a non-toxigen with all toxin genes deleted. A cryptic haemolysin gene locus was introduced in the chromosome of this strain and through a series of genetic manipulations, *ctxB* gene was integrated. This strain provided full protection against the challenging dose of *V. cholerae* in animal model, and the vaccine is now undergoing human trial[5].

A few years ago, scientists from the University of Maryland have found out that *Vibrio cholerae* has unusual high intake of salt, i.e. it absorbs most of the human body salt, thus its ancestral home must be in the ocean. Bhadra and his group from IICB have studied gene products of *Vibrio cholerae* needed for survival under cold shock and nutritional stress. Rukshana Chaudhuri has studied the effects of bile on the cell surface permeability barrier and efflux system of *Vibrio cholerae* strains.

Intestinal infection with vibrio species results in the loss of large volumes of water, leading to severe and rapidly progressing dehydration and shock. 'Without adequate and appropriate rehydration therapy, severe cholera kills about half of affected individuals', says G. B. Nair of ICDDR, Bangladesh. The introduction of oral rehydration therapy (ORT) has been very cost effective and has also simplified the treatment. In most cases patients can be treated initially with ORS.

'Preliminary studies show that Bangladeshi households who first filter their pond water through sari cloth, before drinking water, reduce the risk of cholera infections by approximately 50%', says Rita Colwell. However control of the deadly cholera still rests on education and improvized sanitary conditions besides consumption of hygienic food and water.

In a nutshell, the various strategies that can be followed are: Isolation and treatment of patients; Management of contact of cholera patients; Anti-cholera immunization; Environmental sanitation.

1. Ramamurthy, T., *et al.*, *FEMS Microbiol. Lett.*, 2004, **232**, 23–26.
2. Nandi, S. *et al.*, *Microbiology*, 2003, **149**, 89–97.
3. Mekalanos, J. J. *et al.*, *Infect. Immun.*, 1999, **67**, 5723–5729.
4. Sengupta Nilanjan *et al.*, *Infect. Immun.*, 2003, **71**, 5583–5589.
5. http://icmr.nic.in/niced.htm

ACKNOWLEDGEMENT. I thank Dr Triveni Krishnan, NICED, Kolkata for help.

Minakshi De (*S. Ramaseshan Fellow*) lives at 35, Garpar Road, Kolkata 700 009, India. e-mail: amitkde@satyam.net.in

Aswathanarayana receives AGU award

Uppugunuri Aswathanarayana of the Mahadevan International Center for Water Resources Management, Hyderabad has received the 'Excellence in Geophysical Education Award' (2005) from the American Geophysical Union at a special award ceremony on 25 May 2005 at New Orleans, USA. 'The Award recognizes Aswathanarayana's meritorious services in the cause of geoscience education in different parts of the world. He is the first Indian and the first from the developing countries to get this award.' Aswathanarayana was a Director of Center of Advanced Study at University of Saugar, Sagar, Madhya Pradesh (1967–80). He subsequently served as Professor and Director of State Mining Corporation, Dar es Salaam, Tanzania (1980–90) where he initiated modern laboratories. He is author of several books linking geoscience instruction with natural resource management and job generation.

MEETING REPORT

Towards a tsunami warning system in the Indian Ocean*

The great earthquake of 26 December 2004 of magnitude 9.0 that originated 200 km off the west coast of Sumatra, was perhaps nature's wake-up call. A wake-up call to tell us that nature will continue its own acts, and we need to prepare ourselves to face the inevitable. This time it occurred in the form of a tsunami, quite an unusual occurrence in the Indian coast. Not that it has never occurred in the past. History tells us of three older episodes – 1881, 1941 and 1945 – none so devastating as the 2004 tsunami. The first two originated from earthquakes in the Andaman and Nicobar region, and the third from an earthquake in the Makran coast. The 2004 tsunami was a reiteration of the enormity of damage that could be caused by a tsunami generated more than 2000 km away from the Indian coast. Even countries far away, such as Maldives and Somalia were not spared. The lesson that came through was that we cannot afford to ignore some of these seismic sources located far beyond our political boundaries. How should we gear up to handle such events in future? What are the shortcomings in our existing set-up? How could we improve them? And what should be our approach towards setting up a tsunami warning system in the Indian Ocean?

A brainstorming session provided an excellent forum to deliberate on some of these issues. This event, attended by nearly 200 delegates brought together an array of specialists – seismologists, geo-

*A report on the brainstorming session on tsunamis organized jointly by the Departments of Science and Technology, Ocean Development and Space, together with CSIR and INSA on 21st and 22nd January at INSA, New Delhi.

logists, ocean scientists, physicists, engineers and tsunami experts. Experts from USA, Canada, Germany, Japan, Russia and representatives of the UN as well as diplomats from some of the neighbouring countries attended this meeting.

Deliberations took place in two technical sessions over the two days and a panel discussion that reviewed the main ideas that emerged. An overview by V. K. Gaur (IIA) on the tectonic setting of the region was followed by a review of the events associated with the great earthquake by Dattatrayam (IMD) and a discussion on the sea-level changes and tsunami propagation along the Indian coast. Satish Shetye (NIO) provided necessary background for the discussions. Experience of those associated with the Pacific Tsunami Warning System was an exposure to the critical issues and limitations including false alarms. Tad Murty (Tsunami Society, Honolulu), Rainer Kind (Seismologist, Potsdam), and Costas Synolakis (University of Southern California) shared their experiences with the tsunami warning system in the Pacific. It was evident from the discussions that unless ocean buoys and tide gauges are deployed closer to the source, there would be little time lag between sensing a tsunami wave and issuing a warning. Another issue that was discussed was the need to make real-time earthquake data available, some of which would require data-sharing with nearby countries. An action plan presented by H. K. Gupta (Department of Ocean Development) had considered most of these issues. Various components of the tsunami warning system, such as expansion of connectivity of seismic network, deployment of ocean bottom pressure sensors (DART type systems), numerical modelling of tsunami generation, propagation and inundation were part of the action plan. The basic plan involved deployment of eight DART systems and also linking up some of the seismic observatories to obtain near-real-time data on source parameters. The locations of these DART systems and additional seismic observatories need to be discussed further. DST, committed to monitoring earthquakes in the country, proposed further strengthening of its network and upgradation of the communication network for near-real-time data transfer and strengthening of computing facilities.

The panel discussion, attended by the Hon'ble Minister for Science and Technology, Kapil Sibal, focused on the future course of action. As the various elements of a proper tsunami warning system evolved, the need to improve our manpower in specialized areas of earth sciences became evident. This was recognized as an important prerequisite for success of challenging projects such as setting up a tsunami warning centre.

Highlights of ideas and suggestions that evolved from the brainstorming session resulted in identifying the following actions to be undertaken:

- To strengthen seismological monitoring and upgradation of communication network for near-real-time computation of earthquake source parameters.
- To deploy pressure-monitoring devices (DART-type) at strategic locations in the Indian Ocean.
- To expand the tide gauge network.
- To improve the ocean floor maps, especially near-shore bathymetric maps.
- To prepare tsunami inundation maps for different hazard scenarios.
- To identify older tsunami deposits and work out past history of earthquakes.
- To improve modelling capabilities; develop models of tsunami propagation for various boundary conditions.
- To use advances in space technology to monitor changes in the ocean as well as other possible precursory changes prior to earthquakes/tsunamis.
- To set up a disaster management authority that will coordinate the efforts and maintain line of command in issuing alerts/warnings.
- To set up a 24 h tsunami-warning centre that will have real-time-data processing and computational facilities. The same warning centre can work for other types of disasters, such as cyclones, surges, etc.
- To strengthen earth science education in the country and create more opportunities in earth sciences.
- To strengthen public education and awareness.

As discussions progressed, it became apparent that the Indian Ocean tsunami warning system might need to address issues specific to this region. It is known that the tsunami waves travel at about 800 km/h (much slower than seismic waves) for a water depth of 5000 m. It is this velocity difference that makes it possible to issue a warning after the detection of the seismic wave, but before the arrival of the tsunami. The Pacific warning system located in Hawaii is responsible for issuing warnings for Pacific Ocean tsunamis. It takes several hours for the tsunami to travel across the Pacific Ocean, and in most cases, there is enough lead-time to issue a warning or alert. In the case of regional and local systems, where the source in question is not too far from the regions under threat, a tsunami warning must be issued immediately after the occurrence of an earthquake. For example, the tsunami warning centres operated by Japan Meteorological Agency (JMA) work on such constraints. JMA operates a nation-wide observation system, which includes six regional tsunami-warning centers, where seismologists are on 24 h-duty. Reportedly, JMA issues information on earthquakes within 2 min of their occurrence, followed by a tsunami warning within 1 min. This information is sent out through various media, including televised broadcasting.

The Indian Ocean situation would call for a regional warning system that would not get much lead time, at least for some of its coastal regions under threat, such as the Andaman and Nicobar Islands. The peculiar socio-economic conditions prevailing in the coastal regions of India, especially its high density of rural and poor population is another important issue. There could be situations where an alert needs to be issued, to just keep people away from the immediate regions of the coast. Only at a higher level of risk, should there be a warning for evacuation. Obviously, these decisions have to be based on considerations of the data flowing in from various centres. Obviously, the effectiveness of this system depends on the speed with which information can be communicated to the regions likely to be affected. With our advances in space technology, quick dissemination of information and transmission through audio-visual media, this should be feasible. Admittedly, this is a challenge, but it is not a matter of choice any more. Learning from our own experiences, as well as from similar situations elsewhere in the world, is the only way to develop and meet this challenging task.

G. D. Gupta, Department of Science and Technology, Government of India, New Delhi 110 016, India.
e-mail: guptagd@nic.in