I Congresso Geral
de Energia Nuclear

Rio de Janeiro, 17 a 20 de Março de 1986

ANAIS - PROCEEDINGS

TECHNIQUE OF TRITIUM-TAGGING OF SOIL MOISTURE FOR DETERMINATION OF GROUND WATER RECHARGE. SOME RESULTS FROM NORTH EASTERN REGION OF BRAZIL.

Umesh Chandra

Divisão de Monitoração Ambiental
Instituto de Pesquisas Energéticas e Nucleares
Comissão Nacional de Energia Nuclear - CNEN/SP

Abstract

The technique of reactor produced tritium for tracing downward movement of soil moisture and its application for determination of ground water recharge is described. Data of rainfall infiltration and the consequent recharge in purely sandy sites and one clavey site of semi-arid climate are described.
Tritiated water was injected below 70-90 cm ground surface in five radially concentric points 10 cm appart. Sampling of soil was carried out after one year by a hand auger, at every 10 cm depth interval. Soil samples were vacuum distilled and tritium in distilled moisture was determined by liquid scintillation counting.

Introduction

^3H is a unique tracer for water. It has been used to study the movement of soil moisture in the unsaturated zone. One of the most important parameter thus which can be studied by this technique is recharge to ground water for water resources evaluation. With this objective it has been used in different climatic zones in some countries.[1,2,3] Some empirical methods for evaluating recharge are in use by hydrologists but they can hardly be relied as they give the same results for all sites. Tritium method is a direct method with a typical error of $\pm$ 10% or better. In Brazil this technique was used for the first time by IPEN in clay/sand temperate climate for ground water recharge measurements and also for hydrological evaluation of a radioactive waste storage site[4,5].

In large scale the technique was used in the north eastern state of Rio Grande do Norte covering an area of about 1500 km^2. The region of the study forms part of semi-arid climate and most of the soils were very sandy except one site which was purely clayey and form part the local sand dunes. This study was part of a larger water resources evaluation project the report of which is under preparation[6]. The tritium levels in this region had already come down hence artificial tritium was used. In this work only part of the data are reported while the focus is on the technique, its potential and interpretation.

Experimental Details and Results

Tritiated water was injected 70 to 90 cm below ground surface using a syringe and thin tubes which were inserted into pre-made 7 mm dia holes in each site. Five such radially concentric holes, 10 cm appart formed one meaurement point. In each hole 2.5 ml of $\simeq 1 \mu Ci/ml$ of tritiated water was injected in the form of cross It is considered better than patterns adopted by various other investigators because infiltration of tritium is more uniform. After one year soil samples at the point of measurement were taken at every 10 cm depth interval using a hand operated auger. Soil samples were vacuum distilled to extract the moisture. Tritium in the distilled moisture was determined by liquid scintillation counting. Bulk density D, of the soil was measured in the field while moisture content m, of each sample was determined in laboratory. Recharge of ground water was calculated from the expression: weight of water/cm^2 (recharge) = $m.D.x/(1+m)$, where x=displacement of centre of gravity of tritium concentration (cm). The data of soil moisture infiltration and ground water recharge are shown in Table-1.

Table 1- Data of soil moisture penetration and recharge[6]

* Profile above depth of injection not considered for C.G. but depth of C.G. referenced to ground level.

Site	Depth of injection of ^3H, cm	Centre of gravity-C.G. of ^3H Profile.* cm	Displacement. cm	Average moisture content (from point of injection-centre of gravity) % wt	Bulk density g/cm³	'Recharge' cm
3	70	112.8	42.8	18.7	1.8	11.9
4	70	259.3	189.3	8.1	1.9	26.8
6	90	316.9	226.9	10.2	1.9	39.8
7	70	327.6	257.6	8.9	1.9	39.9
8	70	299.6	229.6	10.6	1.9	41.7
9	90	160.0	70.0	5.6	1.9	7.1

Discussions

Sand dunes with coarser grains let the rain water infiltrate to considerable depth owing to their low field capacity. In regions with annual precipitations < 100 mm there are still appreciable quantities of soil moisture in dune sand profiles. It is surprising but is a proven fact in Saudi Arabia, Kalahari desert. The region studied in this work is not desert but is purely sandy on top and there exit clay lenses which separate the deeper aquifer in many places in both confined and unconfined conditions. The mechanism of recharge, leakages across the clay lenses becomes very clear. Recharge takes place as and when only there are heavy (sometimes torrental) rains. Aquifer finally discharges to sea, a virtual loss of high quality ground water resource.

Almost at all the sites the tritium penetrated more than the depths sampled by the unsophisticated sampler used, surprisingly even at site 3 which is very clayey. The maximun depth sampled and the corresponding moisture (wt.%) are - 2.2m, 17.6%-site 3; 5m, 8.6% - site 4;5.5m, 9.3% - site6;5.5m, 7,5%- site 7;5 m, 9.9%-site-8;2.5m, 22.7%-site 9 [6]. Moisture content at these depths and 'Field capacity' correlations 'may' indicate that these moisture may not be reaching the water table at all. During sampling no hole caved in (except at site 9-due to shallow water table) but manouvering the sampler for every 10 cm sample was not an easy job, although care, known by previous experiences, was always taken. The sampler could have homogenized the tritium profiles. The solution evidently lies in advanced sampling techniques.

The data of site 3 is believable recharge but it is a clayey site, which forces water to spread horizontally than vertically, only to appear at surface at a slight topographical depression observed some 200 m away. The data of site 9 is not valid as it was at a higher topographical plateau and in the recharge zone (water table $\simeq$ 1.5 m). Tritium labelling technique for recharge does not function where water table is too shallow.

In this sandy and coastal region where potential evapotranspirations is larger than precipitation, one should not expect a well defined peak because of upward and downward cycles (day and night) of moisture movement. Even then an excellent peak with near background tails was noted at site 7. The tritium and moisture profiles are being interpreted and remain to be published.

There are criterias for injecting the 'right' concentration of tritium (i.e. detection limit and based on diffusion/dispersion) but it is more a question of intuition and previous experience. 12.5 ml of $\simeq$ 1μCi/ml and the pattern of injection adopted in this study proved resonably good. Undue high concentrations and volumes should always be avoided because of inherent problems.

References

1. ZIMMERMAN,U., et.al. in Isotope in the hydrological cycle, Geophys. Monograph 11, Am. Geophys. Union, 28-36, 1967.
2. BEDENKAMP,D.B., et. al., in Isotope techniques in groundwater hydrology, 1, 73-95, IAEA Proc. Symp., 1974.
3. CHANDRA,U., Studies on exchange and movement of isotopes in soil and water media, Ph.D. Thesis, University of Bombay, 1978.
4. CHANDRA,U., Poli,D.C.R. Hydrological evaluation of radioactive waste disposal site at IPEN: Study of movement of soil moisture and ground water recharge by artificial tritium tagging method, 545-555, 1º Congresso Brasileiro de Águas Subterrâneas, Recife, Nov. 1980.
5. IPEN-Internal report (of CARREI to CPRD, Determinação da infiltração da chuva na área para depósito de resíduos radioativos, do Centro de Proteção Radiológica e Dosimetria) - IPEN-CARREI-AAPARN, Umesh Chandra, Dec. 1982.
6. IPT/IPEN. Estudos hidrológicos utilizando técnicas isotópicas e hidroquímicas na região nordeste do Brasil (Estado do Rio Grande do Norte), Report (In Press).

Acknowledgements

Thanks are due to all the colleagues of CARREI-IPEN and of IPT who collaborated in part in obtaining some of the data discussed in this work.