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# **THE EDUCATION OF ENGINEERS IN ENVIRONMENTAL HEALTH**

**Report of a WHO Expert Committee**

**WORLD HEALTH ORGANIZATION**

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**WHO EXPERT COMMITTEE ON THE EDUCATION  
OF ENGINEERS IN ENVIRONMENTAL HEALTH**

*Geneva, 4-10 July 1967*

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## **THE EDUCATION OF ENGINEERS IN ENVIRONMENTAL HEALTH**

### **Report of a WHO Expert Committee**

A WHO Expert Committee on the Education of Engineers in Environmental Health met in Geneva on 4-10 July 1967. Dr P. Dorolle, Deputy Director-General, opened the meeting on behalf of the Director-General and welcomed the participants. In outlining the purposes of the meeting, Dr Dorolle referred to the high priority given by WHO to programmes in the field of education and training of personnel for health work. He noted the changing scope of environmental health and the part it plays in social and economic development, emphasized the need for educating engineers, architects, and city planners in this field, and requested the Committee to advise on academic and training programmes for engineers who will later be concerned with environmental health problems.

Dr J. A. Logan was elected Chairman, Professor L. Mendia Vice-Chairman, and Professor K. J. Ives Rapporteur.

### **INTRODUCTION**

One of the long-term objectives of WHO is to assist requesting Member States in the education and training of various categories of personnel for service in the field of environmental health. In 1951 the WHO Expert Committee on Environmental Sanitation, in considering this matter, made certain recommendations on "the specific problem of the education, training, and utilization of personnel for environmental sanitation".<sup>1</sup>

More recently, a symposium convened by WHO on "Engineering Education and Training Programmes for Environmental Health"<sup>2</sup> pointed to several problems in this field and indicated the need for a new assess-

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<sup>1</sup> *Wld Hlth Org. techn. Rep. Ser.*, 1952, 47.

<sup>2</sup> See World Health Organization (1965) *Engineering education and training programmes for environmental health: report of a symposium*, Geneva (Unpublished document No. PA/136.65 rev. 1).

ment of the entire situation, particularly the preparation of engineers for service in environmental health work.

The slow rate of development of sanitary engineering education in many areas of the world has been the cause of much concern in WHO. As national and international health programmes have multiplied and expanded in recent years, the lack of qualified engineers has increased to serious proportions almost everywhere. This problem is particularly acute in developing nations, where the needs for the planning, organization, and development of environmental health programmes are greatest.

During the past decade, new trends and new problems in environmental health organization and practice have emerged, requiring a different approach by experts trained in modern methods. For example, in many countries of the world, major programmes of public health importance—such as those involving water supply and waste water disposal—are conducted outside the formal public health organization; yet they form an integral part of the over-all efforts to safeguard public health. Furthermore, the methods used in modern engineering design for solving environmental health problems are quite different from those used in the past. The planning, design, and development of works, equipment, and services are now based, of necessity, on a systems concept. This implies the use of analytical procedures for solving problems caused by the many variables that are involved in the allocation and use of resources.

These trends and developments have had a great effect upon the time-honoured and disease-oriented concept of environmental sanitation, enlarging its scope to include environmental factors that are more directly related to man's health and social well-being as defined by WHO. One result of these developments has been the broadening of certain programmes—e.g., community water supply programmes—in order to ensure that their basic health objectives will be reached through consideration of all the physical, social, and economic factors that are involved, and through the establishment of effective working contact and operation with all national administrations dealing with such programmes.

As a result of this greatly changed situation, there is an urgent need for the revision of training programmes for the traditional type of sanitary (public health) engineer, with a view to the education and training of the "environmental health engineer" of the future.

In accordance with the WHO concept that "health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity", the Committee regarded environmental health in terms of the relationship between man and the physical, chemical, and biological factors of his environment. Furthermore, the Committee defined environmental health engineering as the application of engineering principles to the control, modification, or adaptation of the

physical, chemical, and biological factors of the environment in the interest of man's health, comfort, and social well-being.

## 1. THE CHANGING SCOPE OF ENVIRONMENTAL HEALTH

Advances in technology often entail a risk of lowering the quality of man's environment. Engineering has brought about great progress, but it also bears much of the responsibility for pollution of water and the atmosphere and for the exploitation of timber, soil, and mineral resources. If further harm to the environment is to be avoided, it is necessary for engineers working in the field of environmental health to have a knowledge of biology, ecology, and related subjects in addition to technical skills. For example, those involved in the design and construction of irrigation schemes must know how to avoid the spread of schistosomiasis, filariasis, and ancylostomiasis; designers of power stations must give attention to avoiding the production of atmospheric pollutants that would aggravate bronchitis; and highway engineers must design roads that are not death traps.

The modern expert in environmental health must be equipped to work in the face of famine, parasitism, over-population, and chronic disease; he must be concerned with the provision of adequate shelter and an ample supply of pure water and food; and he must be prepared to deal with the problems of noise and unpleasant odours. In some of these areas, considerations of cost appear to condition the possibility of improving man's environment; in all of them the ability to form rational policies and carry them out effectively is vital to success.

Environmental health requires not merely the abatement of problems and nuisances, but also their prevention; for the latter, planning is an absolute necessity. Yet environmental health planning has scarcely begun even in the most developed countries. Those who are educated in environmental health engineering in the coming years will spend much of their professional lives in planning so as to avoid lowering the quality of the environment and prevent environmental hazards. In doing so, they will work with economists, technicians, politicians, physicians, bankers, and journalists. The expert in environmental health must be able to advise on the location of new cities and power plants; on the extent to which a fertile basin can be built up commercially and residentially; on the type of waste disposal that a new industry, factory, or crop will require; on the type of engine that can be used as the prime mover in a transport system; and on which indigenous materials are suitable for home construction and which must be imported. The environmental health expert must understand all the factors involved in the provision

of water supplies; the transport and disposal of liquid and solid wastes; the provision of wholesome food and of places for its storage; the prevention of occupational illness and accidents; the abatement and prevention of air, land, and water pollution; and the control of disease vectors. However successful an expert may be in devising a solution to a particular problem in a given area, he must always be prepared to find that such a solution is inappropriate for another area or another problem.

The field of environmental health is extremely broad, and covers at least the following : water supply; waste-water engineering and water pollution control; solid-waste collection and disposal; control of disease vectors; air pollution control; environmental radiation control; industrial hygiene and toxicology; noise control; prevention of motor vehicle accidents; urban planning; architecture; and preventive, occupational, and aerospace medicine. Indeed, since all the factors determining human attributes and behaviour are either hereditary or environmental, man's environment plays a very large role in the determination of his health. Furthermore, since it has been demonstrated that malaria can influence the frequency of occurrence of sickle cells and other abnormal traits, it has been accepted that ecologic changes can affect the interaction of hereditary and environmental determinants.

Most of these problems deal with physical, chemical, and biological factors of the environment rather than with the social environment. The latter, which is manifested in culture, social and economic institutions, and political and administrative arrangements, also affects health.

Historically, environmental health engineering is an outgrowth of sanitary engineering, which originally developed in response to the need for safe public water supplies and for the disposal of liquid and solid wastes. Although the techniques used were originally developed in Europe (particularly in England, France, and Germany), it was in the USA that collaboration between engineers and the medical profession — with highly successful results — first became possible.

While municipal water supply and waste disposal continue to be major problems throughout the world, the planning of sanitary installations now takes place in a context entirely different from that of the early part of the century. The rising world population and increasing urbanization have forced responsible engineers to think in terms of "resources" — water resources, air resources, and land resources — rather than in terms of limited health needs.

In the developed nations, planning is essential to avoid catastrophe. In the developing nations, the primary health problems may still be the provision of safe and abundant water, vector control, and the sanitary disposal of solid and liquid wastes. However, there is no reason why developing nations should repeat the mistakes made by others; resource planning should be accepted as a basic premise from the beginning.

## 1.1 Unresolved and new problems

There are many unresolved environmental health problems that can be handled only by new techniques or more intensive application of existing techniques. Cholera, ascariasis, filariasis, schistosomiasis, and onchocerciasis are still prevalent in large areas of the world. More than two-thirds of the people of the world are without an adequate water supply. Urban blight and the presence of squatters around cities present environmental health problems that are not yet solved. Much needs to be done to provide a healthful environment in both the home and place of work.

New problems are growing in importance, and education and training programmes must take them into account. Modern technology is adequate for the solution of many of these problems, but it frequently cannot be applied owing to a lack of the necessary resources or organization. A systematic approach is necessary to identify and cope with old and new problems alike.

New environmental health problems include the following: the presence in the environment of trace residual chemicals, often synthetic and organic, that do not break down rapidly and whose long-term effects on man are not fully known; other adverse environmental factors from which there is no ready escape, such as city noise, water of doubtful quality, and crowded transportation; growing need, in many areas, for the use of brackish water or sea water, or the re-use of waste water; the multiplicity of demands that a single resource may have to supply; the growing menace of oil pollution of marine and inland waters; and the importance of viruses.

## 1.2 New techniques

With the growth of modern technology a number of new techniques have become available to help the engineer solve some of the problems of environmental health. These new techniques include the following:

(1) *Information sciences.* Because of the growing volume of world literature in science, medicine, and technology, the use of computer storage of published material is increasing. Titles, key words, authors' names, and cross-reference material can be maintained in computer files, and can readily be retrieved when needed. Published material in environmental health engineering should be compatible with such systems so that relevant information can be retrieved quickly and efficiently.

(2) *The systems concept.* New methods of assessing, controlling, and designing a system require that the system be approached as a whole in order to determine the proper function of its components. The alter-

native is the unit approach, in which individual components or units are designed and then integrated into a system, often resulting in a poor balance among the components, no matter how well these are designed.

The systems approach covers a wide range. At one extreme is the formulation of a problem, in the knowledge that the correct solution may be inherent in its proper formulation; at the other extreme there is the use of advanced mathematics to obtain alternative solutions to a problem.

Systems analysis is a method of problem solving, choosing, decision making, and planning. In recent years it has been widely used in the USA, both by government and by industry; it has also been used, to a more limited extent, in other countries.

The systems concept requires a broad appreciation of a problem, a mathematical or logical model of the problem, and usually a high-speed computer to deal with the large range of interdependent variables that are involved. It is, of course, difficult to assign numerical values to certain factors involved in environmental health — e.g., recreation, amenity, and cleanliness — but attempts are being made to assign at least benefit and cost values to such factors. The systems concept can make environmental management, decision making, and assessment of areas of importance more feasible for the engineer and the administrator.

(3) *New concepts of organization.* The adoption of a regional approach to administration and finance is leading to the more efficient use and management of resources. An increase in the size of the financial and administrative community often makes possible the provision of services that could not be made available in smaller units, as illustrated by the regrouping of water-supply undertakings in the United Kingdom. New administrative concepts can help to identify not only what must be done but how it can be done.

(4) *New materials.* Industry is developing new materials and new processes that offer promise in the environmental health field — for example, plastics and glass-fibre reinforced materials for construction, synthetic membranes for selective transport of molecules and particles, synthetic chemicals for treatment processes, and the use of ionizing radiations for sterilization and other purposes.

(5) *Analytical methods.* New laboratory methods (e.g., chromatography, electron microscopy, and adsorption spectrometry) are available for the detection and analysis of chemicals, particularly at the trace level, in the environment. Automatic recording of analytical data on tape or in other ways permits not only economical record-keeping, but also rapid processing of the data.

(6) *Water management.* When the systems approach is applied to the management of water resources, various quantities and qualities of

water can be assigned to the most appropriate and economic use. Furthermore, the regulation of water and waste water by storage permits controlled release under optimum conditions.

(7) *Solid-waste management.* Joint management of solid and liquid wastes, with unified control of treatment and disposal, is already in effect in some cities.<sup>1</sup> Joint management in other aspects of environmental health could be beneficial.

(8) *United urban services.* As much urban construction will be required before the end of this century as has been produced in our entire history, and new approaches to urban services are required. Such municipal services include conventional ones and others that are becoming available and that can be introduced in new communities: fuel, power, and heat; water of different qualities for a wide variety of purposes (but all safe for occasional ingestion); communication cables, such as those for telephone and television; sewers for household wastes, industrial effluents, and storm water run-off; conduits for refuse collection; and individual and mass transportation. Integration in the design, construction, and maintenance of such services is highly desirable.

(9) *Advances in other fields.* New discoveries in medicine, space technology, oceanography and other fields often lead to developments that can be used in environmental health.

### 1.3 The place of environmental health in social and economic development

In his report on the work of WHO for 1962, the Director-General pointed out the need for using "more resources... to help overcome the serious handicap that the absence of health constitutes for any undertaking to improve the economic and social status of the individual, the family and the community."<sup>2</sup>

The Twentieth World Health Assembly, in 1967, in a resolution on "Health and Economic Development", affirmed that "improvements in health conditions are not only desirable in themselves, but also essential for economic growth and therefore form an integral element of any meaningful development programme."<sup>3</sup> It called the attention of Members to the importance of developing national health plans as a part of their economic and social development plans.

Referring specifically to water, the Twelfth World Health Assembly in 1959 stated that "safe and adequate supplies of water to inhabitants of communities constitute an important measure for the protection and

<sup>1</sup> For further information, and a bibliography, on this subject see *Wld Hlth Org. techn. Rep. Ser.*, 1967, 367.

<sup>2</sup> *Off. Rec. Wld Hlth Org.*, 1963, No. 123, page vi.

<sup>3</sup> *Off. Rec. Wld Hlth Org.*, 1967, No. 160, p. 30.

improvement of health and are indispensable for economic and social development.”<sup>1</sup>

The Inter-American Development Bank<sup>2</sup> recently pointed out that health is essential to long-term economic development. If the work force of a given country is unhealthy, workers will be lost through death and work time will be lost through illness; consequently, the productivity of the country will suffer. Furthermore, failure to introduce measures to prevent illness will necessitate increased expenditure on curative services. Measures to better the health and increase the life span of the working force bring about a longer productive period in the lives of skilled and professional workers. From the economic point of view, this is particularly important in the developing countries.

A comparative study of a Latin American country and the USA has shown that, taking into account the difference in efficiency of workers and the percentage of the population in the productive age group in the two countries, the over-all advantage of the USA was 250%.<sup>3</sup>

The Community Water Supply Programme of WHO has shown the economic value of one important element in environmental health. This programme — which is attractive to banks because it can be financially self-supporting — could be used as a model for projects in other environmental health areas.

Good environmental health practices — such as the elimination of mosquitos, the provision of reliable drinking water, and the maintenance of clean beaches — is important for the attraction of tourism. Furthermore, investments in the commercial and industrial development of an area depend to a great extent on the ability of industry to attract people to live and work in the area. A further benefit of improved environmental conditions is a reduction in corrosion and disfigurement of buildings and other structures by atmospheric pollutants.

## 2. EDUCATION AND TRAINING

### 2.1 General considerations

A part of any educative process is the acquisition of the ability (1) to perceive problems and solve them; (2) to understand people, to communicate with them, and to deal with them as individuals and in groups; (3) to organize; (4) to concentrate; and (5) to memorize.<sup>4</sup>

<sup>1</sup> WHO (1965) *Handbook of resolutions and decisions of the World Health Assembly and the Executive Board*, 8th ed., Geneva, p. 103 (Resolution WHA12.48).

<sup>2</sup> *Bol. Ofic. sanit. panamer.*, 62, No. 4.

<sup>3</sup> Logan, J. A. (1963) *Int. Rev. trop. Med.*, 2, 27.

<sup>4</sup> Yntema, T. O. (1965) *The economics of education*, Chicago, Ill., University of Chicago.

## 2.2 Particular considerations

Teaching methods in the field of environmental health, the choice of instructors, and the place of such teaching in over-all education vary according to the general educational systems of different countries.

Since it was not possible to examine all particular situations, the Committee gave detailed attention to one general type of education in environmental health engineering that is now spreading throughout the world; however, the proposals made may be easily adapted to other situations.

### 2.2.1 *Role of all professional personnel*

Professionals in all fields are often called upon to deal with problems that indirectly affect environmental health. It follows that such persons should, in the normal course of their education and training, be made aware of the necessity to bear in mind the possible environmental health consequences of their work. This can be achieved by their receiving instruction from "environmental-health-minded" teachers in their own fields, to inculcate in them an attitude of concern for the environment that will persist through their practice.

### 2.2.2 *Role of professional personnel requiring orientation courses*

Many disciplines other than that of environmental health engineering are involved in the solution of environmental health problems, and their number may increase as problems become more complex.

Many professions are involved in the economic, administrative, and physical planning of important projects whose consequences, if health considerations are ignored, may be such as to require expensive remedial measures, or whose full potential may not be achieved. These professional groups include public administrators, economists, scientists, physicians, architects, city and regional planners, and engineers of all types. In view of the wide interpretation of environmental health that has been made previously, any professional group that may produce alterations in the environment, whether favourable or unfavourable, should receive some instruction in the requirements of this field. It is appropriate that all such groups should, in their formal academic training, receive courses in the principles and practice of environmental health engineering. The presentation of such courses must be compatible with the qualifications and interests of the students in the various fields.

Co-operation among the different departments of educational institution is desirable, but an educator qualified in environmental health engineering would be the most suitable person to assume the responsibility for such courses.

### 2.2.3 *Role of engineers and others specializing in environmental health*

Because of the changing scope of environmental health the role of the engineer and other specialists in this field must be re-appraised.

Water resource management and development, city and regional planning, housing and industrial development, transport, and recreational services would come within the purview of the environmental health engineer. In so far as they might affect environmental health, questions of government planning, administration, finance, and legislation would also be within his sphere of interest, as would both public and private industry.

To these extended areas of engineering interest must be added, of course, the traditional areas of sanitary (public health) engineering: water supply, waste-water disposal, solid-waste collection and disposal, air pollution control, vector control, and disease prevention.

## 2.3 **Training in environmental health engineering**

### 2.3.1 *Existing educational systems*

The ways in which environmental health education programmes are carried out in different countries appear to fall into four principal categories:

(1) A full-time programme in environmental health engineering, lasting about 5 years, following the completion of secondary education (i.e., commencing at about 17 or 18 years of age);

(2) Courses in environmental health engineering incorporated in existing full-time engineering programmes (such as those for civil engineers) which last about 5 years and which follow completion of secondary education;

(3) Courses of a post-graduate nature, which last one year or more, following (but not necessarily without interruption) a full-time programme of study and qualification in a basic field of engineering (e.g., civil or chemical engineering); and

(4) Short refresher courses for certain groups — e.g., educators and those in practice in environmental health fields (it must be emphasized that such short courses supplement formal education but are not a substitute for it).

### 2.3.2 *Trends in education*

Some of the more important of the recent trends in education, particularly as related to environmental health engineering, are outlined below.

(1) The continued trend towards a more scientific basis for engineering education has, in turn, resulted in less "professional" material being

offered in basic engineering programmes, which are tending to become more pre-professional than professional in character.

(2) The increasing science and mathematics content of basic educational programmes has been accompanied by a rapid growth of advanced and specialized professional education throughout the world.

(3) Engineering has become more demanding in terms of the intellectual capacity required.

(4) There has been increasing awareness of the professional responsibility that engineers must assume. To prepare them for this responsibility, engineers must be educated in the humanities. Such education should comprise not merely a random assortment of subjects, but a carefully planned series of courses designed to provide a background for understanding and working with people.

(5) There has been increasing recognition of the value of an analytically-based education, not only for engineers, but in such varied fields as economics, psychology, the social sciences, and business administration. Increasing numbers of the world's industrial leaders find it necessary to have an education based on engineering or science. One of the results of these trends has been an increased emphasis on decision-making as an integral part of engineering education.

(6) Industrial-internship programmes, which provide opportunities for student engineers to obtain practical experience as an integral part of their education, have been growing in importance.

(7) Independent study at all educational levels, and continuing education for graduates, have been growing in importance as ways of insuring against out-of-date knowledge. Independent study enables the young engineer to keep abreast of new knowledge by reading the literature, without having to depend on formal academic assistance; continuing education usually consists of special courses (often in new fields) that are sponsored by universities, governments, and/or engineering societies.

(8) Because of the availability of high-speed computers, methods of instruction have been changed to teach the student how to formulate problems in a manner suitable for computer programming.

(9) The growth of "new mathematics", "new physics", "new biology", and "new chemistry" represents an attempt to teach the fundamentals of these subjects as early as possible in the educational process.

(10) The development of miniature laboratory equipment to replace cumbersome conventional equipment has resulted in considerable savings in cost and space.

(11) The growth of bio-engineering, bio-mechanics, and related subjects represents a co-operative effort of engineers, physiologists, physi-

cians, biologists, and others to apply common principles towards the attainment of a better understanding of the life process and of ways to preserve man's health.

(12) The development of new teaching methods, such as programmed instruction, represents a rational approach to individual study and makes available teaching material that can be adapted for use anywhere in the world.

(13) Even the largest libraries are finding it increasingly difficult to cope with the flood of material that is being published. This has led to the concept of regional, national, and international information networks using information storage and retrieval by electronic means.

(15) Regional and metropolitan planning and concepts of water, air, and soil resources emphasize the broad social and economic responsibilities of the engineer, and the necessity of integrating water supply, waste disposal, and similar programmes into broader national objectives.

Teachers and potential teachers of environmental health engineering should be aware of these and future developments as they arise. To this end, regular seminars or courses for teachers should be arranged nationally or regionally. Another fundamental requirement for modern educators is skill in the use of new techniques.<sup>1</sup>

### 2.3.3 *Educational programmes*

The Committee drew up the following lists of suggested subject areas in which the training of engineers is desirable. It must be pointed out that no one environmental health engineer would study all the topics in the specialized areas, nor would he have to study them in the order given.

The lists may be useful as guides to educators in the planning of syllabi for engineers preparing themselves for one of the specialities in environmental health. They are not intended to be either completely inclusive or exclusive; it is recognized that educational systems, preparation for university-level study, and specific professional requirements vary widely from country to country.

#### *Courses for all engineering students*

The following subjects are desirable in the training of all engineers, regardless of their field (if a subject has been adequately covered in pre-university education, it may be dispensed with at university level).

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<sup>1</sup> Much useful information on modern teaching methods will be found in UNESCO (1963) *New methods and techniques in education*, Paris (Educational Studies and Documents, No. 48). The importance of modern educational methods is also discussed in *Wld Hlth Org. techn. Rep. Ser.*, 1966, 337.

*Basic sciences.* The following are essential "building blocks" in the education of all scientists and engineers: mathematics, including mathematical statistics; physics, including ionizing radiation; chemistry (organic, inorganic, and physical); and biology, including molecular biology and biochemistry.

*Engineering sciences.* The following are the basic studies in preparation for engineering design: thermodynamics; fluid and solid mechanics; materials; electrical science; project design, including drawing; and instrumentation and measurement (e.g., surveying).

*Humanities and social science.* If man is to be a "good steward" of his environment, he must have a concern for the humanities and social sciences, such as: economics; social philosophy and psychology; sociology; political science; and literature, art, and similar subjects.

#### *Courses for all environmental health engineers*

The following additional subjects are essential in preparing for a career in any field of environmental health: systems analysis, including computer technology; epidemiology, in relation to the diseases of a given region; human ecology, in relation to the environment of a given region; applied statistics; applied biology (including physiology, biochemistry, and other specialities as appropriate); and management, including policy, law, administration and finance.

#### *Courses for specialists in environmental health*

Not all educational institutions are likely to be in a position to prepare engineering specialists in all fields of environmental health. The following courses are grouped according to areas of speciality; it is understood that, in the organization of any specific curriculum, it may be desirable to select from several of the areas, depending upon local needs and resources.

*Water resources* : water analysis (physical, chemical and biological); water and waste-water treatment processes for multiple uses; design of water supply and waste-water disposal facilities; hydrology (surface water and ground water); industrial water supply and waste disposal; and limnology and water pollution, including hydrobiology.

*Public health* : vector control; industrial hygiene and occupational health; air hygiene; radiological hygiene; parasitology; food sanitation; rural sanitation; and public health administration.

*Land use and shelter* : urban and land-use planning; solid-waste collection and management; housing, including ventilation, heating, air conditioning, and lighting; recreation (urban and country, land and water); and noise control.

*Air resources* : meteorology and climatology; air chemistry, including aerosols; toxicology; analytical chemistry; air pollution control.

*Management* : Engineers in the above specialities may find it desirable to prepare themselves for careers in resource management, for which the following study areas are suitable : planning of resource systems; public development economics; and public and business administration.

It should be noted that no specific level of accomplishment is implied in any of the subject areas indicated. In some instances a brief survey may be adequate; in others, a sequence of three or four courses of increasing complexity may be necessary to prepare the individual engineering student.

#### 2.3.4 *Education of the research specialist*

With the increasing complexity of problems in environmental health, it is clear that there will be need for a special category of research personnel who will devote significant parts of their careers to fundamental investigation. Such research personnel will be well-qualified in any of the specialized areas listed above. A common need is competence in information retrieval and communications, which may be obtained at universities or at special research institutes.

In addition, practising engineers should be encouraged, and prepared during their educational programmes, to conduct investigations as an essential and continuing professional responsibility.

Assessment of national problems and establishment of national priorities may help to indicate the type and number of individuals who must be prepared to direct themselves exclusively to research.

#### 2.3.5 *Differing environments*

In many instances it will not be possible or practical to prepare personnel to provide service in all aspects of environmental health. Educational programmes should start, if necessary, in the area of greatest need, and grow into other fields as the needs become evident.

Although environments and developmental stages of countries or regions may differ, the basic requirements of education are universal. It is in the area of specialization that choices appropriate to local conditions will have to be made.

In establishing priority, there must be due regard to the effect that a given programme will have on the health status of the people and the economic and social development of the area. For example, community water supply programmes, and the necessary education and training in this field, have properly been given high priority.

## 2.4 Courses for technicians

The work of the engineer or other specialist in environmental health would not be possible without the supporting part played by technicians. In the laboratory and in field work, plant operation, data collection, enforcement, and many other areas, the technician relieves the professional of many of the more routine tasks, freeing him for the role of initiator, educator, planner, designer, or administrator.

Such technicians require training in appropriate aspects of environmental health at a level suitable for the degree of responsibility that they will assume. It is possible that, with different degrees of responsibility among technicians, different grades of technicians will be trained. Owing to variations in educational practices and the variety of training institutions in different countries, no single pattern can be recommended for training courses for technicians.

## 3. IMPACT OF RESEARCH ON EDUCATION

The Committee endorsed the conclusions of the 1965 inter-Regional symposium<sup>1</sup> with regard to the utilization and value of research and demonstration activities.

Research is necessary in every country, no matter what its stage of development. It may bring about advances in knowledge and practice, or it may assist in the adaptation of established practices to local conditions and in the maximum utilization of indigenous land, labour, and economic resources.

Research and demonstrations at an academic institution are a part of the teaching process. They stimulate students and staff and develop a critical attitude and an attitude of inquiry.

Research can be directed towards problems facing both government (local and national) and industry. Funds (e.g., grants and contracts) for research performed by the academic institution can increase the facilities for teaching at the institution and permit additions to the scientific and technical staff. Research can also be conducted by students and staff at non-academic institutions, both public and private, to the profit of both. In fact, much is to be gained by locating new research and demonstration services, regardless of their methods of support, in or near an educational institution.

Similarly, new techniques carried out in operating or pilot plants can be used for demonstration purposes by the educational staff. In some instances, operators of environmental health services are happy

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<sup>1</sup> See footnote 2, page 5.

to share in the educational process by making their services available for demonstration or by direct participation in teaching.

Field studies also offer an excellent opportunity for student and staff participation, and serve to exemplify co-operation among a wide variety of disciplines. Apprentice-type employment may provide the young student with professional insights that can enrich his education.

In general, every opportunity should be explored to involve the student in research, demonstrations, and practice during his period of formal education.

#### **4. ESTABLISHMENT OF EDUCATIONAL PROGRAMMES IN ENVIRONMENTAL HEALTH ENGINEERING**

##### **4.1 General**

Educational institutions themselves must determine whether new programmes in environmental health engineering should be established, or the ways in which existing programmes can be modified to make them adequate for the widening concept of environmental health engineering, both present and future. Nevertheless, certain general guidelines can be formulated to assist the making of such decisions.

The initiation of new educational activities in environmental health engineering should be closely connected with an over-all national plan for the preparation of technological personnel. In larger countries, this may imply division of responsibility among several institutions, each of which, depending upon its capabilities and interests, might treat in detail one or more of the subject areas outlined previously. Duplication of effort and competition among institutions for students, if they are limited in number, must not tax limited resources. In areas where countries are too small for each to support a specialized programme, a regional plan for the preparation of professionals may have great merit.

The objectives of any programme of education in environmental health engineering should be formulated as clearly and as precisely as possible by the institution wishing to initiate (or modify) such activities. They may then form the basis for assistance by agencies (international, national, or private) that may be able to participate in the programmes. The objectives should be reviewed periodically, in order to evaluate the effectiveness of the programme and to indicate any modifications that may be necessary.

Continuity of effort is of particular importance in programmes of engineering education, and both the university and collaborating agencies should bear this in mind when reaching decisions as to whether to initiate activities. No time limit should be set for the accomplishment of long-

range objectives, but every effort should be made to reach them expeditiously.

Although the cost of education is dealt with in more detail elsewhere in this report, the considerations involved in the establishment of a new programme in environmental health engineering include the following :

(1) The demand, present and future, for engineers in this field and their chances of support by society, bearing in mind that the provision of a few leaders in new specialities often brings about a demand for more.

(2) The availability of the necessary supporting courses from other departments of the educational institution, which is important in terms of cost and of quality of content.

(3) The possibility of sharing laboratory services and technicians with other departments of the engineering school and with other institutions.

(4) The probable ratio of students to instructors at the beginning of the programme and for several years thereafter.

(5) The probable return on society's investment in education which the graduates of the programme may be expected to make throughout their professional careers. This point may be of particular importance in helping to establish the appropriate priority of the programme within the over-all plan for education.

#### **4.2 Academic staff**

The requirements for instructional staff depend upon the nature of the educational programme being developed. In principle, it is sound to provide an adequately remunerated nucleus of full-time staff. This staff may be supplemented as necessary by practising professionals, on a part-time basis, who can inform students of the latest developments. However, such professionals should be chosen with care, as there is always a danger that their non-university commitments may interfere with the discharge of their academic responsibilities.

At least three full-time professional educators in the field of environmental health engineering should, in general, comprise the teaching staff. Where specialists in closely related environmental health sciences are not immediately available, it may be desirable to include specialists in chemistry and/or biology in the teaching staff. This would provide, for example, the essential staff for the preparation of personnel to work within the "water sector" of the field. Programmes that are to provide a wider coverage of the field of environmental health would need additional faculty members.

Professionals from many different disciplines may participate in programmes of education in environmental health. Such specialists

may be members of the environmental health department or they may be drawn upon as desired from other departments of the university. Although there are advantages to both systems, it is preferable, particularly in post-graduate programmes in which considerable research activity is planned, to include within the environmental health department as many different disciplines as required. However, care must be taken not to isolate such members of the teaching and research staff from the mainstream of their own specialities in the educational institution and the field. There should be the widest possible dissemination of knowledge about the environmental health department and its programmes, in order to interest other disciplines and make maximum use of available resources.

A fellowship programme for teachers to reinforce, and create leadership within, the environmental health department should be an important element of the development programme. In a field in which change is so rapid, it is necessary that the instructional and research staff be given every opportunity for advanced training, and for keeping informed of the latest developments. In a number of countries the need is felt for the awarding of higher degrees, including the doctorate, in environmental health engineering. Agencies that may collaborate in advanced education of the educational staff should take into account the several years of study required for the attainment of a doctorate.

Educational staff should be drawn from a variety of institutions. In this way, different points of view and experience will be available for the solution of local problems. A situation in which most staff members have received their training at one institution has inherent disadvantages.

#### **4.3 Equipment and library requirements**

Laboratory equipment and library services are an important consideration in any programme for the education of engineers in environmental health. The modern tendency in engineering education is towards the use of miniature laboratory equipment, which results in economies without affecting the objective of giving students an understanding of engineering principles.

Existing public service laboratories have often been transferred to educational institutions for purposes of instruction and service, or such institutions have been able to take advantage of research institutes located on campus or nearby. Institutions considering the establishment of new programmes in environmental health engineering would be well advised to explore the possibilities of acquiring existing service laboratories, and of using them for instruction and continuing service to the community. Indeed, any environmental health engineering laboratory should, once the requirements for instruction have been satisfied, be thought of

as a service laboratory for studying the problems of the community at large, as a natural extension of the role of the university in society.

The use of existing laboratories in other departments of the university and in research institutes is an additional way in which economies can be effected without sacrificing the quality of instruction needed in environmental health engineering.

In view of recent advances in information sciences, institutions should begin now to prepare themselves to take full advantage of the impact these will have on the storage and retrieval of information. The library, in whatever form, has always had an important role in education, but in many instances library needs have not been fully met in existing programmes. The acquisition of back issues of technical journals is not enough; educational institutions should budget funds annually so as to be able to provide their students with up-to-date information from current publications. Much might be done through the increased use of modern techniques, including the use of microfilm and international library exchange, to increase the services provided by existing libraries.

International organizations, together with learned societies and the publishers of scientific and technical journals, should explore ways in which libraries in existing and future programmes in environmental health engineering could provide students with a wider opportunity for study and review.

#### **4.4 Cost of programmes**

The Committee examined data on the cost of education programmes in environmental health from a number of institutions, and noted that such costs vary widely, depending upon the location of an institution and the way in which costs are calculated. Programmes that prepare environmental health engineers directly following graduation from secondary school need cost no more than similar programmes for the preparation of engineers in other fields. Programmes of advanced training, beyond the basic engineering programme, are more costly in terms of the overall investment in education of the individual, but are justified and desirable if society is to discharge its obligations to itself and maintain an environment in which it can live without undue risk.

Institutions establishing new programmes in education for environmental health might wish to consult WHO for assistance in assessing the probable costs involved, and guidelines for number of staff, use of space, investment in equipment and libraries, etc. might be prepared upon the basis of data from existing programmes.

Financing of education in environmental health may be obtained from a wide variety of sources. Each institution may seek support from local and national government, international agencies, industry, and

foundations. Institutions should explore, with those who may have use for environmental health engineers, the ways in which inducements and assistance might be given to students wishing to enter the field.

#### **4.5 Regional programmes**

A regional programme for the graduate education of sanitary engineers has been established at the University of San Carlos, Guatemala, to serve all of Central America, and plans are being made for a regional programme for part of French-speaking Africa. The use of regional programmes has great merit in areas where countries cannot afford individual programmes. In addition to economy, there are great advantages to educating professionals, at whatever level, within their own environment, in which the identification of problems and the solutions suggested may be more closely linked to the student's experience.

#### **4.6 Recruitment**

The Committee endorsed the view of the 1965 symposium,<sup>1</sup> to the effect that in recruitment, the social and intellectual challenges that the profession of environmental health engineering provides should be stressed. Young people should be made aware of these challenges, and of the fact that the solution of environmental problems requires the co-ordinated efforts of scientists, engineers, and members of other professions.

In some countries, educational institutions have specific ways of bringing the opportunities in various fields to the attention of students, and all universities conducting programmes in environmental health engineering should make such an effort. The agencies most likely to employ environmental health engineers should be made aware of existing educational programmes, and should be encouraged to use them for advancement of their staffs; this applies particularly to programmes at an advanced level. Subsidies from future employers of students may be an important element in recruitment, and should be encouraged.

### **5. OPPORTUNITIES IN ENVIRONMENTAL HEALTH ENGINEERING**

As man becomes increasingly aware of his responsibilities as custodian of the environment, the need for engineers specialized in environmental health increases. Environmental health engineering has evolved from

<sup>1</sup> See footnote 2, page 5.

sanitary engineering, which in turn was created to apply engineering principles to the solution of disease problems. Environmental health engineering will always be concerned with the prevention of disease, but it also has responsibility for reversing the tendency of man to spoil his environment, and for preserving a healthy environment for future generations.

Environmental health engineers will find a variety of challenges and opportunities, both public and private. Within government, they may be expected to work in planning agencies, public works agencies, public utilities organizations, health departments, research institutes, and similar agencies, whether these be at the national, regional, or local level. In industry they may be employed in the management of industrial water and wastes, in the control of the occupational environment, and in the sanitation of manufactured products. Industry offers opportunity to specialized engineers in the conception, design, construction, and marketing of equipment for the control of pollution. In many countries, consulting engineering organizations that specialize in water supply, wastewater treatment and disposal, air pollution control, etc. offer attractive career opportunities. In universities, environmental health engineers may assist in the study and solution of the increasingly complex problems that man creates for himself within his environment.

In view of the wide responsibilities that the environmental health engineer now has and may be expected to assume in the future, health authorities should review and, if necessary, revise his role in public health institutions. Unless the engineer's role is adequately recognized, and career opportunities are offered by health departments, other institutions may attract the engineering talent necessary to assist in the prevention of communicable disease as well as the control of pollution. The Committee recommended that WHO continue its efforts to bring this matter to the attention of health authorities, to the end that public health agencies may be strengthened by the engineering profession.

## 6. RECOMMENDATIONS

(1) Educational programmes in environmental health engineering, where they do not now exist, should be made available throughout the world, either nationally or regionally.

(2) Many organizations — international, national, and private — are concerned with various aspects of practice, research, and education in environmental health engineering. It is in the interest of both economy and efficiency that such agencies co-operate — e.g., in the exchange

of information, in support for educational programmes, in the provision of fellowships, and in programme planning.

(3) Where educational programmes are established, it is essential that such projects be long-range activities that will continue on a firm basis after the termination of outside assistance. Use should be made of highly qualified, capable, and adaptable personnel for consultation, particularly in the early stages of development. It is important that research, key personnel, and planning be of the highest calibre. The production of key personnel is essential in educational and training programmes, since it is on such personnel that future education and training will depend.

(4) Regional and national co-operation is urgently recommended for countries developing university-level programmes in environmental health engineering. Co-operative action by international and other agencies can play an important role in promoting such regional co-operation. The creation of educational and training institutions for technicians should be encouraged in every country.

(5) It is recommended that regional meetings of environmental health engineering teachers be held periodically. Such meetings can be invaluable as a means of exchanging information and solving common problems.

(6) In view of the importance of environmental health engineering concepts for all branches of engineering, architecture, and planning, they should be introduced, wherever possible, into educational programmes in such fields.

(7) An international directory of institutions giving training in environmental health engineering should be prepared.