

## Role of mathematical modelling in groundwater resources management\*

The contact course on 'Role of Mathematical Modelling in Groundwater Resources Management', was organized by National Geophysical Research Institute (NGRI), Hyderabad. This course was sponsored by the Department of Science & Technology (DST), New Delhi. Twenty-five participants from various Universities/IITs and National Research Institutes attended this course.

In his brief lecture M. C. Reddy (Central Ground Water Board, Hyderabad) mentioned the importance of the mathematical modelling in groundwater study. V. P. Dimri (NGRI) discussed the quality of life, which is proportional to the availability of water. A. Legtchenko (University of France) delivered the inaugural lecture on 'Magnetic Resonance Sounding (MRS) method for groundwater investigation in hard rock terrain'. This method is the direct method for investigation of hidden groundwater resources in any subsurface.

The session began with an introduction by S. N. Rai on the groundwater system. In his talk he referred to the origin and types of groundwater systems along with various related problems. This was followed by another lecture on formulation of groundwater flow models and methods of analytical and numerical (Finite Difference) solutions. A. K. Rastogi (IIT, Mumbai) talked about the role of mathematical modelling in groundwater system using Finite Element Method.

The second day's lecture series started with a talk on 'Inverse modelling in groundwater flow' by A. K. Rastogi, who focused on the behaviour of a groundwater system prediction of the aquifer response to any external changes such as extraction and recharge. This was followed by S. N. Rai's lecture on 'Analytical methods and numerical methods for solving the groundwater flow equations', followed by R. Rangarajan (NGRI) on 'Groundwater recharge scenario in India' covering application of artificial tracers in the estimation of natural groundwater recharge in different hydrological provinces of India. He noted that the

recharge rate ranges from 24 to 198 mm/yr or 4.1 to 19.7% of the local average seasonal rainfall; linear relationship between rainfall and natural recharge exists in granites, basalts, sediments and alluvium separately. D. Murlidharan (NGRI) gave a lecture on 'Data acquisition and processing'. For groundwater modelling enormous data are required. It is necessary first to acquire the data and after that to process using different softwares.

On the third day, the first lecture was by V. K. Saxena (NGRI) who discussed the delineation processes of fresh groundwater resources in delta regions using hydrochemical approaches, followed by V. S. Singh (NGRI) on 'Introduction to SUTRA' a groundwater modelling technique and he dealt with the problem of seawater intrusion. In a lecture on 'Introduction to MODFLOW', N. C. Mondal (NGRI) spoke on the importance of Visual MODFLOW. These recent advance techniques are required for exploration, management and utilization of groundwater resources.

The fourth day's session started with a lecture on 'An introduction to hydrogeology' by A. K. Sinha, followed by M. Shekhar (IISc, Bangalore), who discussed the utility of modelling for non-reactive solute transport. He dealt with sources and processes consisting of advection, diffusion and dispersion and the models related to groundwater pollution in detail. The next talk was by A. K. Sinha on 'An overview of groundwater modelling', followed by a lecture of M. Shekhar on 'Solute transport in fractured and heterogeneous porous medium and practical in groundwater quality modelling'. He discussed model simulations of non-reactive solute transport equations (both in 1D & 2D cases) and also solute transport behaviour in fractured rock aquifers.

On the fifth day, I. Radhakrishna (NGRI) described subsurface hydrological processes, development and management strategies for coastal aquifers. After this, V. Anand Rao (NGRI) talked on 'Application of resistivity tomography for delineation of aquifer geometry'. The dimensions of an aquifer are important for groundwater modelling. V. S. Singh (NGRI) delivered a lecture on 'Simulation of seawater intrusion using

SUTRA'. At the end of the day, N. C. Mondal (NGRI) gave a lecture on 'Application of MODFLOW in the study of solute transport' and also demonstrated its application in solving a real field problem. Next day, all participants visited the NGRI laboratories. On the seventh day, field training was arranged at Maheshwaram watershed, which is located about 30 km south of Hyderabad.

On the eighth day, B. S. Sukhija (NGRI) talked about 'Applications of environmental tracers in hydrological studies' covering basic concept of tracers and its applications in identification of source origin, recharge estimation, travel time estimation, hydraulic connectivity of different aquifers, interaction of surface-groundwater systems, groundwater dating, etc. A. Manglik (NGRI) delivered two lectures on 'Geophysical inverse theory-linear approach'. He spoke about the properties of matrices, various inversion approaches for rectangular full-rank, rank-deficient, and weak matrices, SVD, a powerful tool for matrix analysis and inversion. He also gave an example of DC resistivity inversion to illustrate various concepts. On the same day, R. K. Tiwari (NGRI) gave two lectures on 'Non-linear time series analysis and predictability of geohydrological phenomena'. He covered the definition, principles and components of Artificial Neural Networks (ANN) and dealt with a comparative study of human brain and the computer and finally a case study of the ANN model application in the interpretation of DC resistivity data in Puga Valley.

The ninth day's session started with a lecture on 'Mathematical modelling to evolve predevelopment management schemes in Boro river valley of Okavango Delta, Botswana' by M. Thangarajan (NGRI), followed by V. S. Singh (NGRI) on 'Pumping test methods for the estimation of aquifer parameters'. He discussed the basic concepts of pumping test and the processing of pumping test data for estimation of aquifer parameters. On the same day practical training for interpretation in pumping test was given. Afterwards, S. Ahmed (NGRI) talked on 'Application of geostatistics in parameter estimation to predictive aquifer modelling'.

\*Based on a Contact Course on Role of Mathematical Modelling in Groundwater Resources Management at Hyderabad from 13 to 23 December 2004.

The tenth day's session started with lecture by V. P. Dimri who talked on 'Non-linear inversion of resistivity data using Occam's approach'. He mentioned that the resistivity problem is nonlinear in nature and the general practice to linearize this nonlinear problem by neglecting second order derivative terms in the Taylor series of objective function, results in loss of very useful information. The truncation of Taylor series affects the stability of inversion and hence it is recommended to solve a nonlinear problem in a nonlinear

manner by using the modified Occam's inversion algorithm. Following this talk, Ramesh Chand (NGRI) talked on 'Recharge estimation using Neutron probe', dealing with direct detection of soil moisture in an unsaturated zone as well as water content in a saturated zone.

The last day's session started with 'Scenario of groundwater pollution in India' by S. N. Rai (NGRI) who discussed the status of groundwater pollution owing to industrial and municipal waste, fertilizers and pesticides, natural sources resulting

from water-rock interaction, and seawater intrusions, etc. The last lecture of this contact course was a case study on 'Prediction of groundwater contaminant migration in Patancheru watershed: a post audit' by V. V. S. G. Rao (NGRI) who talked about the assessment of groundwater resources.

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## Emerging trends in tuberculosis research\*

The Symposium on 'Emerging Trends in Tuberculosis Research' was co-funded by the International Centre for Genetic Engineering and Biotechnology (ICGEB) New Delhi and the Global Alliance for TB Drug Development. The meeting was attended by over 200 international and national participants representing 18 countries and unfolded with an inaugural lecture by Douglas Young (Imperial College School of Medicine, London). He explained the mysteries of *Mycobacterium* infection from the genome perspective.

Following this, Clifton Barry (National Institute of Allergy and Infectious Diseases, Rockville) spoke on understanding the metabolism of mycobacteria. His work highlighted the importance of distinguishing the pathology between disease models in humans and various animal models. His work focused on the patho-physiological conditions that are generated in patients suffering from multi-drug resistant tuberculosis. Work from his lab showed clear differences in the nature of granuloma with highly ordered and tightly organized structures with distinct microenvironments in human samples where bacterial growth is restricted. The saga was carried over by Rajesh Gokhale (National Institute of Immunology, New Delhi), giving an insight into the mechanism and assembly of cell wall lipids of *M. tuberculosis* as well as the complexity of a large repertoire of metabolically diverse proteins

coming from a small number of genes of the pathogen.

Valerie Mizrahi (Molecular Microbiology Research Unit, Johannesburg) presented elegant studies demarcating mutations that result in genomic variation. These mutations, she emphasized, are of two types. One is environmental in nature and is so transient that eventually it disappears from the population. The other one gets fixed in the population and is thus heritable. Ultraviolet exposure of various strains resulted in mutations related to drug resistance. This was mapped to the novel damage-inducible C family of DNA polymerases that also induce mutations in other bacteria. She later talked about a reporter system developed by her laboratory to identify such mutations. This system has a potential for effectively screening populations harbouring MDR strains.

Anand Ranganathan (ICGEB) talked about a novel technique of Dicondon shuffling suggesting its applications in various fields of pathogen study, specifically in designing and hunting for novel inhibitor proteins against *M. tuberculosis*. On similar lines, Thomas Dick (NITD, Singapore) gave a lecture on the recent progress in his laboratory in the development of inhibitors against an *Mtb* enzyme called peptide deformylase that has already been shown to be crucial for the growth of the pathogen.

The session on host-pathogen interactions was opened by David Russell who focused on new developments regulating phago-lysosome fusions in *Mtb*-infected macrophages. By employing transposon tagged mutants of *Mtb*, he demonstrated

that wild type and mutant mycobacteria segregated phagosomes with altered pH. While wild type bacteria were found in phagosomes with a more acidic pH, mutant bacteria were present in phagosomes with a pH between 5.0 and 5.6. This difference was later mapped to bacterial lipids and other effector molecules thereby identifying bacterial genes directly involved in acidification of phagosomes.

The use of *M. tuberculosis* knockouts in delineating the roles of various genes and operons in *Mtb* was the subject of talk by Anil K. Tyagi (University of Delhi, South Campus). The results of knockout studies in his laboratory indicate that the genes of *mymA* operon that have previously been suggested to have a function in modification of cell wall-associated fatty acids. Also, genes encoding tyrosine phosphatase (*mptp A* and *B*) play important roles in survival of *Mtb* in the host. Jaya Tyagi (AIIMS, New Delhi) emphasized the regulatory roles played by two component signal transduction systems at the level of protein phosphorylation of eleven putative genes thereby affecting the host-pathogen interactions in lung and leprosy bacilli.

Frank Verreck (Biomedical Primate Research Centre, Netherlands) dealt with the roles played by IL-23 and IL-27 and their subsequent regulation of 'macrophage 1' and 'macrophage 2' populations. While macrophage 1 induces Th1 responses, macrophage 2 subvert Th2 responses. Yossef AvGay presented data on signal transduction pathways in mycobacteria. By combining genetics and biochemical approaches, he demonstrated changes in-

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\*Based on the International Symposium on Emerging Trends in Tuberculosis Research held in New Delhi from 15 to 17 November 2004.