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Hydrological Studies Using Isotopes

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Abstract:
Isotope hydrology is a field of hydrology that uses isotopic dating to estimate the age and origins of water and its movement within the hydrologic cycle. Water molecules carry unique fingerprints, based in part on differing proportions of the oxygen and hydrogen isotopes that constitute all water. Isotopes are forms of the same element that have variable numbers of neutrons in their nuclei. This article presents the details of hydrological studies using isotope techniques undertaken by National Institute of Hydrology, Roorkee (India) during the last few years.

1. Introduction

Isotopes are the atoms of an element with the same atomic number but different atomic weight. Isotopes are either radioactive or stable in nature. Now-a-days, environmental isotopes (stable and radioactive) are being widely used for hydrological investigations. Isotope Hydrology deals with the application of isotopes as tracers in water resources development and management. Application of isotopes in hydrology and water resources is relatively a new subject, but its importance has been felt more in recent years. This is due to tremendous increase of problems in water sector, particularly depleting groundwater quantity, deterioration in water quality and many other unpredictable natural events that affect the hydrological cycle. The conventional methods often fail to provide proper insight to many of these problems, while isotope techniques provide a clear picture and help in finding a suitable solution.

Applications of isotopes in hydrology are based on the general concept of "tracing", in which either intentionally introduced isotopes or naturally occurring (environmental) isotopes are employed. Environmental isotopes (either radio-active or stable) have a distinct advantage over injected (artificial) tracers in the sense that they facilitate the study of various hydrological processes on a much larger temporal and spatial scale through their natural distribution in a hydrological system. Thus, environmental isotope methodologies are unique in regional studies of water resources to obtain time and space integrated characteristics, whereas artificial tracers are generally effective for site-specific, local applications.

Generally, isotope tracers are not used as an independent tool but to supplement hydrogeological, geophysical and geochemical information for a better understanding of the processes taking place on a hydrological system. Therefore, in hydrological investigations, isotope techniques should be used routinely along with hydrochemical and hydrogeological techniques. As all isotopic, hydrogeological, hydrochemical and hydrodynamic interpretations are space and time related, it is imperative that one should consider all the related aspects of water sampling and prevailing hydrogeological conditions in a study area.

A large variety of environmental stable and radio-active isotopes are employed for hydrological studies (e.g., ^{2}H, ^{3}H, ^{3}He, ^{4}He, ^{6}Li, ^{11}B, ^{13}C, ^{14}C, ^{15}N, ^{18}O, ^{34}S, ^{36}Cl, ^{37}Cl, ^{81}Br, ^{81}Kr, ^{87}Sr, ^{129}I, ^{137}Cs ^{210}Pb etc.). However, as indicated earlier, the stable isotopes have distinct advantage over injected (artificial) tracers (^{3}H, ^{46}Sc, ^{60}Co, ^{82}Br, ^{131}I, ^{198}Au etc.) because they facilitate the study of various hydrological processes on a much larger temporal and spatial scale through their natural distribution in a system. Earlier, artificially produced radio-active isotopes were being used with a very limited scope of their use as tracers only, but now environmental isotopes both radio-active and stable isotopes are being widely used for a variety of applications with no fear of health hazards. Environmental isotopes are freely available in the atmosphere and automatically injected into the hydrologic cycle. Therefore, the users neither have to purchase these isotopes nor to inject them in the hydrological system.

The conventional hydrological data are collected by a number of State and Central Government organizations. However, some specific hydrological information/data may be needed to understand and suggest remedial measures for various hydrological problems. This may require the use of advanced techniques like isotope techniques, advanced instrumentation, remote sensing techniques etc. Isotope techniques can be used to study surface water and groundwater interaction; seepage from water bodies; salinity ingress in coastal aquifers; baseflow contribution in rivers during lean flow period; separation of snow melt, glacial melt, base flow and rainfall-runoff from river runoff; groundwater age using tritium and C-14 dating techniques; sedimentation in water bodies using Cs-137 and Pb-210 dating techniques; identification of recharge zones of springs in mountainous areas; identification of different sources of air moisture, arrival and withdrawal of monsoon vapours etc.

2. Application of Isotopes in Hydrology

The various sources/sinks in the hydrologic cycle have distinct isotope ratios. As water moves into different processes in the hydrologic cycle (e.g., evaporation or infiltration etc.), it undergoes small but important and measurable changes in its relative abundance of different isotopes through a process called fractionation (isotope ratio is modified e.g. lighter isotopes are enriched). Thus, distinct isotopic signatures or fingerprints of water develop in various components/processes which provide valuable information to understand the hydrological processes. In this way, isotopes provide information in tracing the origin and movement of water in the hydrologic cycle.

Stable isotope fractionation occurs naturally through evaporation/condensation. Lighter isotopes preferentially evaporate while heavier isotopes condense to form precipitation preferentially to light isotopes. This said, the journey of a water molecule can be traced from its source to a given catchment based on fractionation ratios. The greater the distance between the ocean and inland storm event are, the more likely that rain will be lighter due to rain out of heavier isotopes from processes such as orographic uplift or previous storm events.

A schematic diagram of the isotope fractionation process via evaporation, condensation, and evapotranspiration (combination of evaporation and transpiration) is given below. Notice that waters are lighter when they evaporate and are relatively heavier when condensed in the form of precipitation.

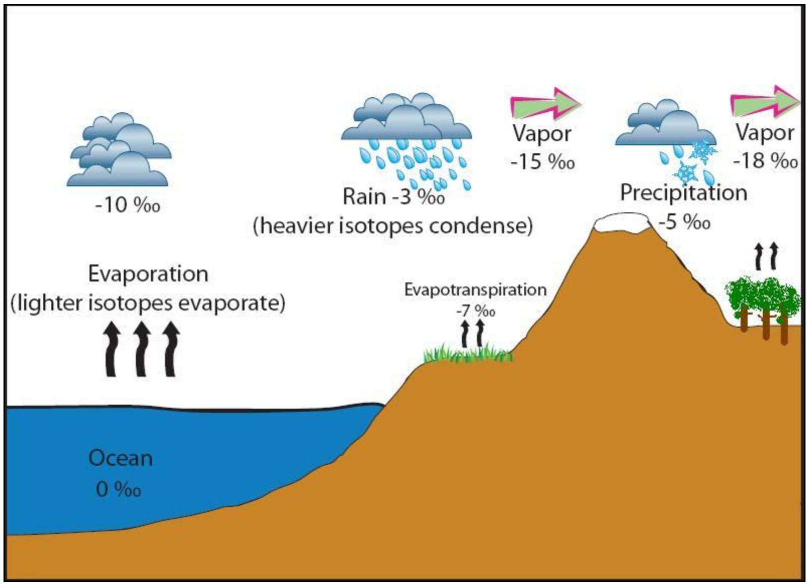

Figure 1

Source: A Primer on Stable Isotopes and Some Common Uses in Hydrology

http://serc.carleton.edu/microbelife/research_methods/environ_sampling/stableisotopes.html

Isotopes can be used for various investigations in order to understand and identify the problem for suggesting the possible remedial solutions. Some of the applications are listed below.

- Estimation of groundwater recharge
- Identification of groundwater recharge sources
- Base flow contribution in rivers during lean flow period
- Separation of snow melt, glacial melt, base flow and rainfall-runoff
- Surface water and groundwater interaction using isotopes
- Groundwater age using Tritium and Carbon-14 dating techniques
- Delineation of groundwater flow paths
- Sedimentation in water bodies using Cs-137 and Pb-210 dating techniques
- Identification of recharge zones of springs in mountainous areas
- Salinity ingress in coastal aquifers
- Seepage from water bodies and leakage from dams
- Identification of different sources of air moisture, arrival and withdrawal of monsoon vapours

In India, the potential of isotope techniques is not being fully utilized due to inadequate laboratory facilities for isotopic measurements and less awareness about the techniques and potential for solving water related problems. Use of isotope technology in hydrology and water resources needs to be popularized through some examples of successful studies. The Hydrological Investigations division of National Institute of Hydrology (NIH), Roorkee has taken stride in this direction.

3. Hydrological Studies Using Isotopes at NIH, Roorkee

The Hydrological Investigations division of National Institute of Hydrology, Roorkee, India is actively engaged in conducting field and laboratory based research related to various hydrological investigations using conventional and isotopic techniques, lake hydrology, mining hydrology, and hydrological instrumentation. The division is presently involved in a number of internal, sponsored and consultancy projects related to the above aspects.

The Isotope Laboratory of the Institute (attached with Hydrological Investigations division) has facilities to measure different types of radioactive and stable isotopes. It includes Stable Isotope Ratio Mass Spectrometer, Tritium Enrichment Unit, Benzene Line for Carbon Dating, Liquid Scintillation Counter, Multi-channel Alpha Spectrometer, Multi-channel Gamma Spectrometer, LGR Isotopic Water Analyzer (Liquid+Vapor), Neutron Probe, Ion Chromatograph etc. The Institute has been working on the following hydrological aspects using isotope techniques.

- Separation of snow melt, glacial melt, base flow and rainfall-runoff
- Identification of recharge zones of springs and streams in mountainous areas
- Movement of soil moisture in unsaturated zone
- Interaction between surface water and groundwater
- Base flow contribution in rivers during lean flow period
- Salinity ingress in coastal aquifers
- Seepage from water bodies
- Identification of recharge zones
- Estimation of groundwater recharge
- Groundwater age using Tritium, Carbon-14 and other dating techniques
- Source and migration of contaminants in groundwater
- Sedimentation in water bodies using Cs-137 and Pb-210 dating techniques
- Identification of different sources of air moisture, arrival and withdrawal of monsoon vapours

The following studies using isotope techniques have been undertaken by National Institute of Hydrology, Roorkee (India) during last 10 years.

3.1. Identification of Recharge Zone and Recharge Sources for Deeper Aquifer in Parts of Ganga-Yamuna Doab Using Environmental Isotopes (2004)

Environmental tritium and Oxygen-18 isotopes have been used to identify the recharge zones to deep-seated aquifers in parts of the Gangetic alluvial plains in India and to find out the contribution of different recharge sources. The study reveals that rainfall actively recharges the local aquifers in the Saharanpur district where, the aquifers upto a depth of around 100 m are well inter-connected to form a single unit. This is in stark contrast to the conditions in Hardwar district (mainly the area falling in the river Solani – river Ganga interfluve) where, the recharge is mainly taking place at higher altitudes, and the unconfined aquifer is poorly or not connected to the deep seated aquifers. In general, it is found that the area characterized by sandbars developed in the paleo-channels act as local recharge zone in the plains, while the Bhabhar and Shiwalik Hills (above an altitude of 400 m above m.s.l.) act as regional recharge zones.

3.2. Integrated Hydrological Study of Two Watersheds in Uttaranchal (2005)

This study presents the database on hydro-meteorological parameters from two watersheds located in Tehri-Garhwal district (Uttaranchal). Water balance computation was performed for the study period. After performing the rainfall-runoff analysis on monthly interval, flow duration and flow-mass curves were drawn for Chandrabhaga watershed. Average 11 to 17% runoff was observed in Chandrabhaga watershed during the years 1999-2004. Total annual spring discharge during 2004 from all the springs works out to be 1,12,061 m^3, i.e. about 0.11 MCM. Recession curve analysis was also performed to estimate the hydrological significance of the discharge function parameters and the hydrological properties of the aquifer. Based on the analysis of spring hydrographs, including their recession curves, the study has provided an insight into the dynamics of spring flows in the study area. Chemical and isotopic investigations were also done to assess recharge zone and recharge sources identification, evaporation during recharge and stream-aquifer interconnectivity.

3.3. Integrated Hydrological Studies of the Kandi Belt, J&K (2005)

The Kandi belt (also known as Bhabhar in Uttarakhand) is a steeply sloping, upto 30 km wide, submontane region of the Himalayas fringing the Shiwalik hills, extending discontinuously from Jammu and Kashmir to Assam. A study has been done in the Kandi area of Jammu with the objectives to study the surface water and groundwater regime, groundwater flow velocity, identify the groundwater recharge zones, and identify sites for water harvesting structures. Hydrogeological interpretation of available lithologs indicates that the subsurface material becomes finer as the distance from Shiwalik hills increases. Analysis of stable isotopes of oxygen and hydrogen in rainwater, surface water and groundwater indicates that groundwater in the area is being recharged both by the local precipitation and the rivers passing through the area. Further, it has been concluded that the moisture source of winter rains is different from that of monsoon rains. Tritium content in rainwater, river water and groundwater vary in a narrow range (8 – 9 TU) indicating fresh recharge of groundwater from river and precipitation.

3.4. Regional Network of Isotopes in Precipitation and Groundwater (2006)

The International Atomic Energy Agency (IAEA), in collaboration with World Meteorological Organization (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. The main objectives of this study were (i) isotopic characterization of Indian precipitation and groundwaters, (ii) establishing regional and local meteoric water lines with reference to global meteoric water line, and (iii) establishing continental effect, latitude effect, altitude effect and amount effect in isotopic composition of precipitation in the country. Precipitation and groundwater sampling were carried out at various locations in the country. Precipitation and groundwater samples were analyzed for stable isotopes of Oxygen-18 and Deuterium, and also analyzed for EC, pH and environmental tritium.

3.5. Identification of Recharge Zones for Deeper Aquifers and Sources of Salinity in NCT, Delhi (2006)

The hydrological study of NCT, Delhi was carried out in collaboration with BARC, Mumbai and CGWB, Delhi with the following objectives – (i) delineation of groundwater aquifers, (ii) analysis of groundwater flow pattern and flow velocity, (iii) mapping of recharge areas and recharge sources, (iv) mapping of spatial and depth distribution of salinity in groundwater, (v) identification of causes for the salinity in groundwater, and (vi) suggesting suitable measures. The groundwater samples were collected for water quality, H-3, C-14, O-18 and D isotopic analysis. Based on this analysis and other data conclusions were drawn.

3.6. Study of Recharge Characteristics in Arid/ Semi-Arid Regions Using Isotopes (2008)

The study was taken up to identify the present day modern recharge areas and to estimate the recharge rates using isotopes so that the groundwater resources can be managed judiciously. The specific objectives of the study are: (i) identification of recharge zones and recharge sources (ii) investigation of groundwater flow pattern including flow velocity and (iii) Estimation of the recharge to groundwater due to monsoon.

The present study has been carried out for the districts Jodhpur and Nagaur of Rajasthan state. The district Jodhpur covers the second largest area while the district Nagaur covers the fifth largest area in the state. A total of 382 water samples consisting of groundwater (326), rainfall (52) and pond/lake-water (4) were collected from different locations of the study area during August, October 2006, January, April, July and November 2007. EC and pH were measured for these samples in the field. The salinity and pH in groundwater vary in the range of 720 to 11820 µS/cm and 6.3 to 8.3 respectively. The groundwater samples (215) were analysed for $\delta^{18}O$ and $\delta\ ^2H$ or δD at the Nuclear Hydrology Laboratory at NIH. The plots of ^{18}O Vs ^2H were prepared for both the districts. The isotopic values of $\delta^{18}O/\ \delta^2H$ show that recharge is taking place in shallow aquifer due to rainfall. The analysis of tritium (96 samples) has been carried out at Nuclear Hydrology laboratory. The lower values of TU (0 to 2 TU) found at most of the places reveal that age of groundwater is greater than 25 years and recharge rate is very slow. However, at few places, the TU values range between 3 to 5 TU indicating that groundwater is comparatively younger (age < 10 years) and recharge rate is moderate due to which fresh water is available at those places. A total of 14 groundwater samples were collected from Nagaur and Jodhpur districts for radio carbon dating during April and July. The age of groundwater in the study area varies from 2,500 to 5,000 years.

Soil samples from three sites namely Chaba, Charnai and Phalodi were collected and analysed for volumetric moisture content, bulk density and particle size distribution. The soil moisture extracted through vacuum distillation of soil samples (26) was subjected for ^2H analysis using a Dual Inlet Isotope Ratio Mass Spectrometer available at Nuclear Hydrology laboratory. The percentage of recharge to groundwater was estimated at three aforesaid sites using stable isotopic technique, which varies from 19% to 40%.

3.7. Stream Flow Modelling Of Bhagirathi River: Hydrograph Separation Using Isotopic and Geochemical Techniques (2008)

The Bhagirathi river basin is the part of the headwater catchment of the river Ganga, covering a total area of about 4000 km^2. River Bhagirathi originates from Gangotri Glacier continues to be a more dependable resource of River Ganga for meeting domestic, industrial and agricultural demands in North India. However, a number of fundamental issues such as contribution of groundwater, snow/glacier and runoff are still unknown. In the present study, attempt has been made to separate the hydrograph component of River Bhagirathi using isotopic and geochemical techniques. The study area falls between Gangotri to Devprayag.

The results of $\delta^{18}O$ and δD have been analysed and interpreted to understand the isotopic characteristics of river, groundwater and precipitation in Bhagirathi river basin from Gangotri to Devprayag. The Local Meteoric Water Line of Bhagirathi river basin has been developed, i.e., $\delta D = 8.12 * \delta^{18}O + 11.19$, $R^2 = 0.96$. Isotopic characteristics of groundwater do not vary significantly with time, which represents a well-mixed aggregate of precipitation water. The $\delta^{18}O$-δD relationship of groundwater indicates that isotopic composition of precipitation is well preserved in groundwater of the study area and evaporation during infiltration, if any, is minor. Therefore, $\delta^{18}O$-δD relationship of groundwater ($\delta D = 8.07 * \delta^{18}O + 11.30$, $R^2 = 0.97$) can serve the purpose of rainfall $\delta^{18}O$-δD relationship in Himalayas, if Local Meteoric Water Line is not available for any study area. The altitude effect in $\delta^{18}O$ of precipitation is found in the order of 0.28‰ per 100m while it is 0.24‰ per 100m for groundwater. Therefore, it indicates that altitude effect in groundwater can be used for altitude effect of precipitation for Himalayan basin because establishment of altitude effect in precipitation is a very cumbersome process using precipitation isotopic data. There is consistent enrichment in the isotopic isotopic characteristics of river Bhagirathi as one move downstream from Gangotri to Devprayag. This is due to increasing contribution of groundwater from different altitudes. The isotopic values in river discharge show strong relationship with the precipitation. On the basis of isotopic variations in river discharge, a preliminary exercise has been carried out to compute the contribution of snow/glacier melt, groundwater and runoff component in discharge of Bhagirathi river at Dabrani site. Snow and glacier melt vary from 20% (February) to 68% (April), while groundwater contribution varies from 26% (June) to almost 100% (December/January) in qualitative terms. Quantitatively, the snow and glacier melt has been found maximum during the monsoon months. The surface runoff goes as high as 40-45 % during the monsoon months.

3.8. Identification of Source and Location of Seepage in Tehri Dam Using Isotopic Techniques (2009)

The Tehri dam is constructed on Bhagirathi River, the main tributary of the Ganga. Tehri dam has a height of 855 feet (260.5 m), making it the 5th tallest dam in the world and the highest Earth and Rockfill dam in the Asian Region. For relieving the water pressure in the d/s abutments of dam, a network of drainage galleries has been provided. During the filling and depletion of reservoir, quantum of seepage through various drainage galleries is being regularly observed. High seepage discharge was observed from few locations in the drainage galleries i.e., AGR3 and AGIR. In order to identify the source of seepage, isotopic signatures of seepage discharge, reservoir and other sources like drains, springs (groundwater) and precipitation were monitored. The data of reservoir level variation and discharge of seepages in AGR3 and AGIR were obtained from project authorities and analyzed for studying the correlation between the reservoir level and seepage discharge.

The reservoir level was found to rise to the level of 771 m in 2007 and at 773 m in 2008, seepage in AGR3 gallery increases sharply. Similarly, in AIGR Gallery, seepage increases sharply at reservoir level of 783 m in 2007 and at 785 m in 2008. It clearly indicates that seepage starts in AIGR gallery when the RL reaches above 780 m. Therefore, increase of discharge in seepage galleries during July to October 2008 with rise in reservoir level indicates that source of seepage water is reservoir. The δ^2H and $\delta^{18}O$ analysis indicated that increase in seepage in AGR3 and AIGR galleries are fed by reservoir except at D9 site. As the isotopic signature of D9 ($\delta^{18}O$) matches with the isotopic signatures of groundwater, therefore, seepage from D9 is due to local recharge of precipitation. During high discharge, isotopic composition indicates that seepage in both the galleries is from the two separate fracture zones. 1st zone is located approximately between the elevation range of 781 m and 800 m at the right bank of the reservoir (D5, D6 and D7 of AGR 3 Gallery) while 2nd Zone is located between 783 m and 815 m (D10 and D11 of AIGR Gallery). The time lag in rise of water level in reservoir increase in seepage discharge in drainage gallery (AGR-3) is 5 days while it is 7 days in AIGR gallery. Further investigations are required to pinpoint the location of seepage points through which reservoir water is entering the seepage gallery.

3.9. Surface Water and Groundwater Interaction at Selected Locations along River Yamuna in NCT Delhi (2009)

In Delhi, a number of tube wells have been constructed in the floodplains of the river Yamuna to extract water during non-monsoon season. These wells may induce recharge from the river. Thus, a scientific study has been carried out to understand the effect of large scale pumping of groundwater in the floodplains of the Yamuna River on the natural interaction of groundwater and surface water in the study area.

The river and groundwater interaction has been studied by isotope mass balance method. Isotopic tracers provide a mean for identifying the actual mass transport of water in the hydrologic cycle. The approach is based on the fact that the rivers originates at higher altitudes like the river Yamuna normally has a different stable isotopic composition than that of groundwater recharged by infiltration of local precipitation. In case of a mountainous river, the river transports water, which has generally been originated from precipitation falling at higher elevations than the area where the surface-groundwater relation is under investigation. The difference in isotopic composition of these waters is due to altitude effect. The isotopic composition for ^{18}O in precipitation changes between -0.2 and -0.3 $^0/_{00}$ per 100 m with altitude. Thus, the stable isotopic composition of the river water is more depleted than that of groundwater derived from infiltration of local precipitation. This distinct difference helps in identifying the contribution of one to the other. The studies carried out by NIH, Roorkee and few others have revealed that the river Yamuna has stable isotopic signatures ($\delta^{18}O$) in the range of -8 $^0/_{00}$ to – 9 $^0/_{00}$ while the groundwater in Delhi region varies between –5 $^0/_{00}$ to –6 $^0/_{00}$ where recharge due to precipitation dominates. Therefore, stable isotopes of hydrogen and oxygen can be used to determine the contribution of groundwater to river or vice versa at the selected locations in the study area.

Ten piezometers were constructed (5 each on both sides of the river). Groundwater samples were collected from these constructed piezometers since July 2007. Samples along one more cross-section (from exiting hand pumps) were also collected. Isotopic analysis indicates that Yamuna is recharging groundwater on Delhi side (Palla sector) to a greater extent as compared to UP side. Water level at 15 days interval was measured since July/August 2007 on both the sides of the River Yamuna. Raingauge was installed in July 2007 for collecting the rain samples. The rain water samples were collected during the monsoon season of 2007 and analysed. The isotopic ratios of $\delta^{18}O$ in rain varies from -0.41$^0/_{00}$ to -7.41$^0/_{00.}$ Grain size analysis of the soil samples collected during the drilling of the piezometers was done. The subsurface sediments are mostly sand and loamy sand in texture. Sand percentage in most of the samples is > 90%.

3.10 Dating Of Water from CBM Wells and Nearby Tube Wells By Isotopic Method (^3H and ^{14}C) (2010)

Coal Bed Methane (CBM), is a natural gas occurring in coal seams and is a relatively new source of energy in India. Large amount of groundwater is pumped alongwith the gas from CBM wells, especially in the early stages of production. This may create environmental problems by inducing recharge of water from the overlying leaky aquifers or surface water bodies through fractures and faults. The lowering of water table or drying of surface water bodied may impact the economic and social activities in the area. In view of the above, Reliance Industries Limited, Ahmadabad, awarded this consultancy project to National Institute of Hydrology, Roorkee with the objectives to know if the water being produced from CBM wells is connate water from coal bed of Gondwana and is not connected to ground water of the area through isotopic analysis of water (Preferably ^3H and ^{14}C) from CBM wells and nearby tube wells. The study was carried out in Sohagpur East and Sohagpur West blocks falling in Shahdol and Anuppur districts of Madhya Pradesh. The study indicated: (i) the groundwater present in the shallow and intermediate aquifers (30-75 m) is generated from the recent time precipitation; (ii) the groundwater pumped from deep CBM wells is older than that used for drinking from shallow water; and (iii) the uncorrected age of groundwater abstracted through the CBM wells is >20,000 years.

3.11. Identification of Recharge Zones of Some Selected Springs Of Uttarakhand Using Isotopes (2012)

This study was referred to NIH by the Uttarakhand Jal Sansthan, Dehradun. The study has been carried out to identify recharge areas of few selected springs and to suggest remedial measures for rejuvenation of these springs. Four springs namely Moli, Ratoli, Gothiyara and Kandha Dhangi falling in Chandrabhaga watershed in Jakhanidhar block of Tehri Garhwal district have been studied. The springs selected for the study are the only sources of drinking water in the region. However, these springs have been reported continuous reduction in their discharge in recent times with some springs even drying up during summer. The study has been carried out using environmental isotopes particularly, stable isotopes of oxygen and hydrogen and also environmental tritium. Under the study, hydrological and isotope data have been collected. Daily rainfall data have been collected from 1 June, 2010. Water samples have been collected from various sources such as precipitation, groundwater, spring water etc. More than 600 water samples of springs, rain and groundwater have been collected and analyzed for deuterium and O-18. Spring discharge has been measured initially at 15 days interval and in the second year at weekly interval for all the 4 stations. Response of the springs to rainfall has been analyzed and it has been observed that all the four springs differ in their response which indicates different residence times of water for the various springs. Local meteoric water line for the area has been developed and also the altitude effect has been established using the collected data. Efforts have been made to locate the altitude of the recharge area based on the analysis of collected data. Based upon this altitude identification, topography and hydrogeology of the area, recharge areas of the springs have been identified.

3.12. Estimation of Snow and Glacier Melt Contribution in Melt Water of Gangotri Glacier at Gaumukh Using Isotopic Techniques (2013)

Himalayan glaciers are sensitive indicators of climate change similar to other mountain glaciers in the world. Snow and glacier melt isotopic composition can provide information on atmospheric circulation such as responses to climatic fluctuations, changes in the strength of south-west summer monsoon, and western disturbances. The snow and glacier melt runoff contributes significantly to all north India Himalayan rivers during summer when demand of water increases for hydropower, drinking and irrigation etc. Therefore, this study has been undertaken to study the isotopic composition of snow, rain, ice and melt water which will be useful in separation of various components of stream discharge and in the long term, will be useful to understand the source of moisture and impact of climate change on melting pattern.

The Local Meteoric Water Line (LMWL) has been developed using precipitation data collected during the ablation period of 2004 to 2008. The Local Meteoric Water Line is $\delta^2H = 8.2\ (\pm 0.10) \times \delta^{18}O + 17.1\ (\pm 1.53)$ ($n = 15$, $r^2 = 0.99$) for ablation period (May to October) which shows higher slope and intercept in comparison to GMWL. The Meteoric Water Line for Gangotri glacier melt has been developed. The best fit line slope of 8.7 and intercept of 29.9 are consistent with LMWL of higher Himalayan snow and glacier. The isotopic signatures of fresh snow and surface ice are found to be in the order of -4.5‰ to -14‰ for snow and -13‰ to -25‰ for glacier. It has been observed that the isotopic values of melt initially (April to June) follow the average $\delta^{18}O$ values of snow ranged between -12‰ to -13.8‰. The abrupt change in $\delta^{18}O$ values during the rainfall reflects the significant amount of rainfall contribution during monsoon. Three rain events were monitored in the months of July and September 2005. Hydrograph separation was carried out on daily basis for each rain event which revealed that rainfall-runoff contribution is in the order of 14% to 15% of the total river discharge for each storm. However, for the entire ablation period at Gaumukh site, rainfall-runoff contribution is only 3% and remaining 97% contribution is from snow/glacier melt. The isotopic signatures reveal that snow and ice melt contribution also varies with time. The temporal variation of snow and ice melt is useful to study the impact of climate change.

3.13. Assessment of Radon Concentration In Waters And Identification Of Paleo-Groundwater In Punjab State (2013)

Radon gas is considered to be a health hazard due to its radioactivity. It can cause serious diseases like lung cancer if it exceeds certain limit. It has been found that in a country like USA, more than 30,000 deaths occur every year due to high radon concentration in water as well as in air. High concentrations of Radon have been observed in certain parts of India also during preliminary studies carried out by various investigators. Therefore, a National Working Group has been constituted by the Government of India to study the radon concentration in different materials. NIH has been entrusted to study the radon concentration especially in waters.

Paleo-groundwaters are those groundwaters which are thousands years old. People are drawing groundwater from deeper aquifers without the knowledge of their dynamics. Because of limited recharge, the deeper aquifers may not sustain the water supply for longer time. However, such sources can be used to fulfill some specific needs. Therefore, there is a need to identify the paleo-waters to avoid huge investments on other industrial and/or urbanizational developments in such areas. Keeping these facts in view, this study has been undertaken in Bist doab region of Punjab with the following objectives:

- To measure radon concentration in waters
- To identify paleo-groundwater in deep aquifers

The radon concentrations were monitored at 10 sites in district Nawanshahar, 7 sites in district Hoshiarpur, 4 sites in district Ropar, 9 sites in district Jallandhar and 9 sites in district Kapurthala. The water samples were collected mostly from hand pumps except a few from deep tube wells and rivers. The radon concentration in water varies from 10 Bq/l to 20 Bq/l in district Ropar, 20 Bq/l to 40 Bq/l in district Nawanshahar, 25 Bq/l to 48 Bq/l in district Hoshiarpur, 2 to 24 Bq/l in district Jallandhar and 5 to 24 Bq/l in district Kapurthala. These values fall under the permissible limit recommended by WHO for drinking water. A total of 30 groundwater samples were collected from hand pumps and tube wells from above mentioned sites and analysed for environmental tritium for the dating purposes. Based on the tritium analysis, it has been found that only two sites, one in district Nawanshahar and other in district Kapurthala have tritium values less than one indicating older ages. Rest of the sites may have groundwater younger than 40 years.

3.14. Impact Assessment of Landuse on the Hydrologic Regime in the Selected Micro-watersheds in Lesser Himalayas, Uttarakhand (2013)

The study has been carried out jointly with Forest Research Institute, Dehradun. The main objective was to study the impact of cover on hydrological regime of a micro-watershed. The quantity, timing and quality of water flowing from a watershed serve as sensitive indicators to understand the hydrological response of a watershed. Two watersheds, in Lesser Himalaya near Mussoorie (Uttarakhand), have been selected to study the impact of landuse on hydrological regime. These two watersheds are Arnigad, covering an area of 2.99 km^2 under dense oak forest and Bansigad, covering an area of 1.99 km^2 under degraded oak and pine mixed forest. The geomorphological features, geological set-up and meteorological conditions are almost identical in both watersheds. Both watersheds are equipped with hydrometeorological equipment. To measure the discharge of these watersheds, 120° 'V' notch and automatic water level stage recorder were installed in both watersheds for continuous monitoring of stream discharge. Meteorological observatories were installed near the outlet of each watershed for monitoring the rainfall, temperature, humidity and evaporation etc.

The average air temperature varies between 15.5°C (minimum) and 25°C (maximum) in degraded watershed and 18°C to 22°C in forested watershed. The evaporation rate varies from minimum 2.5 mm/day in rainy months to maximum 6 mm/day in summer months. The continuous discharge and rainfall data have been recorded since June 2008 onwards. Rainfall and runoff data from April 2008 to March 2010 have been analyzed for both micro-watersheds. Discharge of stream from the Bansigad watershed (degraded forest cover) becomes negligible during summer months and maximum flow is recorded in the month of August at the rate of 0.59 m^3/sec. While, discharge from the Arnigad watershed (dense forest cover) was recorded minimum as 0.06 m^3/sec in the month of June and maximum as 0.55 m^3/sec in the month of August. Discharge declines slowly in Arnigad stream during post-monsoon months while it declines at faster rate in Bansigad stream which dries up in summer months. The estimated average runoff coefficients during monsoon season were found to be 0.37 and 0.55 in dense (Arnigad) and degraded (Bansigad) micro-watersheds respectively. Low runoff from the forested watershed is due to delayed subsurface flow and high amount of recharge. Therefore, contribution of subsurface flow is much higher in Arnigad catchment generating 184 mm more runoff during the non-rainy months in comparison to degraded forest watershed. In degraded watershed of Bansigad, groundwater storage is not enough to sustain the stream discharge throughout the year. Therefore, Bansigad watershed stream flow is intermittent and flows for 9 to 10 months in a year.

Average denudation rates were found to be 0.59 mm in dense forested micro-watershed and 1.05 mm in degraded micro-watershed respectively. SWAT model was calibrated and validated for Arnigad and Bansigad watersheds using the observed daily data of discharge and sediment concentration. The results of simulation of Arnigad watershed exhibited the coefficient of determination (r^2) and Nash-Sutcliff efficiency as 0.91 and 84.48% for daily flows and 0.88 and 83.11% for daily sediment concentration during calibration; and r^2 and efficiency as 0.94 and 82.78% for daily flows and 0.88 and 83.28% for daily sediment concentration during validation. The isotopic results show that recharge source for stream and springs are local precipitation.

3.15. Development of Spring Sanctuaries in an Urban and a Rural Watershed in District Pauri Garhwal, Uttarakhand (2013)

Groundwater flows in the form of springs and seepages in the hilly terrain. Springs are the major source of drinking and other household activities in the hilly terrain. The dwindling discharges of springs and spring fed streams in the populated Lesser Himalayan terrain of Western Himalayas has become a matter of serious concern. In this connection, a collaborative study with G. B. Pant Institute of Himalayan Environment and Development (GBPIHED), Srinagar unit has been carried out for identification of recharge zones and implementation of recharge techniques.

The rain, springs and hand pump samples were collected from Pauri urban area and Dugargad watershed rural area. The temporal variation of δ^2H and $\delta^{18}O$ of spring samples show depletion after July and maximum depletion is in the month of September, which indicates quick recharge in the study area. The plot of δ^2H versus $\delta^{18}O$ for all springs and rainfall samples collected during June to September 2010 shows the Local Meteoric Water Line (LMWL) as δ^2H = 8.0) x $\delta^{18}O$ + 10.5 which is similar to GMWL. These results indicate that source of these springs is local precipitation. The detailed geological and geomorphological investigations have also been carried out in the study area. Recharge zones of the selected springs have been identified using the altitude effect, geomorphological and geological settings.

4. Concluding Remarks

The isotope techniques have potential to trace the complete hydrological cycle and processes that take place during the exchange and transition of water from one phase to another phase. Eventually, Isotope Hydrology has developed into a multi-disciplinary field. With the development of sophisticated and automated instrumentation for very precise isotopic measurements, new approaches are being developed and new applications and tools are being added to the isotope toolbox. Now isotope techniques can effectively be used in carrying out various hydrological studies. Specifically, isotopes can be used for tracing the source, movement, and pollution of groundwater.

5. References

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