-Sept. and the parts of South India during Oct.-Dec. Its surface water budget, unlike the AS, is highly variable seasonally due to very large influx of runoff water and heavy precipitation over it. In parallel isotopic composition of surface water of northern BOB also changes, but no data of isotopes in surface waters particularly during the crucial monsoon season are available. BOB component of the IWIN programme has been formulated with Dr. Hema Achyuthan of Geology Department, Anna University and involves periodic sampling of surface waters of BOB using commercial shipping linking Port Blair with Chennai, Kolkata and Vishakhapatanam together with NIO vessels as and when available.

Dr. M.S. Rao of NIH presented a summary of NIH's work in the field of hydrology and also informed that an Indian Network for Isotopes in Precipitation (INIP) is being established at the 8 regional centres of the NIH. At some of these locations, rainwater collection is already in progress since the monsoon season of 2003.

Prof. S.K. Tandon, Dept. of Geology, Delhi University while summarising the deliberations lauded the IWIN proposal as nationally very relevant and timely but also raised issues pertaining to maintenance of the IWIN and INIP networks, need for their complimentarity, questions of data ownership, sharing of data between project partners, nationally with other interested academicians and also globally. He also emphasised that mere measurements of isotopes will only result in a very limited increase in knowledge and to get the maximum benefit of the large effort that will go in this programme, it is necessary that other data such as temperature, relative humidity, ionic concentrations, groundwater levels, river discharges as are collected by participating agencies, namely, IMD, CPCB, CWC, CGWB, other universities and institutions be pooled and joint publications be planned. He also noted that the present awareness of isotopic applications within the various departments of the Govt. of India is limited and as the interaction between the isotope hydrologists and the participating agencies increases, new application will emerge. In this respect the IWIN programme will act as a catalyst for hydrological research in India. Prof. Tandon also suggested that the proposal should be with a 10-yr perspective and for 5-yr period. He also raised the issue of measurement capabilities in our laboratories. It was realised that a stable isotope machine at optimum efficiency can make about 2,000 analyses in a normal working year. It was estimated that the IWIN project requires, about 6,000 analyses every year. This number is arrived at based on the premise that spatial density and periodicity of sampling should be able to track about 0.5‰ change in $\delta^{18}O$ both temporally and spatially and cover >90% of the country. Keeping this in mind the PRL has already proposed to set up an additional Stable Isotope Mass Spectrometer as National Facility with 1/3 contribution from the internal sources of PRL and the balance as a project funding from DST. It was also noted that the DST funded facility at Indian Institute of Technology (IIT); Kharagpur may be able to make another 1,000 analyses. The upcoming NIH facility was already tied to its committed programme and could only analyse the samples from INIP programme. To fill the anticipated shortfall in the required analytical facilities and complement the project activities, it was proposed that there should be another new Stable Isotope Mass Spectrometer at NRL, with partial contribution from the ICAR and the balance as a proposed project funding from the DST. The NRL will explore the possibilities with the ICAR.

Dr. S.K. Gupta and Prof. P.S. Datta agreed to jointly reformulate the IWIN proposal to incorporate issues raised during the workshop. All the participants reconfirmed collaboration of the agencies they represented in this national endeavour.

The meeting ended with vote of thanks to Prof. Moharir and Prof. Tandon, the two Chairpersons of the forenoon and afternoon sessions respectively. The participants also thanked Prof. P.S. Datta and the staff of NRL for the excellent hospitality and the arrangements during the workshop.

(P.S. Datta) (S.K. Gupta)

Isotopes in Waters of India Network (IWIN) Workshop on 14-11-2003
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4. Dr. S.K. Gupta
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25. Mr. B. Sen
Technical Officer, NRL

26. Mr. P.C. Pathak
Technical Officer, NRL

27. Dr. S.K. Guha
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Could not attend the meeting due to prior commitments	
28. Dr. J.S. Samra Dy. Director General ICAR, Krishi Bhawan New Delhi-110 001	29. Dr. S. Nagarajan Director Indian Agricultural Research Institute New Delhi-110 012
30. Dr. B. Sengupta Member Secretary Central Pollution Control Board Parivesh Bhawan East Arjun Nagar Delhi 110 032	31. Dr. A.K. Singh Project Director Water Technology Centre IARI, New Delhi-110 012
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38. Dr. Ramesh Kumar, M.R. Scientist National Institute of Oceanography Dona Paula Goa-403 004	39. Dr. Hema Achyuthan Deptt. of Geology Anna University Chennai
40. Dr. Bhishm Kumar National Institute of Hydrology Roorkee 247 667	41. Prof. S.K. Bhattacharya Physical Research Laboratory Navrangpura, Ahmedabad 380 009

Minutes and recommendations of the Half-day meeting on Isotopes in Waters of India Network (IWIN) held at Central Pollution Control Board (CPCB), Delhi on March 4, 2004

A half-day meeting was held in the afternoon on Thursday, March 4, 2004 to discuss in detail the revised proposal of the Physical Research Laboratory (PRL) on Isotopes in Waters of India Network (IWIN). The participants included scientists of the Physical Research Laboratory (PRL), Indian Agriculture Research Institute (IARI), Central Research Institute for Dryland Agriculture (CRIDA), Nuclear Research Laboratory (NRL), Central Water Commission (CWC), India Meteorology Department

(IMD), Central Pollution Control Board (CPCB), Central Ground Water Board (CGWB), National Institute of Hydrology (NIH), Bhabha Atomic Research Centre (BARC), Indian Institute of Technology (IIT) Kharagpur, Jawaharlal Nehru University (JNU), Department of Science and Technology (DST) and Delhi University.

A list of participants to the meeting is given in Appendix -1.

Dr. B. Sengupta, Member Secretary, CPCB welcomed the participants and requested Prof. S.K. Tandon, Delhi University to chair the meeting. In his initial remarks Prof. Tandon said that it was a very happy situation to have isotope hydrology experts from the entire country on a common platform trying to evolve an important national programme with synergy between research scientists and user departments. He also remarked that the scientific aspects of the proposed study are well addressed in the revised proposal that appears nearly ready for submission to Department of Science and Technology (DST).

Dr. S.K. Gupta of PRL made a presentation detailing the changes that have been made in the revised proposal following recommendations of the first meeting of participating agencies held on Nov 14, 2003. Dr. Gupta re-stated that in addition to improving the basic understanding of the hydrology of the country at different spatial and temporal scales, this programme is vital for predicting the consequences of the impending engineered modification of the hydrological cycle of the country necessitated by increase in population and the need to rapidly develop and exploit the water resources of the country.

It has been estimated that by the year 2050, the per capita availability of flowing water in the country will decrease from the present ~1,700 m^3/yr to ~1,140 m^3/yr. The demand for water will almost triple to ~1,450 km^3/yr. This will require massive effort in conservation of water through rainwater harvesting and groundwater recharge, renovation and reuse of waste water, construction of medium and large surface storage reservoirs and even inter basin transfer of water. Whichever way the water demand is met, there will be large scale modification of the natural hydrological cycle in the country not just due to engineered structures and controlled stream flows but also by changing the residence time of water in aquifers and by increasing water vapour content of the atmosphere over India, significantly during non monsoon months.

It is, therefore, obvious that a detailed understanding of the natural hydrological cycle involving complex feedbacks and interactions between its various reservoirs is vital to accurately predict the consequences of the rapidly changing hydrological scenario.

Identifying dominant sources of seasonal vapour influx to India is also vital to improve understanding of (i) continental scale hydrological circulation and (ii) land-ocean-atmosphere interaction as Indian monsoon is an important component of global atmosphere circulation and source of all important water to India.

The methodology of the programme included the following:

1 Fabrication and procurement of the required number of atmospheric vapour and rainwater samplers.

2 Setting up of atmospheric vapour and rainwater collection stations in consultation with IMD, CRIDA, Universities and other academic Institutions.

3 Setting up of river water collection stations in consultation with CWC, CPCB, Universities and other Academic Institutions.

4 Identifying stations for groundwater sample collection in consultation with CGWB and other agencies for sufficient spatial coverage and specific problems.

5 Establishing a system of training the field staff for proper sample collection, storage, labelling with appropriate data sheets and despatch on regular basis.

6 Finalisation of the purchase of the Stable Isotope Ratio Mass Spectrometer (SIRMS) for the National Programme.

7 Setting up of the SIRMS for the National Programme at PRL and operationalising the same.

8 Hiring of the additional academic (PDF) and other staff for the National programme.

9 Training of the new staff and establishing a protocol for registering and measuring of the received samples and maintaining a library of samples.

10 Establishing a protocol for inter-laboratory calibration reporting of sample measurements between PRL-Ahmedabad, IIT-KGP, NIH-Roorkee, BARC-Mumbai and NRL-New Delhi.

11 Establishing a protocol for periodic workshop of the Laboratory and field staff involved in the project and review of progress. These workshops will also be used as forum for encouraging research in specialised areas of isotope hydrology using results of the IWIN programme by inviting research scholars from academic institutions and also providing hand on experience to students.

12 Inter Laboratory Calibration exercise.

13 Isotopic measurements.

14 Adding additional stations/ deleting unworkable stations depending on the periodic review of progress and results of analyses.

15 Preparation of reports and research contributions.

16 Preparation of New research proposals.

17 Arranging annual workshop for discussion of results and wider dissemination of the knowledge gained.

18 Preparation of IWIN programme for next five years for submission of project proposal

19 The following operational aspects will guide the working of the project. These are:

The network stations for sample collection will be owned and operated by the respective institutions. The collected samples will be sent along with a copy of sample collection record sheet for isotopic analyses to any of the pre-designated laboratory from among the PRL Ahmedabad/ IIT KGP/ NIH Roorkee/ NRL New Delhi. The results of the analyses will be communicated in standard format to (i) sample providing Institution and (ii) the central data warehouse for the IWIN Programme to be maintained by the PRL. The data will be jointly owned by the particular sample providing Institution, the particular isotope analysis laboratory and the IWIN Programme. The PRL isotope laboratory will organise periodic inter laboratory calibration experiments to ensure that all network data conforms to the same high quality standards. Periodic workshops/group meetings of all participating scientists in the network programme will be held to review the progress and to discuss knowledge increments from the work of the programme. Only those results that have been discussed in these workshops will be cleared for publication. All publications will be jointly issued at the time of first reporting of results. Thereafter, the results will form part of the public domain and will also be communicated to IAEA/GNIP programme.

The isotope laboratories at PRL, NIH and IIT-KGP will also act as national facilities for research in stable isotope hydrology by the universities and other academic Institutions. As part of this national facility, yearly training programmes for post graduate students will be conducted with hands on experience in mass spectrometric isotope analysis and sample collection & storage procedures.

Although, the present proposal is for a 5-year period, the National Programme has a 10 years perspective during which several new programmes of local and regional characters will be undertaken in the field of hydrology with several Universities and Academic institutions. Some of these programmes, though not forming part of the present proposal, have been indicated in the detailed project proposal.

Prof. Rajamani of JNU questioned the assumptions leading to increase in vapour loading of the atmosphere as the residence time of vapours in atmosphere was of the order of 9-10 days. He also suggested that the terminology of 'static groundwater' was rather loose as nothing was static. He wondered if the vapour sampling could be so organised that it was always from the same height above the ground.

Dr. K.R. Gupta of DST suggested that the sampling stations in NE should be increased as only 2-3 stations have been indicated.

Dr. Uma Kapoor of CGWB suggested that while selecting locations for groundwater sampling local Geohydrology should be taken into consideration.

Dr. S. V. Navada of BARC suggested that measurement of tritium on samples of rain, stream flow and groundwater would significantly enhance the knowledge value of the project. It was agreed that Dr. Navada should submit a satellite project in collaboration with NIH, Roorkee on this aspect.

Dr. Bhishm Kumar of NIH questioned the assumption that groundwater samples exhibited little seasonal variability. It was agreed that the groundwater sampling strategy will involve verifying this assumption at several locations particularly in case of hard rock and karstic aquifers.

Prof. Rajamani noted that the present proposal has been properly designed to address issues of sizes and fluxes of various hydrological reservoirs and the data will provide a baseline for monitoring anthropogenically induced changes.

Dr. R.M. Bhardwaj of Central Pollution Control Board (CPCB) requested a protocol for participating agencies and specification of their roles.

Dr. P.S. Datta also wanted to have exact responsibilities of the participating agencies clearly identified.

Dr. G.G.S.N. Rao of CRIDA wanted to know the relevance of isotopic work to agriculture and suggested to increase the budget meant for CRIDA.

Dr. B. Mukhopadhyay appreciated the potential of the IWIN programme to identify the large scale climatic features and this aspect matched with the mandate of the IMD. He wanted clear specification of the data requirements from IMD for this programme.

Dr. K.R. Gupta of DST said that SERC welcomed such proposals but noted several administrative loose ends which must be rectified before submission of the final proposal. He also suggested inclusion of neighbouring countries in this network at some stage. Dr. M. Prithviraj of DST, promised to explore UNDP funding for this project at a later stage for international exchange and training in Isotope Hydrology.

Prof. S.K. Tandon summarised the proceedings and suggested that the next meeting should be arranged in 6-8 weeks after tying of all administrative loose ends through a meeting of nominated coordinators of CWC, CPCB, CRIDA, IMD, CGWB, BARC, IIT, PRL, NRL and NIH.

Dr. Gupta was asked to revise the proposal in the light of discussions and to prepare a note on the General Application Areas of Isotopes in Waters of India Network (IWIN) for use in Geohydrology, Agro-ecology, Meteorology and Environmental Pollution so that the participating agencies could visualise expanding role for themselves in the IWIN programme.

Dr. Bhishm Kumar of NIH offered to host the next meeting of IWIN programme at NIH, Roorkee.

The meeting ended with a vote of thanks to Chair and to CPCB for the hospitality.

List of participants:

Half-day meeting on Isotopes in Waters of India Network (IWIN) held at Central Pollution Control Board (CPCB), Delhi on March 4, 2004

Sr. No.	Participant's Name	Participant's Affiliation
1.	Dr. B. Sengupta	Member Secy. Central Pollution Control Board (CPCB), New Delhi
2.	Prof. S.K. Tandon	Dept. of Geology, University of Delhi.
3.	Prof. V. Rajamani	School of Environmental Sciences, Jawaharlal Nehru University (JNU), New Delhi.
4.	Prof. P.S. Datta	Nuclear Research Laboratory (NRL), Indian Agriculture Research Institute (IARI), New Delhi.
5.	Dr. K. R. Gupta	Department of Science and Technology (DST), New Delhi.
6.	Dr. M. Prithviraj	Department of Science and Technology (DST), New Delhi.
7.	Dr. N.V.K. Chakarvarty	Indian Agriculture Research Institute (IARI), New Delhi.
8.	Dr. R.C. Trivedi	Central Pollution Control Board (CPCB), New Delhi.
9.	Dr. Bhishm Kumar	National Institute of Hydrology (NIH), Roorkee.
10.	Dr. S.V. Navada	Bhabha Atomic Research Centre (BARC), Mumbai.
11.	Dr. Anindya Sarkar	Indian Institute of Technology (IIT), Kharagpur.
12.	Dr. G.G.S.N. Rao	Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad.
13.	Dr. S.D. Mokhijani	Central Pollution Control Board (CPCB), New Delhi.
14.	Dr. B. Mukhopadhyay	India Meteorology Department (IMD), New Delhi.
15.	Dr. Uma Kapoor	Central Ground Water Board (CGWB), New Delhi.
16.	Dr. R.M. Bhardwaj	Central Pollution Control Board (CPCB), New Delhi.
17.	Dr. C.S. Sharma	Central Pollution Control Board (CPCB), New Delhi.
18.	Dr. Sanjeev Agrawal	Central Pollution Control Board (CPCB), New Delhi.
19.	Mr. R.D. Deshpande	Physical Research Laboratory (PRL), Ahmedabad.

20.	Mr. V.K. Malhotra	Central Water Commission (CWC), New Delhi.
21.	Dr. S.K. Gupta	Physical Research Laboratory (PRL), Ahmedabad.

Minutes and Final Recommendations of the One-day meeting on National Programme on Isotopes in Waters of India Network (IWIN) held at National Institute of Hydrology, Roorkee on May 3, 2004

A project finalisation meeting of the participants' of the National Programme on Isotopes in Waters of India Network (IWIN) was held on Monday, May 3, 2004 to discuss in detail the revised draft proposal of the Physical Research Laboratory (PRL). The participants included representatives of the Physical Research Laboratory (PRL), the Central Water Commission (CWC), Central Ground Water Board (CGWB), National Institute of Hydrology (NIH), Bhabha Atomic Research Centre (BARC) and the Department of Science and Technology (DST). The representatives of the other participating institutions, namely, the Central Research Institute for Dryland Agriculture (CRIDA), Nuclear Research Laboratory (NRL), India Meteorology Department (IMD) and Central Pollution Control Board (CPCB), though having confirmed their participation could not attend the meeting due to last minute urgent work within their respective organisations.

A list of participants to the meeting is given on p.81.

Dr. K.D. Sharma, Director National Institute of Hydrology, Roorkee welcomed the participants. After a round of self introduction of the participants, Dr. K.D. Sharma, in his opening remarks, noted that it was a very happy situation to have Isotope Hydrology Experts of the country having formulated a common National Programme with synergy between research scientists and user departments to advance the basic understanding of the hydrological cycle in the country. In this connection, Dr. Bhishm Kumar informed that NIH already has planned isotope work on snow and glacier hydrology as part of one of their research project. Dr. K.D. Sharma also noted that the draft programme did not have specific component on snow hydrology that has vital role in the hydrological cycle in the country. He suggested installing some of the network stations in Himalayan region having significant precipitation the form of snow. He also remarked that other scientific aspects of the proposed study have been well addressed in the revised proposal that appears nearly ready for submission to Department of Science and Technology (DST).

Dr. K.D. Sharma then asked Dr. S.K. Gupta to briefly present the salient features of the project proposal and the action taken on the suggestions made by the participants during the last meeting held on 4th March, 2004 at CPCB, Delhi. Dr. S.K. Gupta, noted that the revised draft now had a section on the Role of Participating Agencies and another section on such Practical Applications of Isotopes in Waters of India Network (IWIN) Programme that do not figure directly in the sections on Objectives and Importance of the proposed project in the context of current status. Notes on these additional sections had already been circulated to the participating agencies as requested during the last meeting. Another suggestion made by Dr. Bhishm Kumar in the last meeting regarding provision of a Project Scientist at NIH had also been included in the revised project proposal. The suggestion made by Dr. G.G.S.N. Rao of CRIDA for enhancing the cost of field sample collection had also been complied with in the revised draft. Dr. Bhishm Kumar also felt that the projected cost of sample collection was little less and this provision should be enhanced.

Dr. Gupta also informed that following personnel have been designated by their respective agencies to liaison with the National Programme. The designated Coordinators had promised to bring the Letters of Endorsement from their respective

Heads of the Institutions at the meeting. However, since some have not been able to come to attend the meeting the endorsements from them will be obtained in due course.

Participating Agency	Coordinator for Liaison with the National Programme	Confirmation is Oral/written
Physical Research Laboratory (PRL)	Dr. S.K. Gupta/ Prof. S.K. Bhattacharya	Written
Central Water Commission (CWC)	Mr. S.C. Avasthi	Oral
Central Pollution Control Board (CPCB)	Dr. R.C. Trivedi/ Dr. R.M. Bhardwaj	Oral
India Meteorology Department (IMD)	Dr. B. Mukhopadhyay	Oral
Nuclear Research Laboratory (NRL-IARI)	Prof. P.S. Datta	Written
Central Ground Water Board (CGWB)	Dr. Saleem Romani/ Dr. Uma Kapoor	Written
National Institute of Hydrology (NIH)	Dr. Bhishm Kumar/ Dr. S.P. Rai	Written
Bhabha Atomic Research Centre (BARC)	Dr. U. Sarvan Kumar	Oral
Indian Institute of Technology, Kharagpur (IIT-KGP)	Dr. A. Sarkar	Oral
National Institute of Oceanography (NIO), Goa	Dr. P. Muraleedgaran	Written
Anna University, Chennai	Dr. Hema Achyuthan	Oral
Central Research Institute for Dryland Agriculture (CRIDA)	Dr. G.G.S.N. Rao	Oral

In this connection, Mr. S.C. Avasthi from CWC informed that all discharge data of the Ganga and Brahamputra river basins are confidential in nature and will not be shared with the IWIN National Programme for publication and /or sharing with any other agency. The IWIN National Programme may also be required to give an undertaking to this effect. Mr. Avasthi also informed that as per the current practice there is a nominal charge on the data provided by CWC to other agencies. At suggestions of Dr. K.R. Gupta of Department of Science and Technology and Dr. K.D. Sharma, Mr. Avasthi promised to examine the possibility of obtaining a waiver of payment for CWC data for use of IWIN National Programme as the CWC is the project partner. Mr. Avasthi also informed that Bakhara Management Board should also be approached to participate in the project as they have a vital stake in estimating seasonal variations in inflow components in terms of direct surface runoff, groundwater discharge and snowmelt. Mr. Avasthi also wanted to be informed about any successful case study (within India or abroad) using the proposed isotope monitoring methodology. Dr. K.R. Gupta suggested a detailed programme along Jhelum River. He also suggested the formulation of a project monitoring mechanism within the research proposal.

Dr. K.K.S. Bhatia noted that the IWIN programme did not have a component for lake studies and suggested its inclusion. Dr. S.K. Gupta informed that PRL has partially completed a project for estimation of evaporation using isotopes and salt balance studies in 3 irrigation reservoirs in Gujarat and the results would be published in near future. Dr. Bhishm Kumar noted that NIH has recently completed and published their isotope work on the Nainital Lake with very interesting and useful results. Most participants felt that the proposed number of isotope monitoring stations was too small for a big country like India and as a result the usefulness the proposed project may be limited.

Responding to the various queries, Dr. S.K. Gupta informed that the project will be a quantum addition to available information in the country that presently has only two stations, namely New Delhi and Mumbai with long term record of isotopes in precipitation. The proposed work will no doubt be coarse and he likened the proposed attempt during the 1st '5-yr phase' at drawing a skeleton good enough to know if the body is tall or short, that of a child or a grown up man or an old man or a fat person or a thin person though probably not good enough to identify the person. However, it has been planned to have selected satellite projects that will either draw upon the IWIN National programme or will contribute to it through detailed investigation on some aspect of the hydrology in any particular basin. The satellite projects may also study some other aspect that will advance the knowledge of hydrology of India by measuring some other parameters such as trace elements, certain pollutants etc in some detail in a particular region. Some satellite projects have already been identified and project proposals for submission are being formulated. These are: (i) Seasonal variations in the isotopic composition the Bay of Bengal surface waters in response to influx of Himalayan river water with Dr. Hema Achyuthan of Anna University Chennai as PI; (ii) studying the atmospheric component using isotopes and NCEP/NCAR reanalysis data with Dr. P.M. Muraleedharan of National Institute of Oceanography as PI; (iii) study of spatial and temporal variations of tritium of precipitation, surface water and groundwater from selected locations in the country jointly by BARC and NIH. He also noted that suggested projects like detailed investigations in the Jhelum river basin or the snow and the glacier studies in which the Wadia Institute of Himalayan Geology with its field stations can play a significant role should be considered as additional satellite programmes. It is hoped, that as the proposed project proceeds, several satellite projects will be added as and when interesting problems, interested scientists and institutions can be found to handle these projects. Presently, however, looking into the limitations of measuring instruments that is the mass spectrometer and the available scientific personnel to shoulder the management responsibility of the project it is best to restrict the scope of the main IWIN National programme and the three identified satellite projects. Dr Gupta also promised to send references of successful studies on detailed isotopic studies in river basins to Mr Avasthi. Dr. K.R. Gupta suggested adding a list of the possible satellite projects to the main project proposal. This was agreed to by all.

All the present Coordinators authorised Dr S. K. Gupta to finalise the project proposal keeping in mind the various suggestions made at this meeting.

The meeting ended with Dr S. K. Gupta proposing a vote of thanks to Dr. K.D. Sharma, Director for conducting the meeting and the hospitality extended and to Dr. Bhishm Kumar for the various arrangements and to project coordinators from different National Agencies for having travelled to Roorkee and finally to the staff of the NIH for all the back stage preparations.

List of participants

Sr. No.	Name	From
1.	Dr. K. D. Sharma	NIH Roorkee
2.	Mr. S.C. Avasthi	CWC, New Delhi
3.	Dr. K.R. Gupta	DST, New Delhi
4.	Dr. S.V. Navada	BARC, Mumbai
5.	Dr. Uma Kapoor	CGWB, New Delhi
6.	Dr. S.K. Gupta	PRL, Ahmedabad
7.	Dr. Bhishm Kumar	NIH Roorkee
8.	Dr. Sudheer Kumar	NIH Roorkee
9.	Dr. S.P. Rai	NIH Roorkee
10.	Dr. K.K.S. Bhatia	NIH Roorkee
11.	Dr. A.K. Bhar	NIH Roorkee
12.	Dr. S.K. Jain	NIH Roorkee
13.	Dr. S.K. Verma	NIH Roorkee
14.	Dr. P.K. Garg	NIH Roorkee
15.	Dr. Jagmohan	NIH Roorkee
16.	Dr. Umesh Kumar Singh	NIH Roorkee
The following were expected but could not attend		
17.	Dr. R.C. Trivedi/ Dr. R.M. Bhardwaj	CPCB, Delhi
18.	Dr. B. Mukhopadhyay	IMD, New Delhi
19.	Dr. G.G.S.N. Rao	CRIDA, Hyderabad
20.	Dr. P.S. Datta	NRL, New Delhi
21.	A representative	WIHG, Dehradun

ENDORSEMENTS FROM COLLABORATING SCIENTISTS AND HEAD OF THEIR INSTITUTIONS

राष्ट्रीय समुद्र विज्ञान संस्थान
national institute of oceanography

Dr. N.B. Bhosle
Scientist 'F'

Endorsement from the Head of the Institution

Project title : Isotope Fingerprinting of Waters of India (IWIN):

1. Certified that the Institute welcomes the participation of Dr. P.M.Muraleedharan as the Principal Investigator for the project, and that in the unforeseen event of discontinuance by the Principal Investigator, appropriate person from this Institute will be appointed to resume responsibility of the fruitful completion of the project (with due intimation to DST). [This project is in collaboration with the Physical Research Laboratory, Ahmedabad].
2. Certified that the equipment and other basic facilities, as enumerated in Section 420, and such other administrative facilities, as per terms and conditions of the grant, will be extended to the investigators throughout the duration of the project.
3. The Institute hereby agrees to undertake the financial and other management responsibilities of the project.
4. This project proposal falls in line with the normal research activities of the Institute.

(N.B.Bhosle) 9/8/05
For Director

DIRECTOR
National Institute of Oceanography
Dona Paula, Goa-403 004

Date : 9 August 2005

Place : Dona Paula

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Mumbai, Kochi, Visakhapatnam

SILVER JUBILEE YEAR 2002-03 25

Anna University
PROGRESS THROUGH KNOWLEDGE

ENDORSEMENT FROM THE HEAD OF INSTITUTION

DATE............................

PROJECT TITLE : "ISOTOPE FINGERPRINTING OF WATERS OF INDIA (IWIN): A PROJECT PROPOSAL".

Certified that the Department of Geology, Anna University welcomes participation of Dr. Hema Achyuthan, Assistant Professor as the Principal Investigator for the above National Programme. The programme falls in line with the approved research activities of the Department of Geology, Anna University.

1. Anna University also welcomes participation of Prof. S.K. Gupta, PRL, Ahmedabad as Principal Co-ordinator of this project.

2. Certified that Anna University will adopt the proposed project programme and provide all possible necessary help and facilities as described in the project proposal.

3. Anna University will also undertake the financial and other management responsibilities of the project.

4. Certified that Anna University will provide space and other infrastructure facilities as required successfully undertake this project.

5. This project proposal is in collaboration with Physical research laboratory, Ahmedabad. The roles and responsibilities of respective institutions have been defined in the project proposal.

6. Certified that equipment and other basic facilities as enumerated in section 420 and such other administrative facilities as per terms and condition of the Department of Science and Technology grant will be extended to the investigators throughout the duration of the project.

2/2

9/8/05

REGISTRAR
ANNA UNIVERSITY
CHENNAI-600 025.

Date :

Place : Anna University, Chennai 25.

Name and Signature of the Head of the Institution

9/8/05

Add : Sardar Patel Road, Chennai - 600 025.
Ph: 2235 1126, 2235 2312, 2235 2385, 2235 0526, 2235 2286 Fax : 91-44-22350397 - www.annauniv.edu

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NATIONAL GEOPHYSICAL RESEARCH INSTITUTE
(Council of Scientific & Industrial Research)
Uppal Road, Hyderabad - 500 007, India.

डा. वि.प्र. डिमरी, एफ एन ए, एफ एन ए एससी.
निदेशक

DR. V. P. DIMRI, FNA, FNASc.
Director

Endorsement from the Head of Institution

Project Title: **National Programme on Isotope Fingerprinting of Waters of India (IWIN):A Project Proposal**

1. Certified that the National Geophysical Research Institute, Hyderabad agrees to participate in the above National Programme.
2. Certified that the National Geophysical Research Institute will provide all possible necessary help for Stable Isotope Analyses/ Collection of samples, the details of which will be finalised at a later date after approval of the project.
3. The Institute National Geophysical Research Institute deputes Mr. P. Nagabhushanam to act as Co-Investigator for liaison between the National Programme and the National Geophysical Research Institute.
4. Certified that in the event Mr. P. Nagabhushanam is not able to function as a Co-Investigator with the National Programme, the National Geophysical Research Institute will appoint another person as a Co-Investigator.
5. It is understood that the cost incurred by the institution and as specified in the National Programme Project Budget will be made available to the Institution.

12/7.05

Name and Signature of Head of Institution

Date: 12 July 2005

Place: Hyderabad

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भारत/INDIA.

सत्यमेव जयते

भारत सरकार
GOVERNMENT OF INDIA
भाभा परमाणु अनुसंधान केन्द्र
BHABHA ATOMIC RESEARCH CENTRE
आइसोटोप अनुप्रयोग प्रभाग
ISOTOPE APPLICATIONS DIVISION

डा0 गुरशरन सिंह
अध्यक्ष, आइसोटोप अनुप्रयोग प्रभाग
Dr. Gursharan Singh
Head, Isotope Applications Division

Ref: IAD/79/331.

May 14, 2004

ENDORSEMENT FROM THE HEAD OF INSTITUTION.

Project Title: National Programme on Spatial and Temporal Fingerprinting of waters of India Using stable isotopes to study seasonal evolution, interactions, geographic controls and climatic forcing.

1 It is agreed that Isotope Application Division (IAD), BARC will participate in the above National Programme.

2. IAD, BARC will provide all possible necessary help for stable isotope analyses, the details of which will be finalized at a later date after approval of the project.

3. IAD, BARC agrees to nominate Dr. S.V. Navada to act as Co-ordinator and Dr. K. Shivanna as Joint-coordinator to liaison between the National Programme and IAD, BARC.

4. In the event of Dr. S.V. Navada and Dr. K. Shivanna not being able to function as a Co-ordinator and Jt. Coordinator, IAD, BARC will appoint their substitutes as a Co-ordinator and Jt. Coordinator.

14.5.2004
(Gursharan Singh)

Date: 14.05 2004
Place: Trombay

Dr. S.K. Gupta,
PRL,Navarangpura,
Ahmedabad – 380 009

FAX 079 - 6301502

D:\Isotope Hydrology Section\national programme on spatial and temporal fingerprinting.doc

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सत्यमेव जयते

भारत सरकार
केन्द्रीय भूमि जल बोर्ड
जल संसाधन मंत्रालय

Government of India
Central Ground Water Board
Ministry of Water Resources
Jamnagar House, Man Singh Road
NEW DELHI-110011

Endorsement from the Head of Institution

Project Title: National Programme on Spatial and Temporal Fingerprinting of Waters of India Using Stable Isotopes to Study Seasonal Evolution, Interactions, Geographic Controls and Climatic Forcing.

1. **Certified that the Central Ground Water Board agrees to participate in the above National Programme.**
2. **Certified that the Central Ground Water Board will provide all possible necessary help for Collection of Samples, the details of which will be finalized at a later date after approval of the project.**
3. **The Central Ground Water Board deputes Dr. Saleem Romani, Member (SML) to act as Co-coordinator for liaison between the National Programme and the C.G.W.B.**
4. **Certified that the Central Ground Water Board deputes Dr. Uma Kapoor to act as alternate Coordinator for the National Programme.**

Date: 11.3.2004

Place: New Delhi

(P.C. CHATURVEDI)
CHAIRMAN
CENTRAL GROUND WATER BOARD

Faridabad Office : Central Ground Water Board, New CGO Complex, N.H.IV, Faridabad-121001 (Haryana)
Phone: 95129-2419075 Fax : 95129-2412524 Gram : BHUMIJAL

केन्द्रीय प्रदूषण नियंत्रण बोर्ड
CENTRAL POLLUTION CONTROL BOARD
(पर्यावरण एवं वन मंत्रालय, भारत सरकार)
(MINISTRY OF ENVIRONMENT & FORESTS, GOVT. OF INDIA)

A-14011/1/2003/Mon 15483

29th July, 2003

IWIN

To

Dr. S.K. Gupta,
Scientist `SG'
Physical Research Laboratory
Navrangpura, Ahmedabad-380 009.

Subject : **Spatial and temporal fingerprinting of waters of India using stable isotopes to study seasonal evolution, interactions, geographic controls and climatic forcing: A project proposal for `Isotopes in Waters of India, Network (IWIN)'**

Sir,

Kindly refer to your letter No. NIL dated 07 May 2003 and 12 June 2003 on the above subject. The project proposal submitted by you is reviewed in CPCB. The Central Board may associate itself in the project study to carry out the monitoring without financial commitment. There is a need for training in carrying out specialised monitoring for CPCB officials and procurement of equipments for collection of samples.

CPCB will extend the support for identification of monitoring locations and collection of samples.

Yours faithfully

(B. Sengupta)
Member Secretary

Copy to:

The Director,
Physical Research Laboratory
Navrangpura, Ahmedabad-380 009.

परिवेश भवन, पूर्वी अर्जुन नगर, दिल्ली–110032
Parivesh Bhawan, East Arjun Nagar, Delhi-110032
दूरभाष/Tel. : 2225792, 2222073, 2222856, 2226127, 2222978, 2221699, 2432717
फैक्स/Fax : 2225793, 2217079, 2411539, 2451932
टेलैक्स/Telex : 031-66440 PCON IN ; तार/Gram : "CLEENVIRON"
ई–मेल/e-mail : cpcb@alpha.nic.in; cpcb@sansad.nic.in

सर्व शिक्षा अभियान
सब पढ़ें सब बढ़ें

ICAR

Phone : (Off.) +91-040-24530177
(Res.) 24532262
Fax : 24531802, 24535336
E-mail : ramakrishna.ys@crida.ap.nic.in
Web : http://dryland.ap.nic.in

केन्द्रीय बारानी कृषि अनुसंधान संस्थान
Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad - 500 059, INDIA.

डॉ. वाई. एस. रामकृष्ण
निदेशक

Dr. Y. S. RAMAKRISHNA
DIRECTOR

Endorsement

Project Title: **National Program on Spatial and Temporal Fingerprinting of Waters of India using Stable Isotopes to Study Seasonal Evolution, Interaction, Geographic Controls and Climatic Forcing**

1) Certified that the Institutes (All India Coordinated Research Project on Agrometeorology [AICRPAM], Central Research Institute for Dryland Agriculture [CRIDA]) agrees to participate in the above Program.

2) Certified that the Institute (AICRPAM, CRIDA) will provide all possible necessary help for Stable Isotope Analyses / Collection of samples, the details of which will be finalized at the later date after approval of the Project.

3) The Institute (AICRPAM, CRIDA) depute ***Dr. G.G.S.N. Rao, Principal Scientist (Ag. Met.)*** to act as Coordinator for liaison between the National Program and the Institute (AICRPAM, CRIDA)

4) Certified that in the event of ***Dr. G.G.S.N. Rao*** is not able to function as a Coordinator with the National Program, the Institute (AICRPAM, CRIDA will appoint another person as a Coordinator.

5) It is understood that the cost incurred by the Institution and as specified in the National Program Project Budget will be made available to the Institution.

Date : 21-05-2004
Place : Hyderabad

Y.S. Ramakrishna

No. 6/17-A2003-RDD/ 1304
Government of India
Central Water Commission
River Data Directorate
West Block I, Wing 4, II Floor
R.K. Puram, New Delhi-110066

Dated: 25/05/04

To

Dr. S.K. Gupta,
Scientist 'SG'
Physical Research Laboratory,
Navrangpura, Ahmedabad-380009.

Sub: Spatial and temporal fingerprinting of waters of India using Stable Isotopes to study seasonal evolution, interactions, Geographic controls and climatic forcing: A project proposal for 'Isotopes in Waters of India, Network (IWIN)'.

Sir,

Please refer to the EMail dated 12th May, 2004 requesting for endorsement letter from Head of the Institution and forwarding minutes of the meeting held on 3rd May, 2004 at NIH, Roorkee. It is to inform you that the CWC has already agreed to participate in the above National Programme. CWC would provide all possible necessary assistance in collection of water samples. The CWC shall provide flow data of sites as per existing guidelines & procedures. Chief Engineer (P&D), CWC and Director (RD), CWC will act as Coordinator and Joint-Coordinator respectively for the National Programme. This is for your information and necessary action please.

Yours faithfully,

25/5/04
(S.C. Awasthy)
Chief Engineer (P&D)

15/7

सं०
भारत सरकार
भारत मौसम विज्ञान विभाग
मौसम विज्ञान के महानिदेशक का कार्यालय
मौसम भवन, लोदी रोड,
नई दिल्ली-११०००३
तार का पता :
महामौसम, नई दिल्ली

NO.
GOVERNMENT OF INDIA
INDIA METEOROLOGICAL DEPARTMENT
OFFICE OF THE
DIRECTOR GENERAL OF METEOROLOGY
MAUSAM BHAVAN, LODI ROAD
NEW DELHI-110003
Telegraphic Address :
DIRGENMENT, NEW DELHI

दिनांक/Date.................................199

Endorsement from the Head of Institution

Project Title: National Programme on Spatial and Temporal Fingerprinting of Waters of India Using Stable Isotopes to study seasonal evolution, interactions, geographic controls and climatic forcing.

1. Certified that the Institute **(India Meteorological Department)** agrees to participate in the above National Programme.
2. Certified that Institute **India Meteorological Department** will provide all possible necessary help for Stable Isotope Analyses/collection of samples, the details of which will be finalized at a later date after approval of the project.
3. The Institute **India Meteorological Department** deputes Mr. B. Mukhopadhyay to act as coordinator for liaison between the National Programme and institute (IMD).
4. Certified that in the event Mr. B. Mukhopadhyay is not able to function as coordinator with the National Programme, the Institute **India Meteorological Department** will appoint another person as a coordinator.
5. It is understood that the cost incurred by the Institution and as specified in the National Programme Budget will be made available to the institution.

Date: June 2004

Place: New Delhi

7/6/04

(A. K. Bhatnagar)
Executive Director (EMRC)
For Director General of Meteorology

दूरभाष :
Telephone :
तार : कृषिपूसा
Telegram : KRISHIPUSA

भाकृअनुप
ICAR

भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली-110 012
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI - 110012 (INDIA)

संख्या :
No. :

दिनांक :
Dated :

Endorsement from the Head of Institution

Project Title: National Programme on Spatial and Temporal Fingerprinting of Waters of India Using Stable Isotopes to Study Seasonal Evolution, Interactions, Geographic Controls and Climatic Forcing

Certified that the Institute (NIH/IIT-KGP/NIO/AU/IMD/CPCB/CWC/CGWB/CRIDA/BARC/NRL/PRL) agrees to participate in the above National Programme.
Certified that the Institute (NIH/IIT-KGP/NIO/AU/IMD/CPCB/CWC/CGWB/CRIDA/BARC/NRL/PRL) will provide all possible necessary help for Stable Isotope Analyses/ Collection of samples, the details of which will be finalised at a later date after approval of the project.

The Institute (NIH/IIT-KGP/NIO/AU/IMD/CPCB/CWC/CGWB/CRIDA/BARC/NRL/PRL) deputes (Dr. P.S. DATTA) to act as Co-ordinator for liaison between the National Programme and the Institute (NIH/IIT-KGP/NIO/AU/IMD/CPCB/CWC/CGWB/CRIDA/BARC/NRL/PRL). Additionally, Dr./Mr.______—______is deputed as Joint-coordinator on this programme.

Certified that in the event (Dr. P.S. DATTA or Dr./Mr.______—______) are not able to function as a Co-ordinator or Jt. Coordinator with the National Programme, the Institute (NIH/IIT-KGP/NIO/AU/IMD/CPCB/CWC/CGWB/CRIDA/BARC/NRL/PRL) will appoint other person as a Co-ordinator or Jt. Coordinator. It is Understood that the cost incurred by the institution and as specified in the National Programme Project Budget will be made available to the Institution.

Date: 23/6/04
Place: Delhi

Name and Signature of Head of Institution

निदेशक / Director
भारतीय कृषि अनुसंधान संस्थान
Indian Agricultural Research Institute
नई दिल्ली-110012
New Delhi-110012

राष्ट्रीय जलविज्ञान संस्थान
(जल संसाधन मंत्रालय के अधीन भारत सरकार की समिति)
जलविज्ञान भवन, रुड़की – 247 667 (उत्तरांचल) भारत
NATIONAL INSTITUTE OF HYDROLOGY
(A Govt. of India Society under Ministry of Water Resources)
JALVIGYAN BHAWAN, ROORKEE - 247 667 (Uttaranchal) INDIA

आपो हि ष्ठा मयोभुवः

रजत जयंती वर्ष 2003-2004
SILVER JUBILEE YEAR 2003-2004

डा. कपिल देव शर्मा
निदेशक
Dr. K.D. Sharma
Director

दूरभाष / ☎ : 01332 - 272106 (O)
: 01332 - 276052 (R)
फैक्स / Fax : 91-1332 - 272123, 273976
ई.मेल / E.Mail: sharmakd@nih.ernet.in
kdsharma@nih.ernet.in

Enclosure – 4

Project Title: National Programme on Spatial and Temporal Fingerprinting of Waters of India Using Stable Isotopes to Study Seasonal Evolution, Interactions, Geographic Controls and Climatic Forcing.

1. Certified that the National Institute of Hydrology, Roorkee agrees to participate in the above National Programme.

2. Certified that the Institute (NIH) will provide all possible necessary help for Stable Isotope Analyses/Collection of samples, the details of which will be finalized at a later date after approval of the project.

3. The Institute (NIH) deputes Dr. Bhishm Kumar, Sc.F and Head, H.I. Division to act as Co-ordinator for liaison between the National Programme and the Institute (NIH). Additionally, Dr. S.P. Rai, Sc.'C' is deputed as Joint-coordinator on this programme.

4. Certified that in the event Dr. Bhishm Kumar or Dr. S.P.Rai are not able to function as a Co-ordinator or Jt. Coordinator with the National Programme, the Institute (NIH) will appoint other person as a Co-ordinator or Jt. Coordinator.

5. It is understood that the cost incurred by the institute as specified in the National Programme Project Budget, will be made available to the Institute.

Date: 28th April, 2004

Place: Roorkee

(**K.D. Sharma**) 28/4/04

INDIAN INSTITUTE OF TECHNOLOGY
KHARAGPUR - 721302, INDIA

भारतीय प्रौद्योगिकी संस्थान
खड़गपुर : ७२१३०२, इंडिया

Prof. Partha P. Chakrabarti, FNA, FASc, FNAE
Dean, Sponsored Research & Industrial Consultancy
Professor, Department of Computer Science & Engineering
Professor-in-Charge, Advanced VLSI Design Laboratory

No. : IIT/SRIC/DEAN/2004
June 11, 2004

Endorsement from the Head of the Institution

Project Title : National Programme on Spatial and Temporal Fingerprinting of Waters of India using Stable Isotopes to study Seasonal Evolution, Interactions, Geographic Controls and Climatic Forcing

1. Certified that the Institute agrees to the participation of Dr. Anindya Sarkar in the above National Programme.

2. Certified that the Institute will provide all possible necessary help for Stable Isotope Analyses / collection of samples, the details of which will be finalized at a later date after approval of the project.

3. The Institute agrees Dr. Anindya Sarkar to act as Coordinator for liaison between the National Programme and the Institute.

4. It is understood that the cost incurred by the institution and as specified in the National Programme Project Budget will be made available to the institution.

(Partha P. Chakrabarti)

Phone : ++91-3222-282037/ 277188 (O), 283466 (CSE-Office), 283467 (R), 277932 (R) **Fax :** +91-3222-277190, 278985, 255303
E-mail : deansr@hijli.iitkgp.ernet.in ; ppchak@cse.iitkgp.ernet.in

भौतिक अनुसंधान प्रयोगशाला
(अंतरिक्ष विभाग की युनिट, भारत सरकार)
नवरंगपुरा, अहमदाबाद - 380 009, भारत
तार : ''रिसर्च'' फेक्स : 91-(0)79-6301502
दूरभाष : 6302129 ई-मेल : root@prl.ernet.in

PHYSICAL RESEARCH LABORATORY
(A UNIT OF DEPT. OF SPACE, GOVT. OF INDIA)
NAVRANGPURA, AHMEDABAD-380 009, INDIA.
CABLE : "RESEARCH" FAX : 91-(0)79-6301502
PHONE : 6302129 E-mail : root@prl.ernet.in

Certificate from the Co-Principal Coordinator

Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the project. I shall not request financial support under this project, for procurement of these items.

S.K. Bhattacharya

Date: 02-08-2005
Place: Ahmedabad

(S.K. Bhattacharya)
Name and signature of Co-Principal Coordinator

भौतिक अनुसंधान प्रयोगशाला
(अंतरिक्ष विभाग की युनिट, भारत सरकार)
नवरंगपुरा, अहमदाबाद-380 009, भारत
तार : "रिसर्च" फेक्स : (91)-079-6560502
टेलेक्स : 0121-6397 दूरभाष : 6462129

PHYSICAL RESEARCH LABORATORY
(A UNIT OF DEPT. OF SPACE, GOVT. OF INDIA)
NAVRANGPURA, AHMEDABAD-380 009, INDIA.
CABLE : "RESEARCH" FAX : (91)-079-6560502
TELEX : 0121-6397 TELEPHONE : 6462129

Certificate from the Co-Principal Coordinator

Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the project. I shall not request financial support under this project, for procurement of these items.

Date: 10-08-2005
Place: Ahmedabad

(R. Ramesh)
Name and signature of Co-Principal Coordinator

भौतिक अनुसंधान प्रयोगशाला
(अंतरिक्ष विभाग की युनिट, भारत सरकार)
नवरंगपुरा, अहमदाबाद - 380 009, भारत
तार : ''रिसर्च'' फेक्स : 91-(0)79-6301502
दूरभाष : 6302129 ई-मेल : root@prl.ernet.in

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NAVRANGPURA, AHMEDABAD-380 009, INDIA.
CABLE : "RESEARCH" FAX : 91-(0)79-6301502
PHONE : 6302129 E-mail : root@prl.ernet.in

Certificate from the Co-Investigator

Project Title : National Programme on Isotope Fingerprinting of Waters of India (IWIN) : A project proposal

1. I agree to participate in this national programme.

2. We are already having an ISRO-GBP ongoing project to measure vertical distributions of ozone, relative humidity and temperature using balloon borne sensors from Ahmedabad. We are launching ozone and radio sondes fortnightly for this purpose.

3. As discussed and agreed upon with Dr. S. K. Gupta, Principal Co-ordinator, we will make additional balloon launchings of radiosondes to make it weekly launchings during three months (July to September) for two years only.

4. These three months data of humidity and temperature profiles upto 10 km height for two years will be shared with the IWIN team. It is to be noted that humidity measurements are generally reliable/available only upto about eight km height with these sensors. My team members (at least two) will be made co-authors in each publication where these data will be used. However, we will be free to use these data for our use.

Date : 29 July, 2005
Ahmedabad

Shyam Lal
Shyam Lal
Name and Signature of Co-Investigator

राष्ट्रीय समुद्र विज्ञान संस्थान
national institute of oceanography

Dr. P.M.Muraleedharan
Scientist, E II

Certificate from the Principal Investigator

Project Title : Isotope Fingerprinting of Waters of India (IWIN):

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the project. I shall not request financial support under this project for procurement of these items.
4. I undertake that spare time on permanent equipment (listed in Section 350) will be made available to other users.

PMMuraleedharan 9/8/05
(P.M.Muraleedharan)
Name & Signature of Principal Investigator

Date : 9 August 2005
Place : Dona Paula, Goa

दोना पावला, गोवा 403 004, भारत
DONA PAULA, GOA - 403 004, India
☎ : 91-(O)832-2450 450
fax : 91-(O)832-2450 602/03
e-mail : ocean@darya.nio.org
URL : **http://www.nio.org**
Regional Centres
Mumbai, Kochi, Visakhapatnam

Certificate from the Principal Investigator

Project Title: ISOTOPE FINGERPRINTING OF WATERS OF INDIA (IWIN): A PROJET PROPOSAL

- I agree to abide by the terms and conditions of SERC research grant.
- I did not submit the project proposal elsewhere for financial support.
- I have explored and ensured that equipments and basic facilities remunerated in section 420 will actually be available as and when required for the purpose of the projects. I shall not request financial support under this project for procurement of these items.
- I undertake that spare time on permanent equipment (listed in section 350) will be made available to other users.
- I have enclosed the following materials:

Items	Number of copies
a. endorsement from the head of the institution (on letter head)	one
b. (This) Certificate from the Investigator	one

- **Date: 8.8.2005.**
- **Place: Anna University**

Chennai 600 025.

Hema Achyuthan

Hema Achyuthan

(Name and Signature of the Principal investigator)

नाभिकीय अनुसंधान प्रयोगशाला
भारतीय कृषि अनुसंधान संस्थान, नई दिल्ली-११००१२
NUCLEAR RESEARCH LABORATORY
Indian Agricultural Research Institute
New Delhi-110012, INDIA
Phone : (O) 091-011-5850297, 5784454 (R) 7569348
Fax : 091-011-5741902, 5751719, 5766420
e-mail : psdatta@iari.ernet.in

डा० पी.एस.दत्ता
परियोजना निदेशक एंव प्राध्यापक
DR. P. S. DATTA
Project Director & Professor

No.NRL/PSD/26-11/ 1071

July 1, 2004

Dr. S.K. Gupta
Scientist(SG)
Physical Research Laboratory
Navrangpura
Ahmedabad-380 009.

Sub: **National Programme on Spatial and Temporal Fingerprinting of Waters of India Using Stable Isotopes to Study Seasonal Evolution, Interactions, Geographic Controls and Climatic Forcing.**

Dear Dr. Gupta,

With reference to the above mentioned subject matter and your previous correspondences, as desired, I am enclosing along with a copy of the endorsement from the Head of the Institution conveying approval of my participation in the National Programme as Co-PI and Coordinator, for further necessary action at your end.
Please confirm receipt of the document.

With best regards,

Yours sincerely,

P. Datta
01/07/2004

(P.S. DATTA)
PROJECT DIRECTOR

Encl: As above

New Phone Nos. (O) 091-011-25843297, 25842454; Fax: 25847705, 25842454 (R) 27569348
e-mail: psdatta@iari.res.in

Certificate from the Co-Principal Investigator

Project Title: National Programme on Spatial and Temporal Fingerprinting of Waters of India Using Stable Isotopes to Study Seasonal Evolution, Interactions, Geographic Controls and Climatic Forcing

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the project. I shall not request financial support under this project, for procurement of these items.

Date: 18/5/04
Place: Kharagpur

Anindya Sarkar
(ANINDYA SARKAR)
Name and signature of Co-Principal Investigator

IIT, Kharagpur,
Dept. of Geology & Geophysics
721 302, West Bengal

राष्ट्रीय भूभौतिकीय अनुसंधान संस्थान
NATIONAL GEOPHYSICAL RESEARCH INSTITUTE
वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्
COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

पोस्ट बैग सं. 724
Post Bag No. 724
हैदराबाद - 500 007, भारत
Hyderabad - 500 007. India

Certificate from the Co-Investigator

Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the project. I shall not request financial support under this project, for procurement of these items.

(P. Nagabhushanam)
Name and signature of Co-Investigator

Date: 13-7-2005
Place: Hyderabad

टेलीफोन PHONE : ~~7170141~~ 23434700 ~~7174433~~ (DISA)
तार Grams : GEOPHYSICS
फैक्स FAX : 040 - 7171564, 040 - 7170491
ई-मेल E-MAIL postmast@csngri.ren.nic.in director@ngri.wipro.net.in

भौतिक अनुसंधान प्रयोगशाला
(अंतरिक्ष विभाग की युनिट, भारत सरकार)
नवरंगपुरा, अहमदाबाद - 380 009, भारत
तार : ''रिसर्च'' फेक्स : 91-(0)79-6301502
दूरभाष : 6302129 ई-मेल : root@prl.ernet.in

PHYSICAL RESEARCH LABORATORY
(A UNIT OF DEPT. OF SPACE, GOVT. OF INDIA)
NAVRANGPURA, AHMEDABAD-380 009, INDIA.
CABLE : "RESEARCH" FAX : 91-(0)79-6301502
PHONE : 6302129 E-mail : root@prl.ernet.in

Certificate from the Co-Investigator

Project Title: National Programme on Isotope Fingerprinting of Waters of India (IWIN): A Project Proposal

1. I agree to abide by the terms and conditions of the SERC research grant.
2. I did not submit the project proposal elsewhere for financial support.
3. I have explored and ensured that equipment and basic facilities (enumerated in Section 420) will actually be available as and when required for the purpose of the project. I shall not request financial support under this project, for procurement of these items.

R.D. Deshpande

Date: 02-08-2005
Place: Ahmedabad

(R.D. Deshpande)
Name and signature of Co-Investigator