investment Chemical sciences-related projects receive only about 10% of the total extramural R&D support given by the various funding agencies. In money terms it means about $3-4 million per annum, which is roughly equivalent to the annual budget of a medium-sized chemistry department in a university in the US. There have been other pointers as well of our improved performance and capability during the eighties like more plenary and invited speakers in major international meetings and increase in citations from India.

A plea for funding

While the attainments of the eighties are satisfying, they are by no means enough or what they ought to be. However, one thing does appear to be clear and that is we do have researchers of calibre, competence and dedication in chemical sciences and that improved funding and infrastructure does lead to better outcome in basic research. Therefore, to cope with the emerging challenges in chemical sciences in the nineties the need for enhanced level of funding through new intiatives was imperative. New, state-of-the-art equipment needed to be made available. In addition, most of our universities with antiquated laboratories and obsolete equipment needed to be refurbished. But, in reality we have been witnessing not only stagnation but shrinking in budgetary support for basic research and education in the past couple of years. As a result, the already impoverished university system has been hit hard. In fact, university budgets now seem to be made only for disbursement of salaries and there is very little or negligible support available for maintaining infrastructure and academic needs like research, maintenance of laboratories and libraries. With unprecedented increases in the cost of chemicals, equipment and library journals, due to devaluation of the Rupee among other factors, the situation has so deteriorated that even the survival of research and teaching programmes at an acceptable level is at stake. We can now find chemistry departments with no journals, no chemicals and, in some cases, not even assured of running water supply! Universities are being mentioned here specifically because that is where most of our chemists work and Ph D students are trained. Chemists, in particular, for whom bench-level logistic support is absolutely essential, are in deep trouble. There is an air of resignation and demoralization among the research community, in general, and the universities in particular. Something needs to be done on an urgent footing to rectify the situation and prevent further damage to our research capabilities. The university system, learning and research are too precious to be left to the mercy of market forces. No matter what the economic compulsions of the day may be, the intellectual wealth and the creativity of our scientists has to be nurtured and protected through pragmatic investments. It is bound to repay in the long run. Therefore, there is no alternative to massive funding, with appropriate structural changes, to sustain our research capabilities. It is to be hoped that the political leadership and those charged with promoting and protecting our scientific base will recognize the seriousness of the situation.

Summary

In summary, chemical sciences research is in the midst of major changes globally and new interdisciplinary frontiers are emerging. In our country, chemical sciences research made steady progress in the eighties due to improved funding and healthy support for science. However, the nineties have started on a depressing note and unless major funding is made available we may not be able to measure up to the challenges that lie ahead in this important branch of science. Chemical sciences research in the university system needs special attention, without which it may not survive for long.

Earth sciences in India: the concerns ahead

Vinod K. Gaur

The past decade witnessed a qualitative shift in Indian endeavours in earth sciences—a shift from description to dynamics, that is enquiry into the nature and progression of critical earth processes in space-time, which whilst continually refashioning the earth, helpfully leave behind distinctive signatures in the fine structure of natural systems such as variations in their isotopic compositions and fabric. More importantly, the shift was in the approach to these studies led by the new conceptual advances which would need to be sharpened by incisive analytical tools. True, that this new culture was only cultivated by a few, but even as the majority continued to regard data

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collection as a valid scientific activity in itself and rational frameworks for experiment design of complex systems were still in being, the basic issues questioning the discriminating power of a proposed scientific approach, increasingly raised at project evaluation meetings, were quietly disturbing the *status quo*.

This fledgling revolution already over a decade late in happening in this country, predictably followed developments that had taken place globally, in the wake of the new overarching paradigm of plate tectonics, sophisticated instrumentation, space probes and computational physics, which a few individual scientists had struggled to foster by applying the new software and hardware tools, borrowed from western colleagues, to problems of Indian geology and environment. So, when in the opening years of eighties, the Department of Science and Technology announced its plans to selectively fund a few high-quality research projects in solid earth and atmospheric sciences under its new Thrust Area Programmes, these scattered groups were quick to seize the opportunity to articulate a bold scientific agenda aimed at modelling earth system processes following modern approaches of hypothesis formulation, experiment design and analysis. About half a dozen inter-institutional programmes in solid earth sciences were thus hammered out at two workshops held at Presidency College, Calcutta, in 1982. These programmes sought as scientific understanding of how the continental lithosphere and, in particular, the Indian lithosphere evolved, by exploiting the extraordinary opportunity provided by the wide variety and chronology of geological materials and structures that constitute the Indian land mass. By drawing attention to potential clues which could be unlocked by studying the fine scale physicochemical structure of these sample relics belonging to various energetic phases of the earth's progressive evolution, a well-argued case was thus, for the first time, made for developing a modern infrastructure for earth science studies.

Modest infrastructure

As a result of these recommendations, a few state-of-the-art experimental and analytical facilities notably high pressure equipment, electron probe microanalysers and inductively coupled plasma spectrometers were set up in some university departments as well as some sophisticated geophysical equipment acquired and placed centrally for seismic, geomagnetic and magnetotelluric probing of the earth to study its deep structure. Indeed, this initiative induced a much larger fall out beyond what could be directly realized under the Thrust Area Programmes of DST. For, within a year or so when the premier CSIR institute for earth sciences, the National Geophysical Research Institute began restructuring its research programmes and the UGC embarked on a new programme to strengthen the scientific infrastructure in universities, the motivations of earth scientists were already keenly poised to utilize these opportunities purposefully. Similar initiatives aimed at creating a deeper understanding of the variability of the tropical atmosphere and particularly of the monsoons which have an important bearing on our national life and economy, led to the establishment of two centres for atmospheric sciences, one at IIT Delhi and the other at the Indian Institute of Science, Bangalore.

These developments considerably augmented the sensing, analytical and computing facilities available for studies of the various components of the earth system on modern lines, while the new analytical-experimental culture in earth system sciences was carefully nourished through selective funding of research projects. A strong base thus came to be created in the country for developing a high level of scientific capability that would, if sustained, have the potential of advancing knowledge and stimulating originality—the two intrinsic cultural resources which need to be kept alive and vibrant to ensure that we are able to evolve creative solutions to the increasingly complex problems of managing our natural resources and environment through a period of rapid and as yet unpredictable changes.

Some notable achievements

The modest investments made in developing this basic infrastructure have already borne some noteworthy results including discoveries of new features in the deep structure of the south Indian land mass, in our coastal circulation and in monsoon variability and ocean–atmosphere coupling in the world's warmest ocean. Pioneering contributions have also been made to our understanding of high pressure mineral phases of the early evolution of the solar system based on studies of meteorites and lunar samples and of the Indian crust around the nuclear Dharwar shield, as well as of marine geochemical processes of sedimentation and particulate and nutrient transport which, by inducing gas exchange between atmosphere and oceans, play an important role in determining climate. In this process have also grown some highly creative groups of scientists with interdisciplinary interests and skills and analytical culture, potentially capable of addressing the new emerging concerns of protecting the wholesomeness of large interacting systems specific to our cultural and geophysical environment, and designing effective strategies for managing their hazards and bounties.

This expectation too has, in some cases, been realized; in the formulation of a few bold and imaginative research programmes of far-reaching significance and implications to future developments and interdisciplinary research, notably the Monsoon Trough

Boundary Layer Experiment (MONTBLEX), Very Long Base Interferometry Experiment (VLBI) and the Bay of Bengal Crust (BOBCRUST). Of these, the first one aimed at modelling the monsoon trough boundary layer which plays a crucial role in monsoon dynamics, was conceptulized and designed by scientists of the Indian Institute of Science. This ambitious programme was supported by a large interdisciplinary group from IMD, IITM, NIO, IAF, NPL and NPOL, Cochin and implemented jointly with four other institutions, IIT Kharagpur, Banaras Hindu University, IIT Delhi and CAZRI at Jodhpur roughly lying along the axis of the monsoon trough. It is an outstanding example of authentic scientific endeavour executed with rigour and technological finesse comparable to any in the world. The last two programmes, and no doubt some others, are however still languishing in files for want of adequate support and I suspect, adequate appreciation of their manifest scientific value in advancing knowledge that would be socially useful and vast cascading potential in spurring interdisciplinary research on a wide front.

The long way ahead

But these developments are at best a good starting point for the long road ahead. In order to turn their potential into the cutting edge of a rationally designed and managed society, effective mechanisms need to be devised so that new conceptual and technological advances are quickly internalized in the vision and work of the large government-run scientific establishments responsible for the development of natural resources and environment. These organizations represent a valuable human resource unmatched in their operational capacity for testing and large-scale application of promising scientific approaches which, through feedback, have the potential of spurring further conceptual advances. This unfortunately is still in being. For, the extant system is not geared to harnessing their intellectual resources. For example, even in the nineties we found ourselves unprepared to take advantage of two great but rare natural events that occurred on Indian territory: the Uttarkashi earthquake and Barren Island volcanic eruption, thus forfeiting a great opportunity to learn more about the attendant earth system and processes which are of great concern to us. It is therefore all the more necessary that academic groups in the country capable of refining existing conceptual frameworks and contributing to new developments are indulgently supported till a more viable self-sustaining base of active science geared to our national life and work comes into being.

Vulnerabilities

The foregoing is not an account of all major earth science activities in the country nor of all the notable achievements made. Rather, it is a brief account of how a modest scientific infrastructure for studying the earth system came to be established in the eighties, which led to some truly creative endeavours. I consider these significant, as the high level of scientific capabilities developed in the process have the potential to answer some of the urgent questions of today as well as of propagating a culture of excellence that would keep this resource alive and vibrant to serve future generations.

At the same time, the relative smallness of these analytical interdisciplinary groups, with the large majority still to be animated, poses a real threat as to whether and how long will their impact endure. The alround drying of funds in academic and research institutions has all but cut off the infusion of young, energetic minds into the system as also of contemporary scientific literature on account of its rising costs. In some departments known to me, even expensive analytical equipment already received, remains unpacked for want of requisite funds to create environmental and technical support facilities for their operation.

Meanwhile, those few who painstakingly fostered and assiduously advanced the futuristic approach, continue to age whilst a briefly erected edifice of great potential faces attrition by uncertain attitudes that appear too intent on looking at the price of an enterprise to appreciate its value.