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EARTH SCIENCE IN HYDROLOGY EDUCATION - AN APPRAISAL

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ABSTRACT

There has been a growing awareness that hydrology as a geophysical science is making slow progress and lacks solid foundations. A major factor in this unsatisfactory situation is the fact that the majority of hydrologists are not trained as scientists but as technologists. An IAHS/UNESCO panel on hydrological education has recently reported that the UNESCO sponsored Hydrology Course in several developing countries have emerged to be merely topping up programmes in general hydrology for graduates trained in other disciplines. It is felt that the solutions to such problems can be tried by increasing geoscientific content into the currently run Postgraduate Hydrology programmes. It is believed that introduction of separate Postgraduate and Masters Courses in specialised areas of hydrology like Groundwater Hydrology, Surface Hydrology, Watershed Management and Environmental Hydrology, would go a long way in alleviating the above malaise. A proposal has been formulated in the present paper, for introduction of a separate P.G./Master's Course in Groundwater Hydrology and Management in significant Universities of India and abroad depending on local needs and employment potential. Such a course as open to young scientists as well as inservice personnel is also likely to promote further research and development in Groundwater Hydrology.

INTRODUCTION

Hydrology involves the totality of physical processes involved in the hydrological cycle and related phenomenon. The central role of water in the evaluation and operation of Earth Science System provides the rationale for seeing hydrology as a geoscience, of status similar to that of the atmospheric, oceanic and solid earth sciences (NRC, 1990). It is supported by the basic sciences of mathematics, Physics, Chemistry and Biology. A formal recognition to hydrology as a branch of geophysics was first accorded in 1992, when the International Branch of Scientific Hydrology was created within the International Union of Geology and Geophysics (IUGG) which was founded in 1919 to promote and coordinate physical, chemical and mathematical studies of the earth and its immediate spatial environment.

A further important step towards the arfirmation of hydrology as a geoscience occurred in 1930 when the American Geophysical Union (AGU) designated hydrology as one of its sections.

These developments provided a strong impetus for the study of hydrology as a unifield field of natural science and not merely as a tool in the solution of various adhoc engineering, agricultural and other water related problems (Nash et al., 1990). Today, there is a widespread unease among hydrologists that in the past forty years the practice of hydrology as a technology for the solution of the problems arising in water resources development has not progressed adequately. Hydrology as a science has failed to develop as coherent discipline, and the technology failed to meet the challenges of the emerging situation. Nash et al. (Op. Cit.) have called for

thorough review of the science and technology of hydrology and a reassessment of the manner of education of hydrological scientists and technologists. Further, the challenges to hydrology can be met only through a conscious and concerted effort to consolidate and develop hydrology intensively as a coherent geoscience and as a technology resting on a sound scientific basis.

One of the main objectives of the International Hydrological Decade (IHD) launched by UNESCO was to raise the level of hydrological research and education in the world, in general, and developing countries in particular. UNESCO as a part of its IHD and International Hydrological Programme (IHP) is supporting 24 International Courses in Hydrology in various countries like Yugoslavia, United Kingdom, Hungary, Argentina, Egypt, Central America, Tanzania, Netherlands, USA, Austria, Volta, Italy, Czechoslovakia and India (UNESCO, 1983). However, majority of participants in these courses are professional inservice engineers from various government organisations of the developing countries. These inservice personnel return to their parent organisations on completion of their courses, and as such, the possibility of dissemination of the advanced knowledge gained by these professionals to younger scientific community in their respective countries remains remote. Further, only a few, if any, of these professionals stay back to these centres of hydrological education for pursuing research leading to higher degree like Ph.D.

The UNESCO IHP committee on Education and Training met in Paris during March, 1984 and felt that proper selection of candiates with an adequate background and knowledge in the basics is essential for participation in the UNESCO sponsored International Hydrology Courses (UNESCO, 1984). Narayanaswamy (1989) took this as a clue for the need for introducing integrated hydrology courses in various Universities in developing countries to produce hydrologists with basic scientific bias.

Sharma and Sharma (1989) dealt with the need and status of education and training in groundwater hydrology and identified various areas of groundwater hydrology requiring R&D efforts. Seth (1992) made a comprehensive review of hydrological developments in India since independence and has outlined the broad policies and programmes in hydrological education as reflected in the long term science and technology programme for research in water resources development. This included the need to identify highly specialized areas for postgraduate programmes to meet the requirements of national economy, and to examine the desirability of orientation of doctoral work in engineering towards design and technology research. Seth (Op. Cit.) also concurred with the report of the Nash panel on Hydrological Education. The National Water Policy development released by Ministry of Water Resources, Govt. of India in September, 1987 lays due emphasis on training and recommends that a perspective plan for standardising training should be an integral part of water resources development and the training should extend to all categories of personnel involved in these activities as also the farmers.

Silar (1981) opened that due to general scarcity of surface water resources in arid countries the water management and economy of such countries depends to a considerable degree on ground water resources. Thus, groundwater hydrology and hydrogeology should become a substantial part of the postgraduate hydrological courses and we should prepare the participants for the specific water management problems of arid regions in emphasizing the methods of groundwater research, prospecting, development and conservation, besides other hydrological topics.

In many of the UNESCO sponsored P.G. Hydrology courses, majority of the participants coming from arid and semiarid countries were civil engineers and specialists in water management and agriculture. Only a major fraction (within 10%) of the participants have had some direct background in hydrogeology, or basic knowledge of geology (Silar, Op Cit.). Dyck (1981) has highlighted the need to start programmes of Continuing Education through separate postgraduate courses of 2 years duration in Ground Water as already in vogue in University of Dresden in the German Democratic Republic.

The present paper aims to discuss the role of Earth Science in hydrological education, with the objective of consolidating and developing hydrological education so that hydrologists with a necessary mix of basic background and expertise are made available, matching with the in-

creasing demands of the society. The spectrum of Earth Sciences, implied in the paper encompasses mainly the disciplines of Geology and Geophysics.

PRESENT STATUS OF EARTH SCIENCES IN HYDROLOGICAL EDUCATION:

Earth science as a profession is often granted the recognition of a distinct undergraduate and graduate programme. Besides, as a subject matter, it often occurs in the curricula of studies of many postgraduate courses in applied science and engineering, eg. meteorology, hydrology, geography, civil and mathematical engineering and forestry. However, in these courses it is treated as a subject of peripheral interest or as a component topic, as in Civil Engineering and Hydrology.

Walton (1964), while describing education facilities in hydrological education in USA and Canadian Universities, mentioned that in the year 1964, there were 64 departments which offered courses in hydrology in USA with majority of them (46) being in Earth Sciences Departments and 15 in engineering departments. Further, graduate degrees (M.S. or Ph.D.) with a major in groundwater geology or hydrology were granted at 8 engineering and 16 geology departments in 1964. The U.S. Geological Survey has also made notable contributions in hydrology by organising several training programmes for scientists/engineers from developing countries. The titles of the courses most commonly offered were groundwater geology, geology of groundwater, hydrogeology, groundwater hydrology, groundwater flow and seepage, geology of water resources and flow in porous media.

At the Postgraduate level, the UNESCO sponsored Hydrology course at Roorkee have included only a few courses of Earth Science, viz. Hydrogeology (1/2 unit) and Geophysical Investigations (1/2 unit) as part of the Ground Water stream of P.G. Hydrology, and Geohydrology (1 unit) as a part of Surface Water Hydrology programme. Further, the Master's programme by Course Work option includes half unit courses, each on geological topics of Geomorphology, Hydrogeology of hard rocks, and Subsurface Investigation. The coverage of courses related to Earth sciences in similar other hydrology programmes in Anna University and in other countries is only marginally different (Chandra, 1981). In India, Mysore University and Aligarh Muslim University have started exclusive Postgraduate Diploma programmes in Hydrogeology for engineers and geoscientists during last few years, whereas Andhra University, Waltair has started a 2 year M.Sc. course in Hydrology in its Geophysics Department at the College of Science and Technology. The erstwhile High Level Committee on Hydrology (HILTECH) accepted the syllabus and regulations of this M.Sc. Hydrology Course in 1984 (Narayana Swamy, 1989). This hydrology course has incorporated a greater stress on the role of earth sciences in hydrological education, in as much as five out of eight theory papers are related to the disciplines of geology, geophysics and groundwater. Lately, many of the Master's programme in Earth Sciences (viz., Applied Geology and Applied Geophysics etc.) in India have incorporated separate course-papers on Hydrology, Hydrogeology and/or Groundwater Hydrology.

However, groundwater hydrology (and hydrogeology) taught in a fragmented manner is necessarily restricted in depth and scope by the needs or interests of the parent disciplines within which it is taught. Graduates of such courses could certainly not be considered appropriately trained as geohydrologists. Another urgent education problem which has reached crisis proportions in many universities is the lack of field and laboratory experience usually available to earth scientists. Its consequences in hydrology are both profound and disturbing especially with the current emphasis on conceptual modelling. In the absence of appropriate testing, available models especially as software packages take on an impression of reality in the minds of their users, and tend to become a source of unsound science and practice. On the other hand, due to considerable variation in field conditions, it is also not practicable for specialists to come out with multiple softwares incorporating site-specific requirements.

NEED FOR HYDROLOGICAL EDUCATION FOR ADVANCEMENT OF THE SCIENCE:

The present typical postgraduate courses in hydrology, as those sponsored by UNESCO in various countries, do not provide an adequate preparation for the future role of the scientific or applied hydrologist, nor can such a preparation

be provided by a mere extension in the duration or subject matter of the present courses. Though there is a need for exclusive undergraduate courses designed to raise hydrological consciousness in preparation for graduate level study in the geosciences with emphasis on hydrological science the suggestion for a full undergraduate course in engineering hydrology as suggested by Chandra and Mosterman (1983) seems to be unrealistic (Nash et al., 1990). Chandra and Mosterman (Op.Cit.) stated that for the immediate future, however, and in many countries for the foreseeable future, the normal method of training professional (engineering) hydrologists will continue to be by way of postgraduate courses designed to "top up" existing training programmes usually in an appropriate branch of engineering, or to convert a science graduate. Though, the IAHS/UNESCO Panel on hydrological education headed by J.E. Nash agreed with the above observation, but believed it important to stress the directions in which the training of applied hydrology should evolve. These directions comprise of, amongst others, making provision of an increased content of basic sciences and of a greater variety of hydrological sub fields. Further, the panel opened that efforts should be made to ensure that the developments in hydrological science achieved in geoscience departments are made readily available to the applied hydrologists, typically in engineering departments. In the light of the above, the panel also made an important recommendation that undergraduate education, such as now occurs typically in University departments of Earth Sciences, should give explicit attention to hydrology as an integral component of geoscience with sufficient depth and coverage to motivate students to pursue hydrology as a career. Narayanaswamy (1989) recommended that to enable solution of various surface and sub-surface hydrological problems, an integrated 3 years M.Sc. Tech. Course in Hydrology and Water Resources be initiated in the national interest in a few Universitieis of India for B.Sc. (graduates) of Indian Universities. The syllabus of this proposed M.Sc. (Tech.) Course has a bias of of integrated disciplines of hydrology, including 4 full papers related to earth sciences. (viz. geology and hydrogeomorphology, geophysical exploration for ground water , hydrogeochemistry and nuclear hydrology,and geohydrology, and remote sensing and its application in hydrology). It is evident from this discussion that there is a genuine need to incorporate greater inputs of earth science in the present hydrological education in various Universities. The author is of the view that one viable approach for ensuring such increase in geoscientific inputs can be through introduction of a Post Graduate/Mater's programme in Ground Water Hydrology and Management of the groundwater resources broadly as already existing in University of Dresden (Dyck, 1981). Introduction of such a programmes will also take care of the hydrological problems encountered in arid and tropical countries (Silar, 1981).

The above discussion brings out a broad consensus about a clear necessity for development and introduction of an integrated Master's programme in hydrological sciences, with an increased content of geoscience. Evidently, an exclusive Postgraduate/Master's programme in Groundwater Hydrology & Management with greater input of earth sciences than what's presently available in a P.G./Master's programme in hydrology should fill this gap. This postgraduate course is proposed to be of 12 months duration, whereas the Master's programme can be of 16 months duration on the lines of existing UNESCO sponsored P.G. and M.E. (Hydrology) courses. The qualification for entry into such a course will remain similar to the currently run P.G./M.E. Hydrology programme, a M.Sc. in Applied Geology/Geophysics (with Maths at Graduate level) or Bachelor of Civil Engg. In order to encourage academic offerings leading to Ph.D. programmes in hydrological sciences, incumbents with the P.G. (G.W. Hydrology) should be eligible to pursue research in Groundwater for a doctoral degree. The proposed course structure and scheme of teaching for the P.G./M.E. course in Ground Water Hydrology and Management is given in Tabe 1. The mode of admission and financial support to the participants of this course can vary as per conditions prevailing in different countries. However, to encourage a healthy interaction among participants, half of the total intake (20 nos.) to the course introduced in Indian Universities can be through GATE examination, whereas the remaining half should be the Inservice engineers as per current practice for UNESCO sponsored Postgraduate programmes.

Table 1 : Scheme of Teaching and Examination for Proposed P.G. Diploma Courses in Groundwater Hydrology and Management

S.No.	Subject	Teaching Unit	L	T	P	Examination Th.	Course work	Total	Exam. duration (hrs.)
(I)	**Autumn Semester**								
1.	Hydrologic Element and Hydrometeorology	14	2	2/2		100	50	150	3
2.	Computer Methods	1/2	2	2/2	2/2	50	25	75	2
3.	Basic Hydraulics	1/2	2	2/2	2/2	50	25	75	2
	or								
	Elements of Hydro-geology	1/2	2	2/2	2/2	50	25	75	2
4.	Probability and Statistics in Hydrology	1/2	2	2		50	25	75	2
5.	Mathematics & Optimisation Theory	1/2	2	2		50	25	75	2
6.	Exploration of Groundwater	1/2	2	2		50	25	75	2
(II)	**Spring Semester**								
1.	Ground Water Quality & Environment	14	2/2	2/2		100	50	150	3
2.	Remote Sensing Application in Hydrology	1/2	2	2/2	2/2	50	25	75	2
3.	Groundwater Hydraulics	1/2	2	2/2	2/2	50	25	75	2
4.	Ground Water Resources Evaluation	13	2/2	2/2		100	50	150	3
5.	Ground Water Flow Transport Modelling	1/2	2	2/2	2/2	50	25	75	2
6.	Ground Water Management	1/2	2	2/2	2/2	50	25	75	2
7.	Geophysical Investigations	1/2	2	2/2	2/2	50	25	75	2
Total		**4½ Units**						**675 Marks**	

Summary

P.G. Diploma Course Duration 12 Months

		Units	Marks
(i)	I Semester	4	600
(ii)	II Semester	4½	675
(iii)	Field Work	½	50
(iv)	Seminar	½	50
(v)	Project	1½	225
		11	**1600**

Scheme of Teaching & Examination for Proposed Master's Course (M.E.) in Ground Water Management

III - Autumn Semester

1. Dissertation/Thesis 4 months 400 marks

EMPLOYMENT POTENTIAL

On completion of the P.G./Master's programme in Groundwater Hydrology and Management, the professionals are likely to have sound background in various facets of groundwater hydrology and management of groundwater resources, with greater inputs of Earth sciences and engineering at their disposal. As such, they would be capable of tackling different types of field problems related to groundwater in an integrated manner, especially in drought prone arid and semiarid developing countries. However, if necessary, the employers can offer these professionals further specialized training tailored to their requirements. In developing countries like India, besides the possible employment opportunities in the Central and State groundwater and other agencies, ample opportunities exist for private enterpreneurships in fields related to ground water management etc.

SUMMARY AND FUTURE DIRECTIONS

The major inadequacies of present day hydrological education are the unevenness of the advance of our scientific understanding of hydrology through research, and slow diffusion of hydrological knowledge from research to practice. The time has come to better define the position of hydrology as a geophysical science and accordingly, determine the educational hydrological requirements for hydrologists.

To enable an increase in geoscientific inputs into hydrological education, and to develop the connections between the basic disciplines related to hydrology and the scientific study of various hydrologic processes, following recommendations may be made, in line with those suggested by the IAHS/UNESCO Panel on hydrological education (Nash et al., 1990) :

(i) Undergraduate education, such as now occurs typically in University departments of Earth Sciences, should give explicit attention to hydrology as an integral component of geoscience with sufficient depth and coverage to motivate students to pursue hydrology as a career.

(ii) The Universities should consider the establishment of the institutional mechanisms and academic offerings necessary to the support of multi-disciplinary Ph.D. programmes in hydrological science. These would differ due to local tradition and constraints.

(iii) Present postgraduate professional courses in Hydrology should be examined critically with a view to providing for greater emphasis on the basic sciences and a greater variety of hydrology sub fields. A conscious effort should also be made to introduce experimental and observational material into the courses.

In conformity with the above recommendations, a proposal has been made in the present paper to introduce a new Postgraduate/Master's Course in Groundwater Hydrology and Management to be run as a parallel programme with the current UNESCO sponsored Hydrology Courses.

It is expected that introduction of such a specialised course in Ground Water can be beginning towards formulation of other courses in fields like Surface Water Hydrology, Watershed Management and Environmental Hydrology. It is also felt that such programmes will provide the necessary scientific impetus to the future hydrological education.

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