

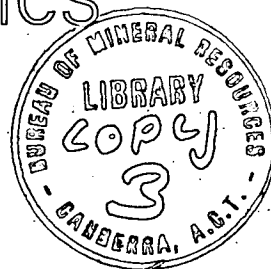
DEPARTMENT OF
MINERALS AND ENERGY



BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

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REPORT ON THE INTERNATIONAL ATOMIC ENERGY AGENCY SYMPOSIUM
ON ISOTOPE TECHNIQUES IN GROUNDWATER HYDROLOGY, VIENNA,
MARCH 1974.

by

G.R. Pettifer

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SUMMARY

The author attended the International Atomic Energy Agency Symposium on Isotope Techniques in Groundwater Hydrology held in Vienna, Austria, the first of its type devoted exclusively to the field of subsurface hydrology. The symposium was well attended by 241 scientists from 45 countries and 8 international agencies, reflecting the growing worldwide interest in these techniques. The last decade has shown considerable growth of interest and research in isotope techniques, and the current state of the art is such that several overseas geological organizations now use isotope techniques as an integral part of studies of both localized and regional groundwater regimes. The papers presented at the symposium placed a strong emphasis on case histories and practical applications including critical analysis of the effectiveness and limitations of existing techniques.

Sessions were devoted to groundwater recharge studies using the environmental isotopes tritium and deuterium. The recharge studies have enabled determination of the volume and rate of recharge by direct infiltration of rainwater. Variations in isotopic ratios of oxygen, hydrogen, and carbon have been studied, and these yield information of the source and age of recharge waters in deeper aquifers.

Studies of geothermal waters using the isotopic ratios of the noble gases has yielded information on the source and palaeotemperatures of the geothermal water. Several papers discussed the use of relatively new isotopes including uranium, silicon, argon, sulphur, and nitrogen. The carbon dating method is in a continuous stage of development and several case histories presented on this method highlight its limitations and future potential in groundwater studies.

Some excellent case histories on the use of injected isotopes indicate useful applications to civil engineering problems. Several papers deal with both mathematical and practical studies of dispersion, particularly the dispersion of chemical pollutants and radioactive waste.

The papers presented suggest that great value is to be gained by routine use of isotopic data in groundwater projects, particularly in conjunction with detailed hydrochemical studies.

1. INTRODUCTION

The International Atomic Energy Agency (IAEA), in its role as the United Nations Organization co-ordinating body for standardization of techniques and dissemination of information on nuclear technology and its applications, convened a Symposium on Isotope Techniques in Groundwater Hydrology. The symposium was held in the IAEA headquarters in Vienna, Austria over the period 11 to 15 March 1974. Previous symposia held by the IAEA in isotope hydrology had covered meteorological, surface water, and groundwater hydrological studies; however, because of the rapid growth of interest in the field of isotope hydrology for groundwater studies the present symposium was confined principally to this subject. The Australian Government as a member of the IAEA was invited to nominate scientists to participate in the symposium. The author attended, in an observing capacity, as a representative of the Bureau of Mineral Resources. Three other scientists from Australia attended the symposium and presented papers: Dr G.B. Allison of CSIRO Division of Soils, Adelaide; Professor J.W. Holmes of Flinders University, and W.T. Spragg of AAEC Research Establishment.

The purpose of the Symposium was to enable scientists and institutions, actively engaged or interested in the application of isotope hydrology to groundwater studies, to meet and discuss the results of experimental research, most of which has taken place in the last decade. Most of the groundwater recharge studies have by nature been of several years' duration, and the conference provided for the first time a forum for presentation of case histories in this field. Critical review of the techniques and philosophy of the methods was an inherent feature of the discussion periods held during the symposium. The symposium was attended by 241 scientists (physicists, chemists, hydrologists, geologists, geophysicists, engineers, and water resources management personnel) from 45 countries. Eight international agencies were also represented. Altogether 51 papers were presented by representatives from 21 countries. Appendix 1 shows a statistical summary of countries and people participating in the symposium and serves to indicate the wide interest in the topics presented.

2. PAPERS PRESENTED

The 51 papers presented were given over a series of nine sessions (two per day), each session being devoted to particular aspects of groundwater hydrology using isotope techniques. No parallel sessions were conducted, so maximum participation in all the sessions was possible. The

symposium was extremely well run with translation facilities in English, French, German, Spanish, and Russian. All but a few papers were available before the symposium for study by participants. One extra session was devoted entirely to discussion of topics proposed by the participants. Papers were presented in 20 minutes followed by 10 minutes for discussion, and this arrangement proved very fruitful for interchange of ideas. Table 1 shows the program for the symposium.

Table 1. Program

Opening of the Symposium

Session I	Groundwater recharge studies
Session II	Groundwater recharge studies (continued). Interrelation between groundwater and surface waters.
Session III	Interrelation between groundwater and surface waters (continued). Field studies with environmental isotopes.
Session IV	Field studies with environmental isotopes. Field studies with environmental isotopes (continued).
Session V	Field studies with environmental isotopes (continued). Geothermal waters.
Open Session -	Discussion of topics proposed by the participants.
Session VI	Problems in using environmental isotopes for groundwater studies.
Session VII	Environmental isotopes, other than hydrogen, oxygen, and carbon isotopes in groundwater studies.

Session VIII

Aquifer characteristics studies.

Session IX

Aquifer characteristics studies
(continued).

Movement of dissolved salts in
groundwater.

Modelling of movement of
isotopic tracers in ground-
water.

Closing of the Symposium

The advance of research in the field of isotope hydrology in groundwater studies has resulted in several specializations developing within this field, and this is obvious in the papers that were presented. The author, having no experience in these specializations, is not qualified to comment fully on the finer points of technology and method contained in the papers, but a general discussion of subjects of particular interest to BMR workers is included in Section 3. A complete list of papers is presented below (Table 2) with summaries on the contents of each paper. The reader is referred to the individual papers for fuller information. Copies of the papers are held with the BMR librarian.

Table 2. List of Papers

Session I

Groundwater recharge studies

IAEA/

SM-182/1

L.J. Anderson
T. Sevel

Geological Survey of
Denmark, Danish
Isotope Centre,
Copenhagen, Denmark

6-years environ-
mental tritium
profiles in the
unsaturated and
saturated zones,
Grønhøj, Denmark

The pioneer study of recharge using environmental isotopes. The studies give insight into the mechanism of recharge through soils. Soil moisture profiles and tritium profiles in the saturated zone show recharge velocities of 3 to 3.5 metres per month in the area studies, with a 6 to 7 month lag between infiltration and recharge.

SM-182/2

Y. Atakan
W. Roether
K.O. Munnich
G. Matthes

Zweites Physikalisches Institut,
Heidelberg, and
Hessisches Landesamt
für Bodenforschung,
Wiesbaden, F.R.G.

The Sandhausen
shallow-ground-
water tritium
experiment

Recharge rates in the alluvial plain of the Rhine have been found to be as low as 160 mm per year in an area of precipitation of 680 mm/year and recharge velocities of 3 metre/year.

SM-182/3

N.G. Persson

Geological Survey of
Sweden, Stockholm,
Sweden.

Tritium data from
groundwater in the
Kristianstad Plain,
south Sweden

Study of recharge to Cretaceous limestones.

SM-132/4

G.B. Allison
M.W. Hughes

CSIRO, Division of
Soils, Glen Osmond,
South Australia

Environmental tritium
in the unsaturated
zone; estimation of
recharge to an uncon-
fined aquifer

The difference of the pattern of the tritium input in rainfall in Australia from that in the Northern Hemisphere is discussed. This poses some problems in application of the method to recharge studies in Australia. Several models of recharge are applied to assess their validity to the study area. Three sites each with 760 mm annual rainfall were investigated, and showed variations from 40 to 140 mm annual recharge. Soil cover and soil type appear to be significant factors in recharge.

SM-182/5

D.B. Bredenkamp
J.M. Schutte
G.J. du Toit

Hydrological Research
Division, Department
of Water Affairs,
Pretoria South Africa

Recharge of a
dolomitic aquifer
estimated from
tritium profiles

Successful results were obtained using tritium methods for recharge estimates in a fissured dolomitic aquifer. Problems in estimation of effective porosity are circumvented using tritium methods.

SM-182/6

R.E. Isaacson	Atlantic Richfield	Soil moisture
<u>L.E. Brownell</u>	Hanford Company,	transport in arid
R.W. Nelson	Richland, Washington;	site vadose zones
E.L. Roetman	Computer Sciences	
	Corporation, Richland,	
	Washington, and	
	University of	
	Missouri, Columbia,	
	Missouri, USA	

This study was initiated to examine the possibility that nuclear wastes buried in dry overburden will penetrate to the deep regional water-table. Mechanisms of groundwater movement in arid soils are studied. Temperature variation with depth and time was found to be the most important mechanism and invalidates the assumption of isothermal conditions which some hydrological models use. A critical rainfall value is shown to exist, above which rainwater and buried nuclear wastes can penetrate the vadose zone. Studies are continuing.

SM-182/7

K. Krishnamurthy	Isotope Division,	A simple stable
<u>S.M. Rao</u>	Bhabha Atomic Research	isotope approach
	Centre, Bombay, India	to study the effect-
		iveness of artifi-
		cial recharge from
		percolation tanks

Deuterium stable isotopes are used to study the volume of groundwater storage recharged by percolation tanks. Results show an area of 1.2 km radius from the tanks. The method relies on enrichment of the percolation tank waters in deuterium by evaporation and then tracing the enriched water through the non enriched groundwater. The method is safe to use as no artificial long-half-life isotopes have to be employed.

SM-182/8

P.L. Airey	Australian Atomic	The use of envir-
G.E. Calf	Energy Commission,	onmental isotopes
P.E. Hartley	Lucas Heights NSW,	and artificial
D. Roman	Australia	tracers to study
W.T. Spragg		recharge to ground-
		water in the
		Burdekin Delta,
		Queensland

Description of the continuing investigation of the Burdekin Delta area by the AAEC first started in 1965 by BMR and AAEC. The tritium data are in agreement with recent hydrological models which indicate over 60% of recharge comes from the Burdekin River. Tritium contents decrease away from the river, and estimates of flow on the piezometric surface have been made. Problems with tracers in clay-bearing media are discussed. Laboratory studies with clay tracers have been used to study the problem of decreasing effectiveness of artificial recharge pits with time owing to fine suspended clay particles penetrating into the sand aquifers.

Interrelation between groundwater and surface water

SM-182/9

J. Martinec	Federal Institute for	New insight into
U. Siegenthaler	Snow & Avalanche	the runoff mechan-
H. Oeschger	Research, Weissfluh-	ism by environ-
E. Tongiorgi	joch/Davos, and	mental isotopes
	University of Bern,	
	Switzerland; Univ-	
	ersity of Pisa, Italy	

Study of the types and volume of recharge in alpine basins from melting snows.

SM-182/10

W.G. Mook	Physics Laboratory	The waterbalance
A.E. Brouwn	University of	and runoff charac-
A.J. Van	Groningen Groningen	teristics of a
Ganswijk	The Netherlands	hydrological
D.J. Grownveld		research area
		studies by means
		of Oxygen-18

Changes in the isotopic ratios O^{18}/O^{16} of natural oxygen in rainfall often occur in natural storms whereas O^{18}/O^{16} ratios in groundwater reflect the average annual precipitation ratio. This property is used to measure relative contributions of rainwater and groundwater to runoff in a storm.

SESSION III

SM-182/11

J. Deak	Research Institute for	Use of environ-
	Water Resources,	mental isotopes
	VITUKI, Budapest	for the investi-
	Hungary	gation on the

connexion of
surface and sub-
surface waters in
the Nagykunsag
area, Hungary

Investigations show little connection between deep artesian aquifers and surface aquifers in the Nagykunsag area. Tritium contents of subsurface water depend much on surface soil cover.

SM-182/20

L.J. Brown
C.B. Taylor

New Zealand Geological Survey, Dept of Scientific & Industrial Research, Christchurch, and Institute of Nuclear Sciences, Dept of Scientific & Industrial Research, Lower Hutt, New Zealand

Geohydrology of the Kaikoura Plain, Marlborough, New Zealand

An interesting study of recharge of alluvial outwash plain aquifers using tritium, deuterium, and oxygen determinations. The isotopic data confirms the separateness of the three main aquifers in the area. The streams crossing the outwash fan are derived from various altitudes and because of the increasing isotopic lightness of rainfall at higher altitudes each stream has its characteristic H^3/H^2 and O^{18}/O^{16} ratios. Analyses of groundwater indicate the relative contributions of recharge from each stream to each aquifer.

Field studies with environmental isotopes

SM-182/17

T. Dincer
A.R.K. Javed
M. Noory
S. Nuti
E. Tongiorgi

Ministry of Agriculture and Water and Trust Fund 117 of the UN FAO, and Institute of Geothermal Studies, Pisa, Italy

Study of the groundwater recharge and movement in shallow and deep groundwater in Saudi Arabia with stable isotopes and salinity data

This paper deals with recharge mechanisms in arid zone areas and problems, and applications of isotopes in arid environments.

SM-182/18

E. Mazor	Nuclear Physics	Kalahari ground-
B.Th. Verhagen	Research Unit, Univ-	waters: their
J.P.F. Sellschop	ersity of the	hydrogen, carbon,
N.S. Robins	Witwatersrand,	and oxygen
L.G. Hutton	Johannesburg, S.	isotopes and
	Africa, and The	dissolved ions
	Geological Survey	
	and Mines Division,	
	Lobatsi, Botswana	

A detailed study of the interaction of rock matrix carbonates with groundwater and the resulting effect on C^{14} determinations is given.

SM-182/25

G. Conrad	Faculte des Sciences	Etude isotopique
J-Ch. Fontes	de Rouen et Centre de	de la nappe du
R. Gonfiantini	Recherches sur les	"continental
G. Sauzay	Zones Arides, Paris;	intercalaire" et
B.R. Payne	Laboratoire de	de ses relations
	Geologie Dynamique,	avec les autres
	Universite de Paris,	nappes du Sahara
	France, and LAEA,	septentrional
	Vienna, Austria	

SM-182/26

G. Castany	Service geologique	Etude par les
A. Marce	national du Bureau de	isotopes du milieu
J. Margat	Recherches geologi-	du regime des eaux
H. Moussu	ques et minieres, and	souterraines dans
Y. Vuillaume	Faculte des Sciences,	les aquiferes de
	Lyon, France.	grandes dimensions

These papers deal with C^{14} measurments applied to recharge on a large scale in an arid area.

SESSION IV

SM-182/13

E. Salati	Centre do Energia	Environmental
J.M. Leal	Nuclear na Agricul-	isotopes used in
M.M. Campos	tara, Piracicaba,	a hydrogeological
	S.P.; Superintendencia	study of the
	do Desenvolvimento do	Northeastern part
	Nordeste; Instituto	of Brasil
	de Pesquisas Radio-	
	ativas, Belo Horizonte,	
	Brasil	

Several problems and limitations of the isotope methods are noted in this paper. Deuterium and O^{18} concentration data suggests evidence of climatic changes in the region.

SM-182/53

V.I. Ferronsky	Institute of Water	Regional and local
I.B. Selechi	Problems, Academy of	regularities of
V.A. Poliakov	Sciences of the USSR,	the H^2 distribu-
A.B. Jakubovsky	Moscow, USSR	tion in ground-
N.B. Isajev		water in USSR

No abstracts available.

SM-182/14

<u>R. Gonfiantini</u>	IAEA, Vienna, Austria;	Environmental
<u>T. Dincer</u>	Projet d'etude de mise	isotope hydrology
A.M. Derekoy	en valeur du Hodna,	in the Hodna
	FAO-UNDP, Algiers,	region, Algeria
	Algeria	

Recharge of shallow and deep aquifers is studied in the area of large wadis.

SM-182/15

<u>W. Stahl</u>	Bundesanstalt fur	Origin of artesian
<u>H. Aust</u>	Boedenforschung,	and thermal waters,
A. Dounas	Hannover, F.R.G.	determined by
		oxygen, hydrogen,
		and carbon isotope
		analyses of water
		samples from the
		Sperkhios Valley,
		Greece

A good example of a combined geological, geophysical, and isotope hydrological investigation of an artesian ground-water regime.

SM-182/16

G.M. Zuppi	Laboratoire de	Isotopes du milieu
<u>J.Ch. Fontes</u>	Geologie Dynamique,	et circulations
<u>R. Letolle</u>	Paris	d'eaux sulfurees
		dans le latium

Study of sulfurous waters using isotopic analyses in a karstic environment in Italy.

SM-182/19

B.R. Payne
Y. Yurtsever

IAEA, Vienna, Austria Environmental
isotopes as a
hydrogeological
tool in Nicaragua

The altitude effect (see SM-182/20, Session III) was used to determine recharge sources on an outwash plain area.

SM-182/22

P. Fritz
F.W. Render
R.J. Drimmie

University of
Waterloo, Waterloo,
Ontario, and Water
Resources Branch,
Dept of Mines &
Natural Resources,
Winnipeg, Manitoba,
Canada Stable isotope
contents of a
major prairie
aquifer in
Central Manitoba,
Canada.

Variations in O^{18} concentrations have been observed in regional aquifer flow systems probably caused by surface man-made features and agricultural activity. This variation was considered a major limitation in comparing recharge and discharge waters. The O^{18} data, with salinity data, enable determination of the effect of seasonally variable well pumping on water quality where confluence of flow systems occurs.

SESSION V

SM-182/23

P. Kirkov
D. Kacurkov
T. Anovski
M. Tolev
G. Stoilovski

Centre of Radioisotope Determination of
Application in Science origin of water
& Industry, Institute in springs with
of Physical & Electro- the simultaneous
chemistry, Faculty of application of
Technology & Metall- natural and
urgy, Faculty of artificial isotopes
Electro & Mechanical (some aspects of
Engineering, Skopje, the originity of
Yugoslavia water in Rashche
spring)

Concerned with the origins of karstic spring waters.

SM-182/24

W. Rauert
W. Stichler

Institut fur Radio- Groundwater investi-
hydrometrie der GSF, gations with
Munchen, F.R.G. environmental
isotopes

Review of techniques of measurement of O^{18} and H^3 concentrations.

SM-182/38

V. Cotecchia
G.S. Tazioli
G. Magri

Istituto di Geologia
Applicata e Geotecnica,
Universita, Bari,
and CNEN, Gruppo
Studio Ambiente
Idrogeologico, Bari,
Italy

Isotopic measurements in researches on sea water ingression into carbonate aquifer of Salentine Peninsula (Southern Italy)

This study presents interesting results on the migration of CO_2 between fresh and brackish waters to underlying intruded sea water as reflected in the C^{14} data. History of the seawater intrusion is also inferred from O^{18} and H^2 measurements.

SM-182/52

V.D. Babushkin
V.T. Dubintschuk
B.V. Karasiev
G.N. Kashkowski
V.M. Kupcov
V.I. Netchaiev
V.A. Poliakov
Iu. B. Selechi

Hydrogeology & Engineering Geology Dept,
All Union Scientific-
Research Institute,
Ministry of Geology
of USSR, Moscow, USSR

Investigation on groundwater recharge conditions by means of stable and radioactive isotopes and of analogical modelling

Abstract not available

SM-182/21

A. Rozkowski

Geological Institute,
Sosnowiec, Poland

Environmental isotope techniques used for hydrogeological investigations in the Lublin Coal Basin

Deuterium and oxygen studies were undertaken to determine the source of water flow into mines.

Geothermal Waters

SM-182/27

R. Celati
P. Noto
C. Panichi
P. Squarci
L. Taffi
E. Tongiorgi

Istituto Internazionale per le Ricerche Geotermiche, Pisa, Italy

Oxygen and hydrogen isotope studies of the Larderello (Italy) geothermal system

Isotopes in conjunction with chemical studies have given insight to origins of geothermal waters and steam.

SM-182/28

E. Mazor
B.Th. Verhagen
E. Negreanu

Nuclear Physics Research Unit, University of the Witwatersrand, Johannesburg, South Africa, and Isotope Dept, The Weizmann Institute of Science, Rehovot, Israel

Hot springs of the igneous terrain of Swaziland: their noble gases, hydrogen, oxygen, and carbon isotopes, and dissolved ions

C^{14} , O^{18} , H^3 , Ar^{40}/Ar^{36} , Kr and Xe measurements show residence times of 4000 years for the spring waters. Noble gas concentrations indicate palaeotemperatures of infiltration little different from present day temperatures.

Open Session - Discussion of topics proposed by the participants See Section 3.

SESSION VI

Problems in using environmental isotopes for groundwater studies

SM-182/29

J.R. Gat

Isotope Research Dept, The Weizmann Institute of Science, Rehovot, Israel

Local variability of the isotope composition of groundwater

SM-182/30

J.C. Vogel
N. van Urk

National Physical Research Laboratory, Pretoria, S. Africa

Isotopic composition of groundwater

SM-182/51

G. Sauzay

IAEA, Vienna, Austria

Sampling of lysimeters for environmental isotopes of water

The above three papers critically analyzed spatial and time variations of isotopic composition of groundwater. Factors contributing to variability of composition include leakage, vegetation and soil cover, and presence of agricultural development, especially irrigation. Rainfall shows variable composition also. The problems require sufficiently broad

sampling techniques to define scatter in composition and hence limitations of any conclusions drawn from isotopic analyses.

SM-182/31

I.J. Winograd
G.M. Farlekas

US Geological
Survey, Reston,
Virginia, USA

Problems in C^{14}
dating of water
from aquifers of
deltaic origin:
an example from
the New Jersey
coastal plain

C^{14} determinations assume variations in the C^{13} composition of formational carbonates to be zero and that no CO_2 is introduced after recharge. The New Jersey deltaic aquifers show CO_2 is generated by chemical and bacterial action on lignitic detritus and with the known mixing of water from other aquifers this has made C^{14} ages meaningless. In situ carbonates also show appreciable variation in C^{13} content. Detailed studies of stratigraphy, hydrochemistry hydrodynamics, dissolved gas contents, and mineralogy are required to resolve the problem.

SM-182/32

F.J. Pearson, Jr.
W.V. Swarzenski

US Geological
Survey, Reston,
Virginia, USA

Carbon-14 evidence
for the origin of
arid region ground-
water: Northeastern
Province, Kenya

Ion exchange processes within the soil between Na and Ca ions apparently causes widely varying C^{14} ages in ground-water which has been recharged by rainwater infiltration through the soil. Further studies are required.

SM-182/33

R.W. Buddemeier
T.H. Hufen
L.S. Lau
P. Kroopnick

Hawaii Institute of
Geophysics, Honolulu,
Hawaii USA

Radiocarbon,
carbon-13 and
tritium in water
samples from
basaltic aquifers
and carbonate
aquifers

In an area of carbonate-free basaltic aquifers overlying carbonate aquifers the contrast in accuracy of C^{14} results becomes clear. A correlation was established between pumping rates, water lens thicknesses, well depths, and radiocarbon ages.

SESSION VII

Environmental isotopes, other than hydrogen, oxygen and carbon isotopes, in groundwater studies

SM-182/34

E. Wakshal
F. Yaron

Groundwater Research
Centre, School of
Applied Science &
Technology, The Hebrew
University, Jerusalem,
Israel

U^{234}/U^{238} dis-
equilibrium in
waters of the
Cenomanian-
Turonian aquifer
in the Galilee,
N. Israel

U^{234}/U^{238} ratios show three main divisions of groundwater in the aquifer. These divisions relate to geological history of the aquifer system and give information on the solid/water contact history of the waters.

SM-182/35

J.B. Cowart
J.K. Osmond

Department of Geology, U^{234}/U^{238} in the
Florida State Univ- carrizo sandstone
ersity, Tallahassee, aquifer of South
Florida, USA Texas

Case history of geochemical effects on uranium in ground-water.

SM-182/36

V.N. Nijampurkar
B.L.K. Somaya-
julu

Archaeology-Hydrology
Group Physical Res-
earch Laboratory,
Navrangpura, Ahmeda-
bad, and Tata
Institute of Funda-
mental Research,
Colaba, Bombay India

An improved
method of
silicon-32 mea-
surement of
groundwaters

Abstract not available.

SM-182/37

H. Oeschger
P. Bucher
A. Gugelmann
H. Loosli
U. Schotterer
U. Siegenthaler
B. Stauffer
W. Wiest

Physikalisches
Institut der
Universitat Bern,
Bern, Switzerland

Preliminary
results of argon-
39 dating of
groundwater,
first results

Argon dating of groundwaters is a new isotopic dating method. Twenty tons of water are required to extract sufficient radiogenic argon to obtain a date. Much effort and equipment is required, and the application of this argon dating technique appears to be limited by the expense of sampling. This paper is presented by the group who have developed the argon dating method. Argon-39 has a half-life of 269 years enabling dates in the range 50 to 1000 years to be determined, so bridging the gap between tritium and C^{14} dates. The main fields of application are thermal springs, glaciology, and oceanography.

SM-182/39

W. Back
C.T. Rightmire
F.J. Pearson
R.O. Rye
B.B. Hanshaw

US Geological
Survey, (Water
Resources Div.)
Reston, Virginia,
USA

Distribution of
sulphur isotopes
in groundwater
from principal
artesian aquifer
of Florida, USA

A complex study of sulphur geochemistry and sources of sulphur in groundwater including H_2S from underlying ore fields, industrial sulphur in the rainfall, in situ sulphates, and ingression of seawater.

SM-182/40

R.R. Letolle

Laboratoire de
Geologie Dynamique,
Paris, France

L'utilisation
possible des
variations
naturelles d'abon-
dance de l'azote
 15 comme traceur
en hydrogeologie

Pioneer study of the possibility of utilization of N^{15} as an isotopic tracer in groundwaters. Problems appear to arise from the role of nitrogen in the biological cycle of plant roots in the soil. Fertilizers also create problems in cultivated areas. Results to date justify further research.

SESSION VIII

Aquifer characteristics studies

SM-182/43

P.Ch. Leveque
J.C. Gros
C. Maurin
J. Severac
Cl. Viguiier

Laboratoire de Radio-
geologie et de
Mecanique des Roches,
Universite de Bordeaux
I Talence, France

Utilisation des
techniques isoto-
piques pour la
resolution de
problems hydro-
logiques en genie
civil. Etude de
3 cas precis.

A good practical study of borehole logging methods applied to civil engineering problems using injected isotopes to delineate permeable zones. Bromium, caesium, and tritium tracers are utilized.

SM-182/12

<u>W. Drost</u>	Institut fur Radio-	Application of
<u>F. Neumaier</u>	hydrometrie der	single borehole
U. Chandra	Gesellschaft fur	methods in
H. Moser	Strahlen u. Umwelt-	groundwater
W. Stichler	forschung mbH,	research
H. Kusamaul	Munchen, F.R.G., and	
	Institut fur Wasser,	
	Boden u. Lufthygiene	
	des Bundesgesundheits-	
	amtes, Aussenstelle,	
	Dusseldorf, F.R.G.	

Examples of applications of single borehole methods to groundwater exploration studies, bank filtration, groundwater pollution, and hydraulic and foundation engineering are given. The methods using a single borehole have been applied in over a hundred projects in alluvial, karstic, and hard rock environments.

SM-182/44

<u>H.A. Munera</u>	Instituto de Asuntos	Modelos matemati-
	Nucleares, Bogota	cos simplificados
	Columbia	para interpreta-
		cion de resultados
		de ensayos por el
		metodo de marcac-
		ion de toda la
		columna piezo-
		metrica en pozos
		de agua

Various hydrological models for dispersion of tracers are discussed.

SM-182/45

<u>A. Zuber</u>	Institute of Nuclear	Theoretical
	Physics, Cracow,	possibilities of
	Poland	the two-well
		pulse method

Problems and limitations of the two-well pulse method are discussed and although it is acknowledged that tracing between two wells may not yield any new information on aquifer characteristics, more widespread use is advocated.

SM-182/46

K. Czauderna
A. Kreft
A.M. Lenda
B. Turek

Hydrological Enterprise "Hydrokop", Cracow, and Institute of Nuclear Techniques, Academy of Mining & Metallurgy, Cracow, Poland

The determination of effective porosities by the two-well pulse method

Abstract not available.

SESSION IX

SM-182/47

L.O. Nordberg
S.M. Modig

Geological Survey of Sweden, Stockholm, Sweden

Investigations of effective porosity of till by means of a combined soil moisture/density gauge

This gives a simple method of determining the effective porosity of the till without encountering the problem of disturbed sampling.

SM-182/42

H. Moser
D. Klotz

Institut fur Radio-Hydrometrie der Gesellschaft fur Strahlen u. Umweltforschung mbH, Munchen, F.R.G.

Hydrodynamic dispersion as aquifer characteristic; model experiments by means of radioactive tracers

Radioactive tracers were used to examine the dependence of the dispersion coefficient of a porous medium on grainsize distribution, grain roughness and angularity. Average grainsize is considered inadequate as characterizing the dispersion properties of a medium. The more uniform the grainsize the higher the dispersion coefficient. The dispersion coefficient, as defined, was found to independent of permeability. The dependence of dispersion coefficient on grainsize and shape was found to be too complex to derive empirical relations as has been the case with permeability.

Movement of dissolved salts in groundwater

SM-182/41

J. Guizerix	Centre d'Etudes	Methods pour la
P. Corompt	Nucleaires de Grenoble	determination de
B. Gaillard	TAAR-AR, Grenoble, and	caracteristiques
R. Margrita	Ministere de	de transfert de
J. Molinari	l'Agriculture et du	substances poll-
R. Corda	Developpement Rural,	uantes dans les
N. Crampon	Service de l'Amenage-	nappes aquiferes
D. Olivier	ment des Eaux de la	
	Region Lorraine,	
	France	

Very mathematical study of predication of dispersion of pollutants.

SM-182/54

V.T. Dubintschuk	Hydrogeology & Engin-	Investigation of
V.S. Goncharov	eering Geology Dept.,	the molecular
Z.G. Kolesnit-	All Union Scientific-	diffuse transport
chenko	Research Institute,	of salts in the
O.F. Laptieva	Ministry of Geology	saturated and
	of USSR, Moscow,	unsaturated zones
	USSR	by means of radio-
		active isotopes

Abstract not available.

Modelling of movement of isotopic tracers in groundwater

SM-182/48

R. Margrita	Centre d'Etudes	Alanyse des infor-
P. Corompt	Nucleaires de Grenoble	mations fournies
J. Guizerix	TAAR-AR, Grenoble, and	par les traceurs
M. Alquier	Institut de Mecanique	naturels ou
	des Fluides de	artificiels dans
	Toulouse, France	l'etude des
		systems aquiferes
		en hydrogeologie

An electrical engineering systems theory approach is used to describe the behaviour of porous media. The study presents the theoretical side of the problem only.

SM-182/49

K. Przewlocki	IAEA, Vienna, Austria	Some conceptual
Y. Yurtsever		mathematical
		models for eval-
		uation of the
		tracer input-
		output relations
		in hydrological
		systems

A finite element technique is presented. Simple conceptual models often adequately define the groundwater balance equations. A desk computer and plotter similar to BMR's Wang 600 and plotter has been used to simulate ground water models of practical application.

SM-182/50

J.B. Robertson	National Reactor Testing Station, Idaho Falls, Idaho, USA	Application of digital modelling to the prediction of radioisotope migration in groundwater.
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A very excellent paper on computer simulation of observed migration of radioactive wastes pumped into seepage ponds. A finite element model was set up and the observed migration has been simulated. This model is then to be used for prediction of further migration in time and response to changes of waste input.

3. SUMMARY OF HIGHLIGHTS OF THE SYMPOSIUM

The symposium was very practically oriented; nearly every paper presented case histories documenting several diversified applications. The papers presented, particularly those dealing with environmental isotopes, make it obvious that use of isotopic ratios adds an extra and virtually unlimited dimension to the study of the chemistry of groundwaters and in turn gives valuable information on the palaeohistory of groundwater systems. Applications range from localized groundwater studies to large-scale basin projects. The isotope techniques were considered to be sufficiently developed to be a necessary tool for routine, detailed studies of groundwater regimes. This fact was strongly brought out in the discussion periods. From a perusal of the organizations presenting papers at the symposium (Table 2, Section 2) it is obvious that isotope techniques in groundwater hydrology are taken seriously by geological organizations overseas. Several of these organizations have acquired the necessary technological facilities (or have access to them) to carry out isotope investigations on a routine basis.

The papers presented on the use of tritium techniques for estimate of recharge show that recharge by rainfall infiltration is, in many cases, less than was previously thought. Time appears to be running out for the tritium technique, as atmospheric thermonuclear testing is diminish-

ing. The persistence of testing in the Pacific area gives Australia perhaps a little time longer than northern hemisphere countries. Recharge studies are necessarily of a long-term nature and are hampered by the problems of choice of suitably representative sites. Extreme local variations in recharge have been noted (Papers SM-182/4 and SM-182/11, Table 2, Section 2) in areas studied in Australia and Hungary, due mainly to soil cover and soil type variations. Thus, only extremal estimates for rainfall recharge over large areas can be made, except where detailed soil mapping is available. The ultimate accuracy of these recharge studies and hence their long-term value must be in question. The papers on the mechanism of recharge in the arid zone environment (SM-182/6, Table 2, Section 2) presented interesting results of application to areas with deep water-tables.

The section on field studies with environmental isotopes was perhaps the most valuable part of the symposium, and many of the case histories were of direct relevance to groundwater studies carried out by BMR. It would appear that much scope exists for using these techniques in Australia, and BMR is in an ideal position to participate in or implement projects in this type of work. Several problems have arisen in use of environmental isotopes, and it would follow that any projects initiated in isotope studies would necessarily have to be backed by intensive research activity.

The development of methods using relatively new isotopic tracers received great interest at the symposium though further research appears to be necessary. The uranium methods suffer from the sensitivity of the high valence uranium ions to pH, and high-effort hydrochemical studies are required to extract maximum information from the uranium data. The work by the United States Geological Survey on sulphur isotopes (SM-182/9, Table 2, Section 2) has shown that sources of sulphate in groundwater can be determined from isotopic data whereas chemical and hydrological data alone cannot give this.

The aquifer characteristic studies session gave excellent examples of relatively simple techniques for civil engineering and groundwater development studies. The technique of injection of short-lived isotopes into boreholes to delineate permeable zones (SM-182/43, Table 2, Section 2) is one which could be easily applied to settlement problems in foundation investigations. With the proposed expansion of BMR's activities in urban development studies, particularly in alluvial areas such as the proposed

Albury-Wodonga growth centre, numerous applications of this technique could be envisaged. Several papers dealing with pollution studies also will be of interest in urban development investigations. (SM-182/50, SM-182/41, SM-182/43 in Table 2, Section 2).

In conclusion the author feels that the abundance of case histories presented at the symposium provides ample proof of the value of the isotope techniques in groundwater investigations, and the use of these methods would increase the value of any groundwater projects undertaken by BMR. In view of the relative lack of application of these techniques in Australia at present, BMR would appear to be in an excellent position to initiate further experiments in isotope hydrology, perhaps in co-operation with the AAEC, and thus extend the excellent work which was begun in the Burdekin Delta project. (Andrew et al, 1965; Wiebenga et al, 1967).

4. GENERAL REFERENCES

- GASPAR, E. & ONESCHU, M., 1972 - Radioactive tracers in Hydrology - Developments in Hydrology 1. Amsterdam, Elsevier
- WIEBENGA, W.A., ELLIS, W.R., SEATONBERRY, W., ANDREW, J.T.G., 1967 - Raduisionioes as griybdwater tracers H, geophys, Res., 72 (16), 4081
- ANDREW, J.T.G., ELLIS, W.R., SEATONBERRY, B.W., & WIEBENGA, W.A., 1965 - The use of radioisotopes as ground water tracers in the Burdekin Delta area of north Queensland, Australia. Aust. Atomic Energy Comm. Rep. AAEC/E137

APPENDIX: SUMMARY OF PARTICIPANTS AND COUNTRIES REPRESENTED
AT THE SYMPOSIUM

<u>Country</u>	<u>Participants</u>	<u>Papers</u>
Australia	4	2
Austria	25	-
Belgium	5	-
Brazil	3	1
Canada	5	1
Chile	2	-
Colombia	1	1
Czechoslovakia	3	-
Cuba	1	-
Denmark	3	1
Finland	4	-
France	31	7
Fed. Repub. of Germany	23	5
Ghana	1	-
Greece	2	-
Hungary	3	1
Iceland	1	-
India	5	2
Indonesia	1	-
Iran	1	-
Israel	4	3
Italy	12	3
Libya	2	-
Mexico	2	-
Morocco	2	-
Netherlands	4	1
New Zealand	1	1
Norway	7	-
Peru	1	-
Philippines	1	-

APPENDIX (cont.)

Poland	6	3
Romania	1	-
Saudi Arabia	2	1
South Africa	7	3
Sweden	3	2
Switzerland	12	2
Spain	3	-
Sri Lanka	1	-
Sudan	1	-
Uruguay	1	-
USSR	2	3
UK	4	-
USA	14	7
Yugoslavia	8	1
Zaire	<u>1</u>	<u>-</u>
<u>TOTAL</u>	<u>226</u>	<u>51</u>

<u>INTERNATIONAL ORGANIZATIONS REPRESENTED</u>	<u>PARTICIPANTS</u>	<u>PAPERS</u>
A.I.H. (Assoc. Intern. des Hydrogeologues)	1	-
C.E.C. (Commiss. of European Communities)	1	-
F.A.O. (U.N.)	4	1
FORATOM (Forum Atomic European)	1	-
IBRD (Int. Bank for Reconst. & Development)	1	-
Intern. Comm. on Irrigation & Drainage.	1	-
U.N.E.S.C.O.	1	-
I.A.E.A. (Int. Atomic. Energy Assoc.)	5	5
<u>TOTAL</u>	<u>15</u>	<u>6</u>