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Importance of Isotopes in Characterizing Water

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***Abstract*— The occurance of light stable isotopes of Hydrogen and Oxygen naturally represents an identification tool of water. Isotopic ratio ($R={}^{2}H/{}^{1}H$ or ${}^{18}O/{}^{16}O$) reported as $\delta^{2}H$ or $\delta^{18}O$, where [$\delta= (R_{sample} - R_{standard})/ R_{standard} \times 1000$] Of fresh water that varies widely across the earth according to its altitude. Another parameter deuterium excess (d-excess), which represents the re-evaporation of the continental water sources where [d-excess = $\delta^{2}H-8\times\delta^{18}O$] the global value of d-excess is +10%. The properties of complexity and power of stable isotopes can be derived from isotopes as a tracer of ultimate source of water. The study also represents that the temperature shows expected positive and negative relationship with individual locations. Studies conducted worldwide during last few decades have established that stable oxygen and hydrogen isotope ratios provide useful tools for hydrological studies. In case of groundwater, stable isotopes have been used to estimate recharge rates and to identify the recharge zones, to determine the effect of evaporation on groundwater system, to estimate diffusion rates in unsaturated zones, to study the groundwater surface water interaction and to identify source of salinity (Bhattacharya et al., 1985, Navada et al., 1986; Deshpande et al., 2003).**

***Index Terms*— Isoptopes, Unsaturated zones, Chemial tracers, Rayleigh isotopic fractionation, Lithology, Soil Geochemistry.**

I. INTRODUCTION

Isotopes can play a vital role in studying the soil moisture variation, its movement and recharge through unsaturated zone. Origin, age, distribution of waters in a region including occurrence and recharge mechanism, interconnections between groundwater bodies and identification of recharge sources and areas can be easily studied using environmental isotopes.

In the past few decades, sophisticated nuclear-hydrological instrumentation have been developed to measure accurately both radioactive as well as stable isotopes and accordingly various isotope techniques have been evolved. Its application in hydrological department is very useful to solve many hydrological problems related to agriculture, industry, habitation etc.

The use of isotopes in hydrology was introduced in early 1950 when the radiocarbon dating technique was employed for determining the age of groundwater. After that a number of applications of isotopes were successfully tried and used to find the effective solutions of various hydrological problems in the developed countries. Later on the International Atomic Energy Agency (IAEA), Vienna, Austria, an independent intergovernmental organisation with in the United Nations System, took a leading role in the development and use of isotope techniques in hydrology.

The applications of environmental isotopes had been initiated in India in early 1960's by the Tata Institute of Fundamental Research, Bombay to determine the age of groundwater and recharge to groundwater bodies in Gujarat and Rajasthan. Later on Bhabha Atomic Research Centre (BARC), Bombay took lead to spread the use of isotope techniques in hydrology in India. Now a days, Physical Research Laboratory, Ahmedabad; National Geophysical Research Laboratory, Hyderabad; National Institute of Hydrology, Roorkee; Defence Research Laboratory, Jodhpur; Nuclear Research Laboratory, Indian Council for Agricultural Research (ICAR), Delhi; Centre for Water resources Development & Management (CWRDM), Kozhikode; UP Irrigation Research Institute, Roorkee; UP Ground Water Department, Lucknow and few more central and state government organisations are actively involved in the isotope hydrology work in India. In hilly regions hydrology become more complex due to high variability of climatic conditions, physiographical conditions and variable geological set-up which leads to significant differences and variations in hydrological behavior of mountain catchments. Further complexities are also added due to presence of snow, glaciers at high altitude region and distribution forest cover in different part of the catchment.

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II. DETAILED STUDY

(S. P. Rai Scientist ‘C’, Hydrological Investigations Division, National Institute of Hydrology, Roorkee-247667,) Says that isotopic technique can be applied in surface hydrology for the determination of discharge measurement of the streams by using non-conventional technique i.e, basically dilution techniques. They are based on the use of various suitable water tracers that are of three types.

(i) Chemical tracers
(ii) Fluorescent dyes
(iii) Radioactive tracers

The outstanding advantage of tracer dilution gauging is that it measures the flow

in an absolute way because the discharge is calculated from measurements of volume and time only; tracer concentrations need be determined only in dimensionless relative readings. Dilution methods may provide the only effective means of estimating the flows in shallow rock-stream rivers or when rivers are in extreme condition of flood or drought.

III. PRINCIPLE

The basic principle of the dilution technique is to mix a suitable tracer with the flowing water at a point and to observe its dilution at some other appropriate distance after its homogeneous mixing with river/stream water. There are three basic criteria, which should be strictly followed in order to get the correct information about discharge.

(1) The tracer should not be lost in the way and it should have the flow characteristics near to water.

(2) There should not be any inlet or outlet for the river/stream water in between the injection and sampling point.

(3) The sampling should be carried out after the proper mixing of tracer with flowing river/stream water (the distance at which proper mixing of a tracer with flowing water of a river/stream (from the injection point) takes place is known as mixing length.

He has used artificial radioactive isotopes for the estimation of ground water recharge. The chemistry of isotopes can be used for a variety of environmental and hydrological studies. Isotopes are defined as atoms of the same element whose nuclei contain the same number of protons but a different number of neutrons. Stable isotopes are naturally occurring isotopes that do not undergo radioactive decay. The different isotopes of the same element have slightly different masses. Isotope fractionation can occur in a variety of chemical and physical processes, resulting from the slight differences in the properties (heat capacity, vapour pressure, density, energy, etc.) of the various isotopic forms of the elements involved. For these reasons the sable isotopes of hydrogen, oxygen, sulfur and carbon can be used in hydrologic studies.

Isotopes of hydrogen and oxygen are used to determine processes related to water flow and sources. Researchers have determined the relative amount that groundwater contributes to steady flow in various environments and at different seasons (Sklash et at., 1976; Sklash and F'arvolden, 1982). Made et al. (1994) examined soil waters near Edmonton, Alberta, determining that waters from snow-melt contributed about 27% to the soil waters whereas the groundwater contributed 44% of the soil water. Lateral flow of waters from nearby depressions may cause the snow-melt waters to pool before entering the soil, leading to the 27% snow-water portion- McCarthy et al. (1992) used δD and $\delta^{18}0$ values to show that the isotopically lighter Columbia River waters contribute *50%* of the water pumped from municipal wells about 1 km away, near Portland, Oregon. Werner e t al. (1991) argued that the simplistic model of two waters, old water and new water, with the old water being forced out by the new water, is too Limited. They claimed that it is a difficult task to recognize different waters because the distinctive isotope values become muted very shortly after entering the soils. A limited discussion of this application will appear in this thesis, as the isotope characters of the precipitation events on the reserve are unknown. Water evaporation trends have long been established on the basis of δD and $\delta^{18}0$ relationships (e.g. Dansgaard, 1964). Changes in the oxygen and hydrogen isotope composition of water from the Aswan High Dam Lake in Egypt were examined to determine the extent of evaporation (Aly et al.. 1993) and in the Gaula river catchment 9 lake waters were found to have enriched δD and 81- values relative to the surrounding streams and rivers due to evaporation (Bartarya et al., 1995). Dansgaard (1964) discussed altitude and latitude effects on the isotopic composition of precipitation over continents. Abundance of $\delta^{18}0$ and δD decreases with the increasing altitude on the windward side of mountains. Typical gradients for $\delta^{18}0$ vary from -0.1% to -0.9960 per l00m and for δD, -15 to 4% per 100m (Yurtser and Gat, 1981). This is not likely to be a controlling factor for δD and $\delta^{18}0$ values on the reserves because the reserve lies on the lee side of the mountains. The δD and $\delta^{18}0$ content decreases with increasing length of storm path due to Rayleigh isotopic fractionation. The δD and $\delta^{18}0$ contents usually decrease with increasing latitude because of larger temperature gradients with distance. This process could affect isotope composition of waters on the reserve as the land lies far inland from any major body of water.

IV. Aqueous Geochemistry Applications

Geochemical studies of waters have been utilized to help define the hydrology of an area For example, the Amazon River waters were examined geo-chemically and the controlling factor on the water chemistry was determined to be substrate lithology and soil geochemistry in the erosion at regime (Konhauser et al., 1994). Linking discharge events such as rainfall and snowmelt to changes in concentrations of a variety of chemical parameters has been examined in several catchments in North America (Stoalemyer and Troendle, 1992; Stednick, 1987; Dethier. 19=, Davis and Keller, 1983). The amount of groundwater contribution to the chemical character of stream and river waters has been studied using water chemistry (Ferguson et al., 1994; Williams et al., 1990; Dethier, 1988). Water rock interactions have been considered as a source of dissolved solids in springs of the Sierra Nevada (Gamls and Mac Kenzie, 1967). Surface water, soils and rock interactions have ken examined using the chemistry of stream waters in Wyoming (Miller and Drever, 1977). Cerling et al. (1989) used cation exchange of Ca^+ ions with Na^+ ions to explain the aqueous chemistry of waters draining shale bedrock regions. Clay mineral cation exchange properties also were studied in an effort to understand soil development in a mountain area in New Zealand (Harrison et al., 1990).

In the topic "Stable hydrogen and oxygen isotope ratios of bottled water of the world" 234 samples of bottle water were analysed and the hydrogen and oxygen isotope ratio values were found in the range -147% to +15 % and -19.1% to +3.0% respectively. Bottled or packaged waters represents an important component of human dietary intake worldwide.

Reference

[1] Available: http://www.bottledwater.org.
[2] Rossmann A. Food Rev. Int. 2001; 17: 347.
[3] Dennis MJ. The Analyst 1998; 123: 121R.
[4] Ingraham NL, Matthews RA, McFadyen R, Franks AL.
[5] Environ. Eng. Geosci. 2004; 10: 361.
[6] Dansgaard W. Tellus 1964; 16: 436.
[7] Bowen GJ, Wilkinson B. Geology 2002; 30: 315.
[8] Dansgaard W. Tellus 1964; 16: 436.
[9] Bowen GJ, Wilkinson B. Geology 2002; 30: 315.
[10] Rozanski K, Araguas-Araguas L, Gonfiantini R. In Climate
[11] Change in Continental Isotopic Records, Swart PK, Lohmann
[12] KC, McKenzie J, Savin S (eds). American Geophysical
[13] Union: Washington, DC, 1993; 1–36.
[14] Bowen GJ, Revenaugh J. Water Resour. Res. 2003; 39, 1299.
[15] Bowen GJ, Wassenaar LI, Hobson KA. Oecologia 2005; 143337.
[16] Craig H. Science 1961; 133: 1702.
[17] Coplen TB, Hanshaw BB. Geochim. Cosmochim. Acta 1973; 2295.
[18] Wanger AL, Dettmer A, Luster T. Draft Report on Seawater Coleman MI, Shepard TJ, Durham JJ, Rouse JE, Moore Anal. Chem. 1982; 54: 993.
[19] Epstein S, Mayeda T. Geochim. Cosmochim. Acta 1953; 213.

[20] Fessenden JE, Cook CS, Lott MJ, Ehleringer JR. Rapid Commun. Mass Spectrom. 2002; 16: 1257.
[21] Sharp ZD, Atudorei V, Durakiewicz T. Chem. Geol. 2001; 178: 197.
[22] Available: http://www.WaterIsotopes.org.
[23] IAEA/WMO. Global Network for Isotopes in Precipitation, the GNIP Database, 2004. Available: http://isohis.iaea.org/.
[24] Dansgaard W. Geochim. Cosmochim. Acta 1954; 6: 241.
[25] Kendall C, Coplen TB. Hydrolog. Process. 2001; 15: 1363.
[26] Araujo ED, Bertranou A. Systemic Study of Water Management Regimes: Mendoza, Argentina. South American Technical Advisory Committee, Global Water Partnership. 2004; 102.
[27] Longinelli A. Geochim. Cosmochim. Acta 1984; 48: 385.
[28] Madioune, D.H., et al., *Application of isotopic tracers as a tool for understanding hydrodynamic behavior of the highly exploited Diass aquifer system (Senegal).* Journal of Hydrology, 2014(511): p. 443-459.