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STUDIES CARRIED OUT BY PINSTECH AT DIFFERENT DAMS

TARBELA DAM

1. Determination of Sinkhole-Piezometer standpipe hydraulic connection at Auxiliary Dam-1 (Tarbela dam) using radioactive tracer (Sponsored by Pakistan Water and Power Development Authority -WAPDA)

2. An Isotopic Approach to study the Recharge Mechanism in Haripur Plain - Contribution to the area from Tarbela dam and Khanpur dam (IAEA Research Contract No. 4794/RB)

3. Isotopic Study of the effect of Tarbela Reservoir on the groundwater system in the downstream areas. (Sponsored by Pakistan Council of Research in Water Resources - PCRWR)

4. Isotopic studies at and around Tarbela Reservoir (Sponsored by WAPDA)

   a) Study of the effect of Tarbela Reservoir on groundwater in Gandaf-Topi area.

   b) Identification of the source of recharge of groundwater/ springs in selected areas of Haripur

5. Monitoring of Dissolved Gases in relation to Dynamic Stabilization in the Right Abutment of Tarbela dam

6. Isotopic characterization of Tarbela Reservoir

STUDIES CARRIED OUT BY PINSTECH AT DIFFERENT DAMS

MANGI DAM

7 INJECTIONS OF BR-82 AND GOLD-198 WERE MADE IN DIFFERENT BORE-HOLES AT PROPOSED SITE FOR MANGI DAM TO KNOW:

- THE SOURCE TWO SPRINGS DOWNSTREAM OF DAM AXIS,
- TRACING OF WATER OF KHUM RIVER LOST IN THE GORGE UPSTREAM OF DAM E AND
- DIRECTION FLOW OF SUB-SOIL WATER AT DAM SITE.

DELAY ACTION DAM

- TO DETERMINE RECHARGE SOURCE OF KAREZES
- TO INVESTIGATE THE HYDRAULIC RELATIONSHIP OF DABA AND KAREZES
- TO ESTIMATE THE RESIDENCE TIME OF WATER

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SUBJECT: SUMMARY OF THE STUDIES CARRIED OUT BY PINSTECH AT AND AROUND TARBELA DAM

Radiation and Isotope Application Division (RIAD), at Pakistan Institute of Nuclear Science and Technology (PINSTECH), Islamabad, has carried out the following studies at and around Tarbela Dam.

1. **Determination of Sinkhole-Piezometer standpipe hydraulic connection at Auxiliary Dam-1 (Tarbela dam) using radioactive tracer (Sponsored by Pakistan Water and Power Development Authority -WAPDA)**

SUMMARY: *Tarbela Dam, the giant multi-purpose dam, completed in 1974 has been built across the river Indus. In 1977, the readings in some piezometers showed an abrupt rise indicating abnormally high water pressure. Later, a sinkhole was found on the upstream slope of the Auxiliary Dam-1. NaCl was injected in sinkhole which was detected in piezometer standpipe after 15 minutes. After injecting filling material into the sinkhole, the response time increased to 2 hours. After further grouting work at sinkhole, the response time increased to 4-5 hours. After carrying out further remedial measure, it was decided to conduct radiotracer test. The Radioactive tracer ^{24}Na was used to determine the hydraulic connection between backfilled sinkhole in the upstream slope of Auxiliary Dam-1 (Tarbela Dam Project) and a piezometer standpipe installed nearby in the same dam. The results of the experiment showed little hydraulic connection between the injection point and the piezometer standpipe under the prevailing conditions of experiment.*

2. **An Isotopic Approach to study the Recharge Mechanism in Haripur Plain - Contribution to the area from Tarbela dam and Khanpur dam (IAEA Research Contract No. 4794/RB)**

SUMMARY: *Haripur plain is located about 160 km. North-east of Peshawar. The purpose of this study was to determine the recharge mechanism of groundwater in the plain and to see if there is any contribution of Tarbela dam and Khanpur dam towards groundwater recharge. Water samples were collected from 55 stations including tubewells, open wells, lakes, rivers and drains in the project area. The samples were analyzed for ^{2}H, ^{3}H, ^{18}O, major anions and cations. Temperature, EC and pH were measured in -situ. The isotopic and chemical data revealed that: (a) the*

major source of groundwater recharge in the plain is rainfall on adjoining hills. (b): Local rainfall only contributes through gullies while most of it is wasted as surface run-off. (c): Isotopic data do not support the proposition of any contribution from Tarbela Reservoir to the rise in water table in certain areas. (d): the residence time of groundwater varies from a few years to more than 50 years depending upon the geology of the area. (e): infiltration from Khanpur lake seemed to be confined only to extreme southern parts of Haripur plain. (f): groundwater is generally good for drinking as well as irrigation purposes.

3. Isotopic Study of the effect of Tarbela Reservoir on the groundwater system in the downstream areas. (Sponsored by Pakistan Council of Research in Water Resources - PCRWR)

SUMMARY: *Isotopic studies were carried out on the right side of river Indus, downstream of Tarbela Reservoir. The main objectives of the study were to determine the hydraulic connection (if any) between Tarbela Reservoir and groundwater appearing in the ponds near Gadoon-Amazai area, see the effect of Tarbela dam on the groundwater system in downstream areas, see relative contribution of different recharge sources towards aquifer system and estimate residence time of groundwater in the area. The isotopic data revealed that the ponds near Gadoon Amazai are being recharged by local rains and there is no contribution of Tarbela Reservoir so far. The project area around Gadoon Amazai, and Kalabat town is solely recharged by local rains while the area around Swabi, Zaida and Lahor has mixed recharge with major contribution from local canal system. Tritium data suggests that the residence time of groundwater in the study area varies from a few years to 30 years. The groundwater in the area has low dissolved salt contents and is, generally, of good quality.*

4. Isotopic studies at and around Tarbela Reservoir (Sponsored by WAPDA)

This study consisted of two parts:

a) Study of the effect of Tarbela Reservoir on groundwater in Gandaf-Topi area.

SUMMARY: *The objective of this project is to assess and monitor the effect of Tarbela reservoir on the groundwater system in Gandaf-Topi area. Quarterly water samplings were carried out from pre-selected sampling stations including tube wells, open wells, hand pumps, surface drains and springs for the last three years. There were 50 sampling stations. Water samples from Tarbela reservoir were also collected. Samples were analyzed for ^{2}H, ^{3}H, ^{18}O and water chemistry. Isotopic data showed that rain water is the main source of groundwater recharge in the Gandaf-Topi area. However, mixing of river/canal water and rain water is found at few places. The contribution of river water is coming from Pehur canal system and there seems no effect of Tarbela reservoir so far. Deep tube wells in the right bank colony are getting recharge from river Indus itself. The enriched isotopic values ($\delta^{18}O$) show rain recharge, depleted isotopic values show recharge from canal/river system and the intermediate isotopic values show mixing of rain and canal/river water*

b) Identification of the source of recharge of groundwater and springs in selected areas of Haripur (sponsored by WAPDA)

SUMMARY: *The objective of the research work is to investigate the origin of springs near Chamba, Bhedian and Siri villages and to investigate whether there is any contribution of Tarbela lake to groundwater recharge in the area around the above villages. Environmental Isotopes of ^{2}H, ^{3}H and ^{18}O were employed to investigate the problem. Quarterly water samplings were carried out from selected stations (springs, open wells, tube wells) in the project area during 1994-97. Each sampling consisted of 20 samples. Physico-chemical parameters (EC, pH, temp.) were measured in situ. Mass spectrometric analyses of water samples were carried out for ^{2}H and ^{18}O. Tritium and chemical analyses of selected samples were also carried out. The results of isotopic data show that there is no contribution of Tarbela lake towards the recharge of springs and groundwater in the area under investigation. The springs as well as groundwater are getting recharge from the local rain fall. The problem of waterlogging, in the limited area, near Chamba village seems to be erupted due to improper land use. Tarbela reservoir has no contribution to this problem.*

5. Monitoring of Dissolved Gases in relation to Gypsum Solutioning in the Right Abutment of Tarbela dam (Sponsored by WAPDA)

SUMMARY: *Three power channels and one irrigation channel pass through the Right Abutment of Tarbela dam. The monitoring of dissolved gases in the water seeping through drain holes in the Right Abutment of the Dam is intended to understand the process of removal of dissolved salts from the rocks of the Abutment. It may help establish the amounts, locations and temporal patterns of gypsum dissolution in terms of potential effects on the engineering structure in the right abutment. The reservoir water entering the right abutment has low dissolved solids, high dissolved oxygen (DO) and low Radon (Rn-222) concentrations. As water moves through the right abutment, it encounters gypsum and starts to accumulate more total dissolved solids with higher Rn-222 concentrations. The measurement of dissolved Oxygen and Radon-222 along with other parameters like EC and temperatures was carried out twice at high reservoir level and twice at low reservoir level. The water samples from pre-selected drain holes in six adit systems were collected and the above mentioned parameters were measured. Water samples from drain holes and Tarbela lake and rock (gypsum/pyrite) samples from Right Abutment were also collected for the measurement of ^{34}S. The data was used to compute transit time of seepage water at different locations in the adit systems and to assess the temporal variations in transit time, salt removal and commulative flow paths of seepage water. ^{34}S data revealed that the major source of sulfur in seepage water is dissolution of gypsum while at some locations the sulfur comes from pyrite. The information obtained is highly valuable for the safety of engineering structure such as major Tunnels and Gate shafts passing through the right abutment.*

6. Isotopic characterization of Tarbela Reservoir

SUMMARY: *Tarbela dam, built across river Indus, contains a big reservoir with a gross storage capacity of 14 billion cubic meter at the maximum lake elevation of 472 meters. Isotopic techniques are considered very suitable for the study of seepage from such big dams and reservoirs, and for the estimation of contributions of various recharging sources towards groundwater. However, for such a study, the isotopic characterization of the reservoir is pre-requisite to establish the seasonal/temporal variations in isotopic input of the reservoir. The isotopic analyses of reservoir water are being carried out since 1987 to establish its isotopic characters over a long duration. For this purpose, Tarbela lake is being sampled for the isotopic analyses of ^{2}H, ^{3}H and ^{18}O. The values of $\delta^{18}O$ vary from -14.24 ‰ to -9.69 ‰ with a mean value of -12.57 ‰. The δD vary from -101.67 ‰ to -60.30 ‰ with a mean value of -87.35 ‰. These variations are closely related with the volume of storage water (lake level). The lake water is isotopically most depleted in September-October when the lake level is maximum and enriched in April-May when lake level is the lowest. Tarbela lake was also sampled along its depth near the dam site. Three depth samplings were carried out. The samples were collected at the lake surface, at 50 ft., 100 ft. and 150 ft. deep from the surface using a special depth sampler. Although temporal variation of isotopes in lake water is also seen along the lake depth, the isotopic values of a single sampling lie in a narrow range. This shows that there is no significant vertical stratification in stable isotope characters of the lake. The mean tritium (1987-1997) of Tarbela Lake is 28±1 TU.*

SUB-SOIL HYDROLOGICAL STUDIES AT MANGI DAM SITE

To meet the increasing demand for water in Quetta, WAPDA investigated the possibility of constructing a storage dam east of Mangi, 100 km north-east of Quetta. The dam site lies in the Chapper Rift gorge through which Khost river flows. It has three tributaries, namely, Khum river, Kach river and Qasan Manda, with a total catchment area of over 1200 km^2 . Two springs appear in the Chapper Rift gorge, downstream from the proposed dam site. The average annual discharge of these springs is about 2000 acre feet.

Tracing of the water of Khum river which is lost one km before the gorge exit, determination of general direction of flow of sub-soil water in Mangi dam area and ascertaining the source of springs downstream the dam axis, could be valuable to a great extent for supplementing the capacity of the reservoir and improving the economics of the project. Realizing the usefulness of radioactive tracer for sub-soil hydrological investigations, studies were undertaken using Radiotracers ^{82}Br and ^{198}Au.

The water table data of different boreholes suggest that the direction of sub-soil flow is approximately from north to south. Consequently two monitoring stations were established one at each of the springs in Chaper Rift gorge down-stream from the dam site. The spring closer to the dam axis is named as spring No.1 while the spring further downstream as spring No.2. Portable battery operated NaI scintillation ratemeter was used to monitor the stream water in the Khost river and water samples from different boreholes for any activity.

In all, seven radioactive tracer injections were made in boreholes MV-10, MRS-18, MV-25, ML-8 and ML-14. In MRS-18, two injections of different activities of tracer were made. Activity from injection in MV-10 was detected in spring No.2, 6.5 hours after the injection. In ML-8, activity due to tracer injected in MRS-18 was detected. Tracers injected in boreholes MV-24 and ML-8 could not be detected anywhere. After 30 minutes of injection in MV-25, activity was detected in spring No.1. Rate of activity discharge increased rapidly showing almost direct connection between the borehole and spring No.1. Activity from the inection in ML-14 was detected only in spring N. 1. It took about 7 hours to reach the spring and 16 hours to attain its maximum value. From the hydrogeological data of the area and the tracer study it was concluded that there is a general underground water bearing strata in the area and that the direction of the sub-soil water is towards south-south west. The source of the springs downstream from the dam axis is the regional groundwater. The water of the springs can be utilized for supplementing the capacity of the reservoir provided adequate measures are taken to prevent any leakage from the dam reservoir.

USE OF ISOTOPES TO STUDY THE EFFECTIVENESS OF DELAY ACTION DAM AT PECHI, PAKISTAN

Balochistan (a province of Pakistan) is mostly arid with meager precipitation and high evaporation. Karezes have long been used for irrigation purposes. Installation of tubewells to get water for various purposes has lowered water table so much so that flow in karezes has been adversely affected. As a result, many karezes have gone completely dry while the flow of others reduced drastically. In order to combat the situation, more than one hundred storage dams called delay action dams were constructed on the alluvial fans in different areas to collect the flow of hilly streams, and allow the water to percolate and supplement the flow in the karezes. The ability of delay action dams to recharge groundwater regime is crucially controlled by the rate of silt deposition in the reservoir. As the siltation of dams progresses, the percolation of water diminishes and may stop altogether at some later stages. It is imperative to study the effectiveness of the existing delay action dams to operate them economically and to further plan such dams. On the request of PCRWR, a study was undertaken to investigate the effectiveness of Pechi Dam.

Pechi Dam is one of the delay action dams situated near Ziarat constructed to store water of rain floods and supplement the flow of four downstream karezes viz. New Pechi, Old Pechi, Chinah and Nomind in dry season. Environmental isotopes (^{2}H, ^{3}H, ^{18}O) alongwith water chemistry has been used to know the hydraulic relationship between the dam reservoir and the karezes. Water samples collected from the dam reservoir and downstream karezes on periodical basis were analyzed for isotopic and chemical contents. $\delta^{18}O$, δD and tritium values of dam reservoir and karezes have been shown in the following table.

Source	$\delta^{18}O$ (‰)			δD (‰)			Tritium (TU)	
	Min	Max	Mean	Min	Max	Mean	Min	Max
Pechi Dam	-4.0	+8.4	-4.0	-12.7	+49.2	-12.7	6	16
Old Pechi Kareze	-6.9	-5.6	-6.3	-39	-27	-34	4	14
New Pechi Kareze	-6.9	-5.6	-6.3	-41	-29	-35	7	19
Chinah Kareze	-7.3	-5.9	-6.6	-39	-30	-36	4	13
Nommind Kareze	-6.8	-5.2	-6.2	-38	-28	-34	4	13
Rain/Snow	-12.8	+1.0	-6.6	-81	+7	-31	4	20

The results show that:

- Hydraulic interconnection does seem to exist between the Pechi Dam reservoir and the karezes under the prevailing conditions,
- Karezes are mainly fed by precipitation,
- Transit time of rainwater to reach the karezes seems to be short.

PRACTICAL APPLICATIONS OF ISOTOPE HYDROLOGY IN PAKISTAN

PINSTECH has carried out a large number of hydrological studies in the following areas:

- Identification of the source of recharge
- The origin of salinity & causes of waterlogging
- Identification of pollution sources
- Dispersion of pollutant in surface water and groundwater
- Seepage from reservoir and canals
- Interrelationship between surface water and groundwater
- Interconnection between different aquifers
- Evaluation of delayed action Dams for artificial recharge
- Evaluation of Geothermal resources
- Residence time estimates
- Sedimentation studies in harbours etc.

FACILITIES AVAILABLE

- 4 mass spectrometers for ratio measurement of stable isotopes
- 3 scintillation spectrometers for dating through ^{3}H and ^{14}C
- 7 sample preparation systems for various isotopes (^{2}H, ^{13}C, ^{15}N, ^{18}O (H_2O), ^{18}O (SO_4) and ^{34}S)
- Benzene synthesis line for ^{14}C dating
- Tritium enrichment system for ^{3}H dating
- Velocity probe for groundwater flow measurement upto 300 feet
- 9 mw research reactor for isotope production
- Atomic absorption spectrophotometer
- Inductively Coupled Plasma spectrometer (ICP)
- Flame Photometer
- XRF and XFD
- HPLC, GC
- Electron Microscopes