Consultation on the public health component of sanitary engineers' training curricula

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CONSULTATION ON THE PUBLIC HEALTH COMPONENT OF SANITARY ENGINEERS' TRAINING CURRICULA

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1. Introduction

A Consultation was convened in the WHO Regional Office for Europe in Copenhagen, from 8 to 10 November 1982, to prepare detailed recommendations regarding the public health, biological and medical components of the training curricula of sanitary engineers in the European Region.

The meeting was opened by Dr A. Wojtczak, Director, Research, Planning and Human Resources, who stated that the regional strategy for attaining health for all by the year 2000 recognizes primary health care as a key component and that this includes nutrition, environment, education and agriculture as well as medicine. The training of sanitary engineers is a part of health manpower development which is an integral part of the strategy. It is essential to provide public health training for engineers, so that public health issues can be dealt with from an engineering and professional point of view. Dr Wojtczak referred briefly to the sanitary engineering training programmes at Delft, Lausanne, Rabat and Warsaw.

Professor L.Y. Maystre and Professor M.S. Hilbert were elected Chairman and Vice-chairman respectively; Professor K.J. Ives was elected Rapporteur.

Mr E. Giroult, Regional Officer for Environmental Health Planning and Management, outlined the subject matter which the Regional Office wished to consider. In broad terms, this was:

(a) the health-related content of sanitary engineering training curricula;

(b) the improvement of communication, through training, between public health medical doctors and sanitary engineers;

(c) the orientation of sanitary engineering training programmes in Europe towards engineering solutions of public health problems.

2. Scope and purpose

The scope was defined as the training curricula in sanitary engineering programmes which apply a public health approach to sanitary engineering. The task of the sanitary engineer was defined: "To adapt man's environment by engineering means to the requirements of his health". This concept was to be applied to public health and not the personal health of the individual. Biomedical engineering (dealing with prosthetic devices, artificial kidney machines, hospital, surgical and medical equipment) was excluded from consideration, as was biotechnology in the production of pharmaceuticals, chemicals, etc., except where there was a public health significance, e.g. in effluents from biotechnology.

The purpose of the meeting was to prepare recommendations to WHO regarding the public health, biological and medical components of the training curricula of sanitary engineering programmes. These components would be in accordance with the public health role of sanitary engineering and would look to future requirements.

3. Educational concepts

Due to the variety of educational systems which exist in the European Region, it is not possible to identify a single model of the education of a sanitary engineer. In some cases, sanitary engineering topics are taught at undergraduate level; in others, they are first introduced at postgraduate level. However, for all the educational systems, about four to five years of education beyond the secondary school level are required.

Most sanitary engineers have a civil engineering background, although some have initial training as agricultural, chemical or mechanical engineers. Normal training of all engineers comprises mathematics, chemistry, physics, electrical technology, materials properties, structures, solid and fluid mechanics, economics, measurement and design.

Normal training for sanitary engineers includes technical aspects of water management and supply, wastewater collection and disposal, air pollution control, solid waste management and other engineering installations and operations.

In addition to these technical aspects, there is a public health dimension in these various contacts of man with water, land, air, radiation, noise and biosphere. The health dimension in sanitary engineering curricula is aimed at benefiting man's health. In this context, health is taken as the WHO definition: "Health is a state of complete physicial, mental and social well-being and not merely the absence of disease or infirmity".

The Consultation therefore decided to concentrate on the health components of training, leaving aside the technical aspects. In considering the health components, the Consultation agreed that the training programmes should impart to the students:

- knowledge;
- skills;
- attitudes.

Attitudes towards the importance of health-related topics cannot be taught, but are imparted by the teachers' enthusiasm, professional commitment and explanations of the relevance of the contents of the curricula. Participation of teachers from medicine and other health professions would be vital and would improve communication between public health medical doctors and sanitary engineers. Likewise, the importance of health-related topics needs to become a conviction on the part of the teachers of sanitary engineering.

4. Requirements of the graduate

4.1 Employment areas

Evidence from several countries in the European Region showed that the professional sanitary engineer is employed in the following areas:

- central government;
- local government (community authorities, water authorities, etc.);
- consulting practices;
- industry (including those which develop public health equipment and construct installations);
- teaching and research.

The relative importance of these varies between countries. For example, governmental agencies are the principal employers in France; in the Federal Republic of Germany, although governmental agencies employ over 50%, the consulting practices are significant; in the USSR, engineers are technical advisers to physicians in the management of the system of sanitary-epidemiological services.

Many European sanitary engineers are employed in developing countries or their work is directed to problems of developing countries, e.g. British engineers in the British Commonwealth and French-speaking engineers in the francophone countries of Africa and Asia.

It was concluded, therefore, that, in addition to health-related topics valid for the European Region, some training in tropical health was necessary.

4.2 Basic competence

Although the sanitary engineer will be expected to be capable of dealing with the health dimension of his professional work, he will still be expected to be competent in his role as an engineer. He may be expected to collaborate effectively with biologists, chemists, medical doctors and other health personnel, and to appreciate and act on the health consequences of an engineering intervention. Nevertheless, he will still be expected to be able to design, execute, supervise and inspect engineering installations relating to sanitary engineering.

4.3 New activities

The strong interest in protecting the environment which has developed in the past 15 years has placed new responsibilities on the sanitary engineer. Although these have been modified by the worldwide energy crisis and economic recession, occasional man-made and natural disasters bring reminders for vigilance.

Toxicological problems of solid waste disposal, contamination of land, water and air and the production of new industrial products often demand engineering solutions. New developments require environmental impact statements. Oil exploration and exploitation pose new hazards. Public concern with radiation hazards and noise nuisance often demands engineering intervention. These and other developments are discussed in the documents by Professor K.J. Ives and Professor M.S. Hilbert, which are appended as Annexes 1 and 2 respectively.

The International Drinking Water Supply and Sanitation Decade has initiated great activity in developing countries and has created a general awareness of public health problems associated with water and waste disposal.

The Consultation referred to these new activities, noting that they placed extra requirements on the health-related curricula of sanitary engineering programmes. WHO was also concerned, for example, in helping with environmental health impact assessment studies.

5. Fields of activity

In order to determine the most relevant public health topics, a number of fields of activity were considered. A list appears as Annex 3. The list is not intended to be exhaustive but covers water (including wastewater), solid wastes, land and soil, atmospheric topics, urban and rural areas, buildings, recreation, entertainment and tourism, noise, radiation and public health aspects of food.

This represented a problem-orientated approach, which followed logically from the previous consideration of the requirements of the graduate. Each of the fields of activity was evaluated in terms of the needs:

- to identify the health implications;
- to decide standards to be achieved;
- to assess the health effects of the engineering intervention.

These evaluations were made asking the question, "What does the sanitary engineer need from public health subjects to carry out his tasks?" It was assumed that, where necessary, he would be working with professional chemists, biologists, medical personnel, etc. For example, in the case of the field of activity of supply of palatable and wholesome drinking-water (Annex 3, No. 1), the following public health subjects were involved:

- sanitary biology and microbiology;
- waterborne diseases;
- epidemiology;
- biostatistics;
- principles of toxicology;
- principles of physiology;
- public health and environmental legislation.

Again, for example, in the field of collection and disposal of solid industrial wastes (Annex 3, No. 8), the following public health subjects were involved:

- vector control;
- determinants of health and disease related to air (air hygiene);
- urban sanitation;
- epidemiology;
- parasitology;
- urban determinants of health and disease (urban hygiene);
- housing determinants of health and disease (housing hygiene);
- principles of toxicology;
- toxicological chemistry;
- public health and environmental legislation.

5.1 Common public health subjects

It can be seen from these two examples that there are common public health subjects in three rather disparate fields of activity:

- epidemiology;
- principles of toxicology;
- public health and environmental legislation.

By following this scheme of evaluation, a matrix was created of the fields of activity and the public health subjects, which produced the 28 topics which appear in Annex 4. The topics most frequently arising are the eight marked with an asterisk (in alphabetical order):

- epidemiology;
- parasitology;
- principles of human physiology;
- principles of toxicology;
- public health and environmental legislation;

- sanitary biology and microbiology;
- vector control;
- waterborne diseases.

These were common for most fields of activity of sanitary engineering and, therefore, could be considered the most relevant.

6. Curriculum topics

An initial list of curriculum topics (comprising about 90 subjects) was taken from the consultant report by Professor L. Mendia.[a] Many of these were in the technical area of sanitary engineering, but the topics of Annex 4 are mostly included in the initial list.

The Consultation concluded that the remaining 20 topics of Annex 4 which are not marked with an asterisk should be considered as optional. The topics selected should depend on the employment envisaged for the sanitary engineering graduate. Other constraints may also affect the choice, depending, for example, on the resources of the training establishment.

Certain terms from the initial list were redefined to make the title more appropriate. Where this has happened, the old title appears in brackets. The new definitions appear as a footnote to Annex 4.

No attempt was made by the Consultation to detail the course content to be covered by the titles in Annex 4. It was felt that this would be more appropriately done by teachers who are experts in the various subjects in the training establishments.

7. Training of teachers

In order to encourage the public health orientation in sanitary engineering training programmes, the Consultation recommended that WHO organize a summer school type of course for teachers of sanitary engineering in the European Region. This should include instruction, particularly in the newer health-related topics, to train the teachers as well as promote a health-orientated attitude.

8. Conclusions

8.1 The scope of the Consultation was the training curricula in the sanitary engineering programmes, which apply a public health approach to sanitary engineering.

8.2 The task of sanitary engineering was defined as: "To adapt man's environment by engineering means to the requirements of his health".

8.3 The purpose of the Consultation was to prepare detailed recommendations to WHO regarding the public health, biological and medical components of sanitary engineers' training curricula, in accordance with the public health role of sanitary engineering.

8.4 The Consultation considered that the training programmes should transfer:

- knowledge (savoir);
- skills (savoir-faire);
- attitudes (savoir-être).

8.5 It was assumed that engineers have a basic training in engineering (mathematics, chemistry, physics, electrical technology, material properties, structures, solid and fluid mechanics, economics, measurement, design) and would come principally from a civil engineering background, although some could be agricultural, chemical or mechanical engineers.

8.6 It was also assumed that sanitary engineering training as such would include technical aspects of water management and supply, wastewater disposal, air pollution control, solid waste management and other engineering installations and operations. This allowed the recommendations, required in 8.3 above, to concentrate on the health components of training.

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[a] Mendia, L. Study of availability and content of environmental health courses in Europe. Copenhagen, WHO Regional Office for Europe, 1982 (ICP/EHP 002).

8.7 The employment of sanitary engineers was considered to be based in central and local governments, consulting, industry, teaching and research. The relative importance of these areas varies among different countries. For example, in France, governmental agencies are the principal employer and, in the USSR, engineers are advisers on technical problems to physicians in the management of the system of sanitary-epidemiological services. Many European engineers work in developing countries.

8.8 A number of fields of activity were identified as being relevant (Annex 3). These were evaluated in terms of needs:

- to identify the health implications;
- to establish standards;
- to assess the health effects of the engineering intervention.

8.9 The 90 curriculum topics from the consultant report by Professor L. Mendia[a] (pp. 18-22) were classified by their application to:

- human health;
- processes and engineering installations;
- the environment and nature.

8.10 The list of 26 curriculum topics from 8.9 above, plus two more which were considered as relating to human health, are shown in Annex 4.

8.11 Certain words were newly defined and the list in Annex 4 is in terms of the new definitions, with the old titles shown in brackets. It was recognized that in some teaching programmes certain words were given different meanings. Therefore, the definitions which appear in Annex 4 were adopted.

8.12 The fields of activity of Annex 3, referred to in 8.8 above, were examined by the criterion, "What does the sanitary engineer need from public health subjects to carry out his task?" This produced eight major curriculum components. Obviously, these are common for most fields of activity of sanitary engineering and, therefore, could be considered the most relevant. The remaining 20 were less frequently required and, therefore, could be considered as optional but relevant and often desirable.

9. Recommendations

9.1 International recognition should be accorded only to those sanitary (or public health) engineering courses in Europe which stress public health in their curriculum.

9.2 Collaboration with the network of European environmental health engineers and scientific training institutions should be maintained in order to develop continuing education of these professionals at national and international level.

9.3 All sanitary (public health) engineering training institutions in Europe should be encouraged to revise their curricula in accordance with the conclusions and training recommendations of this Consultation.

9.4 A refresher course on public health matters for sanitary engineering teachers in Europe should be organized in 1984-1988 in order to promote the recommendations of this report.

9.5 The Directory of Sanitary Engineering Courses in Europe should be finalized in two parts: the first giving broad information on the situation of the training of environmental health engineers and scientists in each country of the Region, the second giving detailed information on existing courses of international significance, this information being needed by fellowship officers among others.

9.6 Training programmes for sanitary engineering should contain curriculum components based on public health topics to enable sanitary engineers to apply a health approach to their professional work.

9.7 The public health curriculum components, as indicated in 8.12 and Annex 4, should accompany the normal technical subjects which are necessary to the planning, design, construction and operation of sanitary engineering installations.

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[a] Mendia, L. op. cit.

9.8 The public health components should include appropriate education in knowledge, skills and attitudes. The latter, in particular, which are important to a health orientation, should be provided by contact with teachers from medicine and other health professions. "The content of other public health components of the curriculum may also benefit from contact with teachers from medicine and other health professions."

9.9 Public health components to be selected should depend on the professional employment envisaged for the sanitary engineering graduate.

9.10 The public health components (in alphabetical order) which should be considered most relevant (marked with an asterisk in Annex 4) are:

- epidemiology;
- parasitology;
- principles of human physiology;
- principles of toxicology;
- public health and environmental legislation;
- sanitary biology and microbiology;
- vector control;
- waterborne diseases.

Annex 1

PUBLIC HEALTH COMPONENT OF SANITARY ENGINEERS TRAINING CURRICULA

by
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1. Introduction

It is 12 years since WHO published a book entitled, "The education and training of engineers for environmental health" (1). That book was the outcome of a report (2) of an expert committee convened in 1967 to review the subject. (The recommendations of that report are reproduced, for information, in Appendix 1; it is not particularly useful to review items as they are rather general in nature.) Those publications were to update the guidelines for engineering education in environmental health, which had appeared in an even earlier monograph in 1956 on "The training of sanitary engineers" (3).

The argument in the 1967 expert committee report was that both the scope of environmental health and the education of engineers had developed dramatically in the previous decade and new requirements and opportunities had arisen. These were discussed in the 1970 book under three principal headings:

- the work of the environmental health engineer;
- trends in modern engineering education;
- new developments in environmental health engineering.

Eleven essays explored various topics under these headings. On the whole, these essays were commentaries in special fields (mathematics, systems analysis, design, social science, computers, epidemiology, instrumentation) and somewhat exhortative to those who prepare and teach engineering curricula. The chapter by J.A. Logan entitled "Trends in environmental health engineering education" particularized most, by quoting a list of recent developments in engineering education from the 1967 expert committee report.

This list included references to the greater scientific, rather than applied, content of basic engineering educational programmes. This scientific content itself was based on school-level fundamental science which was growing less compartmentalized and traditional. The list recognized a more analytical approach to design and decision-making, which with the aid of computers had enabled systems to be planned in a more coherent way than previous methods of linking unit operations. Engineers not only had to be more technically competent but more aware of the social implications of their work. New educational facilities, such as miniaturized laboratory equipment, programmed learning, information storage and retrieval, were recognized. The need for advanced and continuing education for engineers was stressed. It was concluded that, in addition to the humanities and social sciences, all engineers should have a fundamental background in mathematics and statistics, physical sciences and engineering sciences (solid and fluid mechanics, materials, thermodynamics and electrical science).

That fundamental background seems quite acceptable, as it is a restatement of what has been included in university engineering programmes for decades. However, the list reiterated by J.A. Logan included the statement that all environmental health engineers should, in addition, study systems analysis, epidemiology, biology (including physiology), biochemistry and management (including policy, law, administration and finance). This is a most controversial statement, requiring the engineer to be educated in fields of other professional specializations for which he may not have had sufficient background training. The statement also refers to "an environmental health engineer", which J.A. Logan previously defined as one who must deal with the environment as a system, controlling, modifying or adapting it in the interest of the wellbeing of mankind. (This definition followed closely a smiliar one of the 1967 expert committee report.)

It is a pity that the imaginative and rather idealistic requirements of this definition, the list of the trends in education, and the specialized essays of the 1970 book were not met by the examples of educational programmes given in the final part of the book. With the exception of the

American examples (Berkeley, Chapel Hill), the curricula appeared to be traditional in the sanitary engineering mode. It is not clear whether the examples were typical or exceptional in the regions which they represented. However, it must be remembered that these documents, emanating from WHO Geneva, had to take into account the global situation. There are still many areas of the world where conditions of primitive water supply and sanitation and relatively uncontrolled industrial development still require engineers and others trained in traditional skills, without the perception and resources of engineers operating exclusively in the sophisticated societies of highly industrialized countries.

However, that was the case in the late 1960s. The expert committee report of 1967 and the book of 1970 were attempting to set guidelines for the final three decades of the twentieth century. Some of the trends have, indeed, now developed further: computer technology, computerized data bases which are accessible worldwide, regionalization of water management, and international cooperation in monitoring, standards and development. In addition, the revolution in environmental awareness has promoted public interest and participation in areas that were traditionally only the remit of conservationists and ecologists; energy management has become a prime concern of governments and industry; biotechnology has emerged with its attendant servant, genetic engineering.

It is a useful time to take stock of developments in the last one and a half decades to establish for the European Region what should be the public health component of sanitary engineers' training curricula.

2. The environmental revolution

2.1 The Club of Rome and after

It was Rachel Carson's "Silent spring" (4), first published in 1962, which aroused public interest during the 1960s in the damaging effects of pollution of the environment. The Club of Rome's publication "The limits of growth" (5), which appeared in the early 1970s, took an even wider view and saw environmental pollution as one aspect of a rape of the world's resources, both those that were being unrenewably utilized and those that were being irreversibly polluted. A spate of publications followed, some dealing with global society, even advocating an abandonment of modern industrial society for a more agrarian self-sufficiency of diffused populations (6), but many authors dealt with particular problems of limited mineral resources, water and air pollution and recoverable materials from wastes, and thus entered the professional sphere of the sanitary (public health) engineer.

This period also saw a decline in applications to study engineering (in western society), based on a disenchantment with technology, which young people saw as the cause of this plundering of resources. To combat this view, many engineering courses included such subjects as pollution control technology and "the engineer in society". Fortunately, most engineering educators maintained a sound body of instruction based on the required engineering disciplines which produce competent, forward-looking designers and constructors. To these core disciplines were made available optional subjects broadening the engineers' perspectives about their work. A few attempts were made to produce environmental specialists, some based on biological sciences or geography and occasionally on engineering. It seems that very few employment opportunities arose for such graduates, industry and government generally showing a marked preference for traditionally trained engineers (civil, mechanical, chemical), with added specializations in environmental matters. The other factor which led to decline in employment opportunities for environmental specialists was the oil crisis of the mid-1970s.

2.2 The oil crisis

The rapid change in Middle East oil prices and the powerful emergence of OPEC in the mid-1970s changed the industrial world's attitude to energy almost overnight. Protection of the environment became a luxury compared with the necessity of energy conservation. Resources in teaching and research were switched from pollution problems to energy exploitation. Engineers who may have concerned themselves with oil pollution of the sea and coastline found themselves suddenly changing to marine technology of offshore structures for oil exploration and exploitation. This changed the emphasis of much of technology, although certain links between the environment and energy were strengthened, e.g. methane production from sewage sludge, nuclear power production, and waste effluents from coal-to-oil conversion.

2.3 Microchemical contaminants

Proceeding in parallel with the environmental revolution, and sometimes being fed by it, has been a growing concern with microchemical contaminants or micropollutants. The water engineer had been traditionally concerned with substances measured at the milligramme per litre (or part per million) concentration level, e.g. residual chlorine at 0.5, fluoride at 1.0, nitrate nitrogen at 10 mg/l. Now, standards are being advised at the microgramme per litre level, such as lead at 50, mercury at 2, lindane at 4, heptachlor at 0.1 and total trihalomethanes at 100 µg/l.

These new standards are based on the perceptions that (i) industrial or agricultural operations are releasing such substances (and that they may be modified into potentially more dangerous forms, e.g. the microbial methylation of mercury, and the chlorination of hydrocarbons); (ii) the micropollutants may have human toxicological effects (including mutagenic and carcinogenic); and (iii) the chemist has the ability to measure the micropollutant concentrations. Health hazards from new environmental pollutants in air, water, soil and the biosphere were assessed by a WHO study group in 1976 (7).

Fashions come and go in such concern for micropollutants, and technology can too easily be driven into providing expensive control and treatment methods which may not be justified in the long term. Engineering hardware takes longer to develop and lasts longer (using capital and interest) than microchemical analysis. This slower and more costly response in engineering terms must be safeguarded from the fashionable winds of change from chemists, toxicologists and others, so engineers require education in the appraisal and significance of such concerns for the microchemical environment.

Public awareness of microchemical dangers normally remains low, but accidents such as at the nuclear power reactor at Three Mile Island, the spillage of pesticide into the Rhine or the dioxin escape at Seveso suddenly bring pressure to bear for some form of control. The engineer, among others, must respond to such public concern, but in an informed and balanced way, because panic legislation can be modified or rescinded and microchemical analysis can be reappraised, but engineering hardware can stand as a monument to folly if it was designed and constructed in unnecessary haste.

2.4 Sanitary (public health) engineering

In the midst of all this pressure from environmentalists, energy conservationists and micropollutant experts, the sanitary (public health) engineer has had to continue his practical role of locating, designing, constructing and operating engineering works which will safeguard or improve the health of the public. This has involved the traditional areas of responsibility in water and wastewater, air pollution and solid waste management, together with a growing role in noise control. The public health content of these areas has been intensified due to the new concerns in the environmental domain and has resulted in reappraisals of existing technology (such as the role of chlorine in the formation of trihalomethanes and alternatives for disinfection) and consideration of newer technologies (e.g. reverse osmosis).

3. Biotechnology

Biochemical engineering has existed for many years as an educational discipline, which arose from traditional industries concerned with food processing, fermentation and brewing which relied on microorganisms to effect some of the conversions in the manufacturing processes. To these were added developments in the pharmaceutical industry mainly due to antibiotic production, and biochemical engineering became an area associated with chemical engineering, with special requirements of feedstock, reactor design, sterile and monoculture conditions. Occasionally, biochemical engineering acknowledged the presence of sanitary (public health) engineering, but usually when a special industrial waste arising from the biochemical industries had to be treated.

Recently, a new impetus has been given to the use of microorganisms to produce industrially useful products. Some of these are fine chemicals and pharmaceuticals such as specialized enzymes; others are animal food such as single cell protein, and others are biomass production which may be used, for example, as an energy source. This newly emerged biotechnology has attracted industrial and governmental interest, and funds for education and research are now flowing in many cases towards the universities. Its associated subject of genetic engineering offers great potential for the manipulation of microorganisms for specific biochemical processes. This biotechnology is undoubtedly expensive, with very exacting requirements for its process design, and mainly concerns itself with products of very high market value.

Yet it seems that quality and sophistication are not enough. Some advocates of the importance of biotechnology have referred to the large existing operations of biological treatment of wastewater and claimed that they are part of biotechnology. This adds scale to biotechnology's importance, because undoubtedly the tonnages of product - purified effluent - exceed by far any chemical or biochemical engineering production process. However, the enthusiasm of biotechnologists reduced when they realize the extremely low operating costs per tonne, for what is usually a throwaway product, so it does not seem likely that biotechnology will embrace biological wastewater treatment in a very committed manner, although it may insist that it is part of the biotechnology discipline.

This means that sanitary (public health) engineers are not likely to find biological wastewater treatment taken over by biotechnologists, but the advent of biotechnology cannot, therefore, be ignored. There is some evidence that students of biotechnology (and their teachers) are interested in learning about biological wastewater treatment and the disposal of solid organic wastes. The sanitary (public health) engineer will want to know what types of wastes (liquid and solid) are likely to be generated by biotechnology industries; he may learn something of reactor design and operation for microbiological processes; he may find applications of genetic engineering of microbes for special waste treatment problems; he may have to be aware of the hazards of release of gentically manipulated microorganisms into the environment via waste materials or by accident.

Later, a reference will be made to an undergraduate engineering course where civil (sanitary-public health) engineers, chemical engineers and biochemical engineers (biotechnologists) study, and are examined, together.

4. The European context

The European Region of WHO is not homogeneous; it divides in several different ways: culturally, politically, commercially, linguistically and in climate. In terms of sanitary (public health) engineering, the broad division is between the north and south. The north is characterized by an industrial society with a long history of public water supplies, urban sanitation, highly developed waste disposal systems and integrated control over pollution problems. In the south, reliable water supplies are not yet available to all communities (nowhere near approaching the 99%+ of the populations which are served by public water supplies in northern European countries). Sanitation in the south has not generally kept pace with urban growth. Air pollution control has lower priority in the south than in the north; solid waste collection and disposal is less firmly established in the south. The contrasts between such cities as Istanbul and Rotterdam, both large city ports, or Athens and Stockholm, both capitals near the sea, or a rural area in southern Portugal with a rural area in southern England, exemplifies these north-south differences.

It follows that the European sanitary (public health) engineer cannot limit his education only to problems of modern industrial societies of the north European type. The recent (1978) WHO seminar on environmental health impact assessment (8) discussed the merging problems of environmental changes and their health implications in a general way, but it was the case studies from France, the United Kingdom, Czechoslovakia, Greece and Yugoslavia which revealed the difference in emphasis. The French example related to an industrial complex including petrochemical industries. The United Kingdom example dealt with nuclear energy and with oil-related development. Czechoslovakian experience in intensive farming was described. In contrast, the Greek experience with the liquid wastes of Athens and the resulting pollution of the nearby coastal sea waters was recounted. The Yugoslav study, however, concentrated on another typically south European problem: tourist development of coastal areas.

The problems of tourist areas were discussed in detail at another WHO meeting, again in 1978, on environmental sanitation in European tourist areas (9). The report of this meeting dealt mainly with the coastal regions, particularly the Mediterranean basin, but it also referred to the special problems of sanitation and pollution control in mountain resorts, principally for winter sports. These tourist pressures are seasonal and may be expected to recur annually, so engineering investment should be worthwhile even if the design calls for intermittent, but high intensity, operation. Another related problem, not directly referred to in the report, is that of near-singular events, such as a special festival, the Olympic Games or World Cup football series. These bring intense, short-term demands on water, sanitation and health facilities (among others, for hotels, transport, etc.) and are likely to be unique. Some more package-type, temporary design of facilities is required which the engineer must treat in a very different way to a permanent installation.

4.2 Overseas work

European influence in developing countries is strong, particularly in technology. The cultural and linguistic associations of the British Commonwealth and the former French Empire maintain links in education, standards and practices. The bilateral agreements in culture and trade between various European and developing countries often results in transfer of technology. The World Bank and other international agencies (including WHO) often proffer advice, design and supervision of engineering works from Europeans, and international tendering for supply and construction of new works and equipment usually involves European companies (10).

The International Drinking Water Supply and Sanitation Decade has emphasized international collaboration in sanitary (public health) engineering, and there is a steady demand for well-qualified engineers from Europe and elsewhere to advise and work in developing countries. This means that the education of engineers cannot neglect the classical areas of public health engineering: epidemiology of water-related diseases, parasitology, vector control, rural sanitation and waste disposal, as well as the significance of water resource development in tropical areas.

As a number of engineers from developing countries come to Europe to study (at the postgraduate Delft international courses, for example), it may be argued that courses of study for tropical sanitary (public health) engineering should be arranged. These would then operate exclusively for those from tropical developing countries and Europeans who intend to work in them. This would be a false provision if it were to be intended for young engineers undergoing their first university-level education. It would specialize them, on the one hand, yet deny them the intellectual stimulus of dealing with the problems of modern sophisticated societies, on the other. Also, it would assume that European engineers would know, or have to decide in advance, that they were going to work for a significant period in a developing country.

It may be better to limit sanitary (public health) engineering education in Europe to a largely nontropical content and deal with the problems of developing countries in a postgraduate manner, possibly as a series of intensive short courses such as those organized at the Loughborough University of Technology in the United Kingdom.

5. Engineering education

5.1 General

It is difficult to generalize about engineering education in Europe, as there are several different systems currently operating. It seems that a general education provides a background in a wide range of subjects for students up to the age of 18. After that, engineering students engage in studies in universities, polytechnics or special institutes, and some practical training is included in these studies or follows them after academic work is concluded. The overall result is that, after a total of about five to eight years of academic and practical education, the engineer is qualified to practise and take responsibility for design and construction. This leads to the designation Chartered Engineer, Ir., Dipl. Ing., etc. The patterns within each country seem much the same whether the engineer is civil, mechanical, electrical, electronic, chemical, aeronautical, naval, etc.

5.2 The secondary school basis

Secondary schooling, occupying the pre-university years up to the age of 18, usually provides a broad basis in humanities (literature, languages, history, geography, philosophy, art and world affairs) and in sciences (mathematics, chemistry, physics, biology, and technical sciences such as handicraft, technical drawing).

It is the sciences, particularly the physical sciences of mathematics, chemistry and physics, which form the basis of further education in engineering. Generally speaking, engineering students are not so well acquainted with biological sciences, and this becomes a handicap for those who progress through civil engineering to sanitary (public health) engineering.

5.3 Civil engineering courses

Most sanitary (public health) engineers are educated initially as civil engineers, because of the historical connections between the work of the civil engineer and the design, construction and operation of municipal engineering works including water supply, drainage, sanitation and collection and disposal of domestic refuse.

As a consequence, on the basis of mathematics, chemistry and physics learned at school, the civil engineer is educated in further mathematics, statistics and computing, surveying, materials, statistics and dynamics, structural and soil mechanics, process (kinetics), electrical science, fluid mechanics, modelling (physical and computer) and optimization techniques. Associated with these studies are laboratory and design courses In addition to these predominantly physical subjects, there are often other topics, some of which are optional. These include management, law, building science (services engineering for heating, ventilation, lighting, etc.), economics, geology, transportation. Very rarely is a civil engineer instructed in any further biology or biochemistry, except if his subjects include sanitary (public health) engineering.

Sanitary (public health) engineering is offered in some undergraduate courses, but usually only in the final year. Therefore, there has usually been a break of a few years since the student last encountered any biological subjects. It is necessary then to reacquaint the student with biological terms and significance, to partially reorientate his mind from the strongly physical, and rather deterministic, training he has received as an engineer. The biology must then be focused on those aspects which are significant in the domains of public health which are the province of the sanitary engineer. Examples of the curricula of two undergraduate final year courses involving public health aspects, for University College London, are given in Appendices 2 and 3.

Frequently, sanitary (public health) engineering courses are postgraduate, typically one year in duration. In some cases, they follow directly from basic education in civil engineering. In others, they are organized for engineers with several years of experience in the field, as exemplified by the international courses at Delft, Netherlands.

It is significant that among those who study and practice sanitary (public health) engineering are an increasing number of chemical, and latterly biochemical, engineers. Such engineers are already well acquainted with process and reactor design and the chemical changes which take place in purification operations. Usually, they are less familiar with the scale and economic values used in municipal enterprises and the public responsibility aspects of sanitary (public health) engineering. Although their knowledge of process biochemistry is usually far superior to that of the civil sanitary engineer, their knowledge of the health biological consequences is no better developed.

6. Public health

6.1 Limits of application

From the background described in the foregoing pages, it is evident that the public health and biological components of the training curricula of sanitary (public health) engineers fall into three general areas: classical public health and hygiene relating to water supply, sanitation and solid waste disposal, public health aspects of south European areas, and public health of more recently discovered significance of highly industrialized societies (north Europe).

These have to be maintained in the context of the engineer's responsibility: to design, construct and operate hardware, particularly in the municipal engineering field, so that it either causes no danger or reduces or eliminates danger to the health of the public. This does not then confuse the work of the engineer with that, for example, of the medical doctor, the factory inspector or the monitoring chemist, although he may well work in cooperation with all of these. It follows that such an engineer is not involved directly with industrial hygiene, occupational health or safety, which are in the domains of other professionals. The word "hardware" is general, referring to constructed items such as tanks, pipes, chimneys, dams, embankments, filters, etc. The engineer may also be responsible for software such as operating regimes and control strategies, but these should related to hardware and not to areas such as legislative control or political decision. Those are important, and the engineer may give his advice as an expert, but legislation should be drafted and enacted by lawyers, and political decisions by politicians, and economic strategies by economists, etc.

6.2 Classical public health and hygiene

The historical development of public health in the nineteenth century, the appreciation of waterborne and vector-transmitted diseases can be combined with an appreciation of current conditions in tropical developing countries. It follows that the following topics should be taught:

(1) public health and hygiene: historical development;

(2) microbiology: classification of microorganisms, growth conditions, symbiotic and host-predator relationships, ecological factors, hot climates;

(3) epidemiology: human health;

(4) water-related infections: classification, waterborne diseases, water-related diseases, water-based diseases;

(5) water-related insect vectors of diseases;

(6) diseases of defective sanitation;

(7) irrigation schemes and man-made lakes: health implications; health protection for staff and workers; displaced people, immigrants; vector-borne diseases;

(8) entomology and helminthology of sewage treatment, sanitation and waste disposal: flies, other insects, helminth biology and transmission, effects of sewage treatment;

(9) agricultural use of excreta, sewage, reclaimed wastewater, compost in relation to health hazards;

(10) solid wastes: vector control (flies, rodents, dogs, etc.), human scavengers, leachates, fire hazards;

(11) sociocultural aspects of health control in developing country urban and rural communities.

These aspects of public health are dominated by the possible biological hazards. Although there are possible chemical dangers (e.g. high fluoride water), these are not so common as the many biological factors: widespread contamination, endemic diseases, insect and other vectors and high temperatures associated with tropical developing countries.

Much of the foregoing list appears in greater detail in the book edited by Feachem, McGarry and Mara, "Water, wastes and health in hot climates", published in 1977 (11).

6.3 South European public health

The South European situation, as discussed in section 4.1 lies, somewhere between the tropical developing country and a highly industrialized community in its public health. Summer temperatures are high, frequently approaching 35°C, insects breed rapidly and sanitation is not fully developed. Yet there is a technical society, and medical-health framework which can react to a potentially dangerous health situation. In general, provision of water supply exceeds that of adequate sanitation.

Consequently, the principal topics to be taught are:

(1) public health and hygiene, historical development;

(2) microbiology: classification of microorganisms, growth conditions, symbiotic and host-predator relationships, ecological factors, temperature effects;

(3) epidemiology: human health, biostatistics;

(4) parasitology;

(5) vector agents of disease;

(6) diseases of defective sanitation;

(7) solid wastes: vector control (flies, rodents, dogs, etc.), public access, leachates, fire hazards, uncontrolled dumping of dangerous chemicals;

(8) agricultural use of excreta, sewage, reclaimed wastewater, compost in relation to health hazards;

(9) uncontrolled industrial development: pollution of rivers, lakes, sea, air and associated health hazards;

(10) tourism: water and sanitation for tourist hotel complexes, caravan parks and camps, beach resorts, mountain resorts, bathing beach standards;

(11) health considerations of migrant populations.

A book which appears to deal directly with such a south European situation is the WHO Public Health Paper by Brisou on "An environmental sanitation plan for the Mediterranean seaboard" (12). Also, some of it appears in "Environmental sanitation in European tourist areas" (9) and a chapter on "Recreation areas and temporary residences" in the book by Salvato (13).

6.4 North European public health

The north European requirements for a public health element in sanitary (public health) engineering education are complicated by the sophistication of an industrial society: in its integrated technical/commercial/social structure, the highly linked aspects of political control (e.g. the many government ministries involved in environmental affairs at national, provincial and local levels), and high public awareness fed by powerful news media.

From the scientific/medical/technical point of view, it is possible to identify five areas of hazard to the health of the public; these are microbiological, inorganic chemical, organic chemical, radiation and noise. These may operate in the water, air, soil or ambient contexts. The special cases of food and beverages, occupational hygiene and safety are excluded, for although they may affect the overall exposure of any individual, they do not affect the public in the sphere of the professional activities of the sanitary (public health) engineer.

Before embarking on these five public health areas, they must be placed in a context of the exposure of the public to risk and its methods of assessment. This would require some instruction in:

(1) Man and environmental exposure; physiological basis of health hazards from ingestion, inhalation, radiation and excessive noise; toxicology.

(2) Biostatistics and epidemiology.

In addition, some general instruction has to be given, reinforcing existing knowledge in basic science:

(3) Microbiology.

(4) Chemistry, inorganic and organic compounds and their reactions.

(5) Physics, including radiation and acoustics, aerosols and meteorology.

Then it should be possible to proceed to some instruction in the five areas. One possible approach is to take case studies of particular contemporary problems and from these develop a philosophy of approach by the sanitary (public health) engineer in his work of design, construction and operation. The following are examples of contemporary topics for student seminars and are not meant to be exhaustive.

(6) Microbiological hazards. These would include human viruses in water, wastewater and soil (14), droplet infection in aerosols (e.g. near sewage aeration tanks), Legionnaires' disease, health aspects of treated sewage reuse (15), transfer of microorganisms by air travel, genetically manipulated bacteria.

(7) Inorganic chemical hazards. Lead (in water from plumbing, in air from vehicle emissions, in soil from atmospheric fallout or waste disposal), heavy metals in sludges, mercury and its methylation, soft water and cardiovascular disease, nitrates in water, nitrogen compounds in the atmosphere, acid rain, asbestos (and its use in construction, pipes, etc.), ozone compounds, toxic solid wastes, aerosol particles.

(8) Organic chemical hazards. Pesticide residues in water and soil, polycyclic aromatic hydrocarbons in air and water, PCBs, detergent residues, chlorinated hydrocarbons, trihalomethanes, synthetic polyelectrolytes and their monomers in water treatment, aerosol spray gases, toxic sludges and semi-solid wastes.

(9) Radiation hazards. Transport and disposal of radioactive wastes, siting of nuclear power plants, contamination from nuclear accidents.

(10) Noise hazards. Hearing losses over the frequency range: temporary and permanent; acoustic baffling: personal, structural (sound insulation, double glazing, etc.), and environmental (embankments, trees, fences, etc.); noise hazards from construction, road traffic, aircraft, entertainment (discotheques, pop concerts).

Recent commentaries on some of these contemporary problems appear in van Lelyveld & Zoeteman (16) and Chanlett (17).

7. Problem solving

The engineer cannot solve his practical problems in isolation. In a structural-technical sense, the design of the whole is not just a collection of the designs of parts, because of structural interactions. The same is true of designs in the sanitary (public health) engineering domain. The site location, the supply and disposal of the water, wastewater or solid wastes, the flow conditions, the structural conditions, the process requirements and the public health aspects must be integrated.

In addition, the constructed and operated works do not function in isolation: they must fit the economic framework of the community, they provide employment, they generate secondary activities (e.g. transport, parking, canteen facilities, sports and recreation for the workforce, housing). Also, in modern developed communities, there is an awareness, caused partly by the environmental revolution, of public health facilities. This awareness can be a matter of local civic pride or strong local criticism.

It is essential, therefore, that the sanitary (public health) engineer, in his education and training, can exercise this integrative function. The local community is more likely to react and demand action if aspects of public health (as discussed in 6. previously) are posing hazards than to be concerned if the flow in a process unit is unstable or a control valve is malfunctioning. In either case, the engineer's response may have to be a hardware adjustment to rectify the problem, but his knowledge of public health aspects will enable him to evaluate the public concern and take appropriate action. In the United Kingdom, for example, this part of an engineer's training is ensured by testing his understanding of "The engineer and society" before qualifying finally as a chartered engineer.

8. Summary and discussion topics

8.1 Summary

(1) The 1970 WHO publication on "The education and training of engineers for environmental health" provided a very broad view of the components concerning the environment to be included in engineering curricula. The all-embracing nature of its proposals may have deterred educators by the demands for teachers and teaching. Also the "environmental engineer" who would be produced may not yet have a clearly-defined employment opportunity.

(2) Since the meeting of the 1967 expert committee and the 1970 WHO publication, some developments have affected engineering education and research. Principally, these have been the environmental revolution and its associated public awareness and the world energy crisis and economic recession. One focused attention on environmental matters, the other deflected attention away from what industry and some governments regarded as a luxury (concern for the environment).

(3) The International Drinking Water Supply and Sanitation Decade has increased general awareness of public health problems associated with water in developing countries.

(4) The role of the sanitary (public health) engineer has continued to be important in Europe (and elsewhere) in the traditional areas of water supply, wastewater disposal, air pollution control and solid waste disposal.

(5) Chemical and biochemical engineers have shown an increasing interest in these environmental matters, some of this interest being stimulated by the emergence of biotechnology and genetic engineering of microorganisms.

(6) There still appears to be a need for civil engineers (and possibly chemical engineers) trained in their traditional disciplines, including sanitary (public health) engineering. However, new awareness of requirements in tropical developing countries, south Europe and north Europe requires a reappraisal of the public health component of education.

(7) The tropical developing country aspect of public health includes hygiene, microbiology, epidemiology, diseases relating to water, defective sanitation, insect and helminths, agriculture, solid wastes and sociocultural factors.

(8) The south European aspect includes hygiene, microbiology, epidemiology, human health, parasitology, vector agents of disease, sanitation, solid wastes, agriculture, industrial pollution, tourism and migration.

(9) The north European aspects require a more integrated appraisal of environment, toxicology, biostatistics and epidemiology. A stress on microbiology, chemistry and physics should lead to studies in contemporary microbiological hazards, inorganic and organic chemical (including microchemical) hazards, radiation hazards and noise hazards.

8.2 Discussion topics

(1) Has there been a change in the requirement of the public health component of sanitary (public health) engineers' training curricula in the past 15 years?

(2) If yes, what new factors have affected this requirement?

(3) What new knowledge is now required?

(4) Are the traditional subjects of chemistry, microbiology, biostatistics, epidemiology, parasitology and entomology still appropriate?

(5) Is an alternative structure based on: (a) water contact, air contact, soil and ambient conditions; or (b) biological, inorganic chemical, organic chemical, radiation and noise hazards; more appropriate?

(6) Can any parts of traditional curricula now be omitted?

(7) If no, how can the new knowledge be incorporated into the already crowded curricula of engineering education?

(8) What new laboratory or field study provisions will be required?

(9) Should all sanitary (public health) engineers be trained to the same level of competence in public health aspects?

(10) Are there different requirements for tropical, south European and north European components of public health training?

(11) If yes, should these represent options in sanitary (public health) engineering training curricula?

(12) Who will train the teachers?

(13) Is research to be reoriented as a result of changes in the past 15 years?

Appendix 1

RECOMMENDATIONS OF THE EXPERT COMMITTEE ON THE EDUCATION OF ENGINEERS IN ENVIRONMENTAL HEALTH (2)

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 cooperate, e.g. in exchange of information, support for educational programmes, provision of fellowships and 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 cooperation is urgently recommended for countries developing university-level programmes in environmental health engineering. Cooperative action by international and other agencies can play an important role in promoting such regional cooperation. 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.

Appendix 2

UNDERGRADUATE COURSE IN PUBLIC HEALTH ENGINEERING AT UNIVERSITY COLLEGE LONDON

Note: This course is one of 12 options, of which six must be chosen to be studied in the final year of the Bachelor of Science in Civil Engineering degree, together with some compulsory subjects.

Time allotted 46 hours lectures, 9 hours laboratory.

Elementary aquatic biology

Microorganisms: discovery, physiological classification, growth requirements, metabolism and biochemistry, genetic aspects
Bacteria: growth kinetics, water-related diseases, water examination and treatment, sewage treatment
Viruses, higher bacteria, fungi, algae: distribution and significance in health and treatment processes
Higher plants: control in new reservoirs, eutrophication
Protozoa: ecology and health significance, role in treatment processes
Matazoa: growth in pipes
Helminths, crustacea, insects: significance in health and treatment processes

Water chemistry

Equilibrium and kinetics, stoichiometry
Decomposition and synthesis: role of oxygen, BOD, aerobic and anaerobic reactions, organic carbon, nitrogen and sulfur cycles
Disinfection: chlorine, chlorinated compounds, ozone, ultraviolet
Hardness and alkalinity, pH, precipitation
Ion exchange, adsorption processes
Reactor theory
Colloids: electrical and molecular forces, perikinetic flocculation, mineral salts (aluminium, ferric), polyelectrolytes
Radioactivity in water
Standards
Analytical methods

Unit processes

Sedimentation, flocculation, filtration, fluidization, microstraining, flotation
Gas transfer
Aerobic biological processes
Anaerobic biological processes
Sludge dewatering

Water supply

Estimation of supply
Sources
Treatment sequences
Distribution

Wastewater treatment

Flow estimation
Separate and combined systems
Treatment sequences
Sludge disposal

(There are other courses which deal with fluid-particle mechanics, flow in channels, pipes and networks, groundwater flow and river pollution control)

Appendix 3

UNDERGRADUATE COURSE IN CONTROL OF ENVIRONMENTAL POLLUTION AT UNIVERSITY COLLEGE LONDON

Note: This course is one of twelve options of which six must be chosen to be studied in the final year of Bachelor of Science in Civil Engineering, or Chemical Engineering, or Biochemical Engineering degrees, together with some compulsory subjects.

Time allotted 46 hours lectures; 3 essays

Water pollution

Equilibria and kinetics of chemical changes; organic compounds, metals, toxic chemicals, role of N and P.
Biology of rivers and lakes. Biological indicators, toxicity testing, eutrophication.
Oxygen, BOD, re-oxygenation, sag curve.
Temperature and salinity.
Case studies of tidal (Thames) estuary and non-tidal pollution river (Trent).
Pollution modelling and technical and economic methods of control.

Air pollution

Aerosol physics. Sources of particles, shape and nature, physiological effects. Measurement.
Filtration, electrostatic precipitation.
Meteorological effects. Dispersion from chimneys.
Atmospheric stratification, turbulence and velocity profiles.
Long distance and natural pollution.
EEC standards.
UK legislation.

Noise

Acoustics. Weighting networks. Instrumentation.
Perceived noise levels. Physiological basis of noise, and deafness.
Acoustic baffling.
Aircraft, and road traffic noise.
UK legislation.

Solid wastes

Sources: domestic, industrial.
Content, estimation of volumes and masses.
Collection, management, transfer.
Treatment: compression, shredding, grinding.
Materials separation and recovery.
Disposal: sanitary landfill incineration, composting, sea.
Special wastes: toxic chemicals, radioactivity, sludges.

Essays

Each student must write 3 essays each of about 2500 words, suitably illustrated, chosen from the list in Appendix 4.

Appendix 4

ESSAY TOPICS RELATING TO UNDERGRADUATE COURSE ON CONTROL OF ENVIRONMENTAL POLLUTION AT UNIVERSITY COLLEGE LONDON

1. Siting of nuclear power plants.
2. Use and abuse of pesticides.
3. The solution to pollution is dilution.
4. Work of the Royal Commission on Environmental Pollution.
5. Asbestos and health.
6. EEC legislation on water pollution control.
7. Environmental impact assessments.
8. The case for electric vehicles.
9. Lead in the environment.
10. The problem of nitrates in water supplies.
11. The disposal of toxic solid wastes.
12. Detergent phosphates and their possible substitutes.
13. Fish as pollution indicators.
14. Noise-induced hearing loss.
15. Planning new roads to reduce traffic noise annoyance.
16. The global carbon cycle and atmospheric CO_2.
17. Remote sensing of water quality.
18. SO_2 as an indicator of air pollution.
19. Environmental carcinogens.
20. Should aerosol sprays be banned?
21. Environmental effects of tourism.

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Annex 2

PUBLIC HEALTH AND SANITARY ENGINEERING EDUCATION

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Introduction

In order to address the curricula requirements in the training programmes of professionals, it is essential to define, as clearly as possible, the role and function envisioned for the graduates. A discussion of the desirable public health components of sanitary engineering education should start with a number of definitions related to the fields of public health and sanitary engineering. It must be assumed that the graduates will be expected to apply the practice of engineering to those aspects of the environment which may, in one way or another, affect health.

A broad definition of "environmental health" was adopted by the legislative body of the State of Michigan, USA in 1978 as follows: "Environmental health means the area of activity which deals with the protection of human health through the management, control, and prevention of environmental factors which may adversely affect the health of individuals. This activity is concerned with the existence of substances, conditions, or facilities in quantities, of characteristics, and under conditions, circumstances, or durations which are or can be injurious to human health".

In discussing the public health components of sanitary engineering education, this definition of environmental health could serve as the basis for considering desirable curricula development.

Webster's Dictionary defines sanitary engineering as a branch of civil engineering dealing with water supply, sewage and waste disposal and other sanitary problems while a civil engineer is defined as one who is responsible for the design and construction of fixed public works, highways, bridges, water works, canals, harbours and railroads.

Engineers conceive, design and supervise construction of various types of facilities. The field of engineering is considered an applied science concerned with the utilization of inorganic products of earth, properties of matter, sources of power and physical forces for supplying human needs in the form of structures, machines, manufactured products and other productive works.

In 1980, the US Engineers Council for Professional Development adopted the definition of engineering as the profession in which the knowledge of mathematical and natural sciences gained by study, experience and practice is applied with judgement to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

During the past two decades there have been increasing efforts to expand the role of the sanitary engineer in order to address the ever-increasing problems of the environment which affect the health of individuals. In the United States, the term sanitary engineering is being replaceed by the term environmental engineering to reflect the broader impact of engineering efforts on the control and prevention of environmental hazards. Environmental engineering has been defined as that branch of engineering which is concerned with (a) the protection of human populations from the effects of adverse environmental factors, (b) the protection of environments, both local and global, from the potentially deleterious effects of human activities, and (c) the improvement of environmental quality for human health and wellbeing.

The practice of environmental engineering covers the broad scope of environmental areas of specialization including the traditional fields of sanitary engineering, industrial hygiene engineering, air pollution control engineering and radiation and hazard control engineering.

Environmental engineering is, in fact, an interdisciplinary science based on the engineering and applied sciences for which human health and wellbeing is the principal focus. Environmental engineering requires knowledge in the technical fields of air, water, wastewater, solid waste, industrial hygiene, radiation control and other areas of specialization which require engineering consideration of environmental factors affecting human health and wellbeing. In addition, the application of these technical fields to societal needs requires an understanding and knowledge in the fields of law, economics, finance, public administration planning and other social sciences.

Curricula

In the development of an educational programme of study, it is essential to state the objectives in behavioural terms. It is desirable to state what the graduate of the programme is expected to be able to achieve.

If public health and environmental health components are to be incorporated in the education of sanitary engineers, it is necessary to assess the current demand for the services of engineers with the proposed training. The availability of individuals with specialized environmental engineering training which was not previously provided may cause employers to create new positions. On the other hand, if the training programme is expanded to cover new areas of environmental concern at the expense of traditional engineering education, graduates may find it difficult to convince prospective employers of the need for their broad expertise.

If the word "engineering" is part of the degree title, it is essential that the curricula provide the undergraduate student with a sound educational programme of study which should be directed toward the development of the ability to apply pertinent knowledge to the identification and the engineering solution of problems in the several areas of engineering specialization. It is essential to educate all students in the fundamental fields of engineering knowledge in order that they will be able to deal with change.

It would be expected that all students should have a basic undergraduate engineering education which should include at least:

- humanities and social science
- mathematics (through differential equations)
- basic sciences: physics, chemistry, biological sciences
- engineering sciences
- design synthesis and systems

During the undergraduate programme the students should be exposed to the several areas of specialization in the field of environmental engineering in addition to the more traditional sanitary engineering area of specialization. This could include an introduction to problems of industrial hygiene engineering, air resource management, solid waste engineering including hazardous waste problems, radiation control and urban development.

The very nature of the wide range of environmental problems which require engineering solutions poses the problem of breadth as well as depth in the curriculum for environmental engineers. The areas of study include climatological, biological, physical and chemical sciences as well as the social, political, economic and cultural aspects of the engineering approach to problem solution.

The societal needs for environmental engineering cannot be met by engineering generalists who have completed only introductory courses in the broad fields mentioned above. There may be an administrative need for a number of such generalists but the engineering solution to the vast array of environmental problems demands the training of specialists with in-depth course work in the area of specialization.

It is apparent, in order to accomplish the degree of specialization required, that the several areas of specialization should be added to basic undergraduate engineering education through programmes of graduate study in the several areas of specialization. Thus, the student could select the area of specialization which would build on basic sanitary engineering education.

It is not expected that all educational institutions will have the resources required to offer training in all areas of specialization. It is expected that some institutions may find their strength in one area while others will offer programmes of study in others.

The following graduate programme content for four areas of specialization was suggested at the 1980 Conference on Environmental Engineering Education held in Toronto, Canada (1).

1. Air quality engineering - Master's Programme

Fundamentals of air pollution: air pollution dynamics, source factors
Atmospheric sampling and analysis: chemistry of pollutants, sampling and analysis, photochemistry
Meteorology: properties and dynamics of the atmosphere, atmospheric transport and diffusion
Physics: aerosol science and technology, including optical properties of atmospheric aerosols
Air pollution control systems, air pollution management
Applied mathematics: advanced statistics, mathematical models
Biological aspects of air pollution: cell and human biology, effects on vegetation, animals and humans, air microbiology
Thesis options

2. Industrial hygiene engineering - Master's Programme

Applied mathematics: biostatistics, mathematical modelling
Occupational health: audiology, toxicology, radiology, physiology, public health, epidemiology, and safety engineering
Thesis option

3. Solid wastes management - Master's Programme

Resource recovery: conservation and re-use, recycle economics
Microbiology of water, air and soil: applications to environmental pollution control
Analytical analysis: (physical, chemical, and biological) of water, wastewater, air and solid wastes
Solid wastes control and management: characterization, production, storage, collection and transport of solid wastes; alternative disposal methods, design principles and environmental impact; economics of waste management
Combustion engineering: combustion fundamentals, incinerator design
Thesis option

4. Water quality engineering - Master's Programme

General water quality and analysis: sanitary analysis, applied organic and physical chemistry, applied microbiology
Applied mathematics: mathematical models environmental statistics, optimization techniques
Unit operations and design: design of treatment facilities; chemical, physical, and biological systems
Water resources systems analysis, simulation analysis
Thesis option

In all programmes emphasis should be placed on the engineering design component. It is also suggested that the need for communication skills should not be neglected. The above components in the four areas of specialization were offered as a guide for programme development with the full expectation that programmes at various institutions would vary in course content, emphasis, mix of courses and depth of coverage.

Graduate programmes in the United States vary from one institution to another. Some emphasize one or two areas of specialization while others provide graduate educational opportunities in a wide variety of environmental areas. The Association of Environmental Engineering Professors has published a Register of Environmental Engineering Graduate Programs for the United States (2). Although no specific programmes of study have been published, the Register contains a listing of courses offered from which the several graduate programmes of study are developed. Attached to this paper is Appendix A which contains graduate courses offered in environmental engineering from a few selected institutions. These course listings demonstrate the scope of subjects offered, the tendency toward specialization in some schools, a more general approach in others and, above all, the listing demonstrates the lack of uniformity among the several graduate programmes.

Appendix B indicates the scope of environmental health and illustrates the wide range of subjects which may require an engineer's professional involvement.

Appendix A

GRADUATE COURSES OFFERED IN ENVIRONMENTAL ENGINEERING
FROM SELECTED INSTITUTIONS
UNIVERSITY OF FLORIDA

COURSE WORK Designation	Title	Instructor	Credits	Last Pres.	Enrollment
EES 2001	Concepts of EES	Bolch	4	S'80	36
ENV 3003	Environmental Quality and Man	Bevis	4	S'80	43
EES 3008	Energy and Environment	Odum	4	Su'79	21
EGN 3353	Fluid Mechanics	Huber	4	S'80	54
PHM 2142	Systems Philosophy in Ecology	Odum	4	S'80	42
ENV 3939	Undergraduate Seminar	Staff	1	S'80	9
EES 4004	Environmental Engr. Sciences	Heaney	4	S'80	15
ENV 4021	Water and Wastewater Treatment	Zoltek	4	S'80	25
EES 4035C	Environmental Instrumentation	Urone	2	S'80	8
EES 4101	Environmental Microbiology	Bitton	4	S'80	18
ENV 4104	Elements of Atmospheric Pollution	Urone	4	S'80	25
EES 4201	Water Treatment Process Design	Singley	5	W'80	13
ENV 4201	Intro. to Radiological Health	Roessler	4	S'80	25
EES 4241	Intro. to Water Analysis	Hassett	4	S'80	22
ENV 4241	Fundamentals of Radiation Protection	Roessler	4	S'80	18
ENV 4351	Solid Waste Management	Furman	3	W'80	28
EES 4401	Public Health Engineering	Bevis	4	W'80	21
ENV 4404	Water Supply and Wastewater Removal	Furman	3	S'80	20
ENV 4431	Environ. Eng. Design I	Furman	3	W'80	12
ENV 4432	Environ. Eng. Design II	Furman	3	S'80	15
ENV 4514	Treatment of Water and Wastewater	Furman	3	W'80	17
ENV 4905	Individual Studies	Staff	1 - 5	S'80	4
ENV 4932	Special Problems	Staff	1 - 5	S'80	10
ENV 4949	Co-op Work	Staff	1	S'80	3
ENV 5005	Environmental Health	Bevis	4	W'80	5
EES 5007	Ecological and General Systems	Alexander	4	F'79	34
EES 5105	Environmental Biology	Bitton	4	S'80	19
ENV 5126	Intro. to Air Pollution	Urone	4	S'80	8
EES 5206	Survey of Radiological Health	Roessler	4	S'80	4
EES 5245	Water and Wastewater Analysis	Hassett	4	S'80	18
EES 5306	Ecological Engineering Seminar	Odum	2	Su'79	29
ENV 5306	Municipal Refuse Disposal	Furman	3	W'80	4
ENV 5517	Treatment of Wastewater	Zoltek	4	S'80	4
ENV 5930	Special Topics	Zoltek	1 - 5	S'80	7
EES 6006	Health Hazards of Environment	Bitton	4	Su'79	21
EES 6106	Environmental Microbiology	Bitton	4	W'80	14
ENV 6115	Air Pollution Control Measures	Lundgren	4	S'80	10
ENV 6116	Air Pollution Sampling and Analysis	Urone	4	W'80	10
ENV 6117	Environmental Meteorology	Huber	4	Su'79	10
ENV 6118	Environmental Micrometeorology	Lundgren	4	Su'79	10
ENV 6130	Aerosol Mechanics	Lundgren	4	W'80	7
EES 6136	Biology of Aquatic Systems	Crisman	4	S'80	10
EES 6166	Aquatic Microbiology	Crisman	4	W'80	11
EES 6027	Environmental Chemistry	Hassett	4	W'80	16
EES 6208	Principles of Water Chemistry I	Brezonik	3	W'80	5
EES 6209	Principles of Water Chemistry II	Brezonik	3	S'80	4
ENV 6211	Health Physics	Roessler	4	W'80	7
ENV 6216	Radioactive Wastes	Bolch	4	W'80	9
ENV 3236	Radiological Techniques	Bolch	5	F'79	10
EES 6246	Advanced Water Analysis	Brezonik	4	W'80	17
ENV 6286	Electronic Product Radiation	Bolch	4	S'80	11
EES 6355	Pollution Transport Systems	Huber	4	Su'79	13
EES 6356	Estuarian Systems	Odum	4	W'80	20
ENV 6409	Adv. Water Treatment Process Design	Singley	5	W'80	4

UNIVERSITY OF FLORIDA

ENV 6437	Adv. Environmental Engineering Design I	Furman	5	W'80	4
ENV 6438	Adv. Environmental Engineering Design II	Furman	5	S'80	2
EES 6506	Occupational Health	Lundgren	4	W'80	12
ENV 6516	Adv. Waste Treatment Oper.	Zoltek	4	W'80	6
ENV 6606	Environmental Resource Systems	Heaney	4	S'80	7
EGN 6740	Surface Hydrology	Huber	4	F'79	12
EGN 6741	Operational Hydrology I	Huber	4	W'80	8
ENG 6742	Operational Hydrology II	Huber	4	Su'79	10
ENV 6656	Urban Environmental Problems	Heaney	4	W'80	5
ENV 6666	Water Quality Management	Pyatt	4	W'80	15
ENV 6905	Individual Work	Staff	1 - 5	S'80	15
ENV 6910	Supervised Research	Staff	1 - 3	S'80	1
ENV 6916	Non-Thesis Project	Staff	1 - 5	S'80	4
ENV 6932	Special Problems	Zoltek	1 - 5	W'80	13
ENV 6940	Supervised Teaching	Staff	1 - 5	S'80	
ENV 6971	Master's Research	Staff	1 - 5	S'80	17
ENV 7980	Doctoral Research	Staff	1 - 15	S'80	17

UNIVERSITY OF ILLINOIS - URBANA - CHAMPAIGN

COURSE WORK Designation	Title	Instructor	Last Pres.	Enrollment
CE 340	Physical Principles of Env. Eng. Proc.	Suidan	3/4U F'79	25
CE 341	Air Resources Mtg.	Stukel	1/2U S'80	70
CE 342	Water Quality Control Proc.	Snoeyink	3/4U S'80	28
CE 343	Chemical Principles of Env. Engr. Proc.	Snoeyink	1U F'79	20
CE 344	Solid Waste Mtg.	Pfeffer	1U F'79	30
CE 345	Atmospheric Dispersion Modeling	Stukel	3/4U (new)	
CE 346	Biological Princ. of Env. Eng. Proc.	Engelbrecht	3/4U S'80	25
CE 347	Aquatic Ecology	Herricks	3/4U S'80	30
CE 349	Air Resources Eng.	Stukel	3/4U F'79	25
CE 358	Air Pollution and Combustion	Strehlow[a]	1U F'79	12
CE 395	Application of Modeling in Public Sys.	Liebman	3/4U S'80	15
CE 398EW	Ecology and Mtg. of Inland Waters	Herricks	3/4U F'78	12
CE 440	Water Treatment Processes	Randtke	1U F'79	18
CE 442	Wastewater Treatment Processes	Rittmann	1U S'80	20
CE 443	Unit Operations in Env. Eng.	Suidan	1U S'79	8
CE 444	Treatment of Industrial Wastes	Randtke	3/4U Su'79	22
CE 445	Modeling of Opt. of Water Qual. Sys.	Brill	1U F'79	9
CE 446	Design of Water and Waste Treat. Plants	Randtke	1U S'80	10
CE 448	Control of Air Pollution	Forney[b]	1U S'79	5
CE 495G	Envir. Eng. Seminar	Pfeffer	1/4U S'80	25
CE 495AG	Advanced Envir. Eng. Seminar	Snoeyink	0U S'80	12
CE 497	Independent Study			
CE 498AC	Advanced Aquatic Chemistry	Snoeyink	1U S'79	8
CE 498WQ	Deterministic Water Qual. Modeling	Eheart	1U S'80	12
CE 499	Thesis Research			

Recommended Elective Courses[c]

CE 352	Water Resources Design	Alavian	3/4U F'79	30
CE 353	Analysis and Design of Hydraulic Sys.	Wenzel	3/4U S'80	45
CE 356	Hydraulics of Surface Drainage	Yen	3/4U S'80	50
CE 357	Ground Water	Holley	3/4U F'78	35
CE 452	Water Resources	Chow	1U S'79	15
BIOCH 350	General Biochemistry	Conrad	3/4U S'80	200+
CH E 381	Chem. Rate Proc. and Reactor Design		1/2U F'79	
CHEM 328	Prin. of Env. Chemistry	Hopke	3/4U S'80	
CHEM 329	Inst. Methods in Env. Science	Jonas	1U S'80	
CHEM 340	Principles of Physical Chemistry	Kaufmann	1U F'79	
MCBIO 309	Comparative Microbial Chemistry	Wolfe	1/2U F'79	
MCBIO 409	Cultivation and Prop. of Microorg.	Wolfe	1U F'79	

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[a] Not a member of Civil Engineering's environmental programme.
[b] No longer on staff at Illinois.
[c] Instructors are not part of Civil Engineering's environmental programme and are not listed in Faculty Section.

JOHNS HOPKINS UNIVERSITY - PUBLIC HEALTH

DIVISION COURSES

Designation	Title	Instructors	Credit
18M01	The Environment	Krusé & Staff	5
18A11	Municipal Sanitation	Kawata & Staff	4
18A12	Vector Control	Krusé	4
18A13	Air Pollution Control & Strategy	Krusé & Staff	4
18A14	Air Pollution & Industrial Hygiene Laboratory	Billings & Staff	4
18A15	Airborne Particulates	Swift	3
18A16	Research Methods in Environmental Microbiology	Olivieri	4
18A17	Seminar in Environmental Health	Kawata & Staff	2
18B17	Seminar in Environmental Health	Kawata & Staff	2
18A18	Environmental Law	Lewis	3
18A19	Administration of Environmental Health Services	Cropper	3
18A21	Environmental Health Field Work	Kawata	tba
18A22	Industrial Ventilation	Billings	4
18A23	Occupational Safety Management	Billings	3
18A24	Legal & Social Implications of Environmental Health Programs	Boland	3
18A25	Principles of Industrial Hygiene	Billings	2
18A27	Analytical Methods in Environmental Engineering	Olivieri	3
18A28	Instrumental Analysis in Environmental Engineering	Olivieri	4
18A29	Safety & Health Research Laboratory	Billings	2
18A29A	Industrial Hygiene & Safety by Process and Operations	Billings	2
18A29B	Human Factors Engineering	Billings	2
18A90	Physical and Biological Effects of Air Pollutants	Swift & Staff	4
18A220	Issues in Environmental Health Management	Kawata	2
18A221	Principles of Occupational Safety	Billings	2

UNIVERSITY OF NORTH CAROLINA - CHAPEL HILL

COURSE WORK Designation	Title	Instructor	Credits	Last Pres.	Enrollment
ENVR 122	Water Chemistry	O'Melia	4	F 79	36
ENVR 123	Organic Materials Nat. Waters	Christman	3	S 80	12
ENVR 131	Biology in Envir. Science	Francisco	3	S 80	13
ENVR 132	Limnology & Water Pollution	Weiss	3	F 79	6
ENVR 143	Appl. Physiol. & Toxicology	Fraser	3	F 79	37
ENVR 144	Air Pollution Measuring, Monitoring and Survey	Jeffries	3	S 80	2
ENVR 145	Instrumentation and Data Acquisition	Jeffries	3	F 79	10
ENVR 146,L	Industrial Hygiene Eng. Control Design, Lab	Harris	3,1	F 79	9
ENVR 171	Water Quality Eval. & Control	Lamb	3	F 79	29
ENVR 174,L	Water and Wastes Treatment Processes, Lab	Lamb	3,1	S 80	20
ENVR 183	Spec. Topics in Water Resources	Okun	2	F 79	6
ENVR 217	Systems Analysis in Envir. Plan.	Sherwani	3	F 79	22
ENVR 218	Environmental Systems Analysis I	Sherwani	3	S 80	8
ENVR 241	Mechanics of Aerosols	Reist, Coover	3,1	F 79	24
ENVR 242	Industrial Hygiene Practices	Fraser	3	S 80	20
ENVR 243	Air and Its Contaminants	Fox	3	F 79	5
ENVR 245	Air Pollution Control	Harris	3	S 80	5
ENVR 247	Chemistry of the Troposphere	Fox	3	S 80	5
ENVR 248	Industrial Medicine	Fraser	3	S 80	23
ENVR 249	Air Pollution Meteorology	Slater	3	S 80	5
ENVR 271	Modeling in Natural Aquat Syst.	Lauria	3	S 79	15
ENVR 272	Water Supply, WW Disposal Sys.	Lauria	3	F 78	15
ENVR 273	WW Trmt. Plant Design	Okun	3	Su 79	13
ENVR 274	Adv W/W Treatment Processes I	Singer	3	F 79	8
ENVR 275	Adv W/W Treatment Processes II	O'Melia	3	S 80	7
ENVR 276	Industrial Water Quality Mgmt.	Lamb	3	F 79	10
ENVR 277	Engineering Project Design	Sherwani	3	Su 79	9
ENVR 278	Development of a Water Project	Okun	3	S 80	7
ENVR 281	Advanced Hydrology	Sherwani	3	S 80	2
ENVR 283	Natural Resource Law, Policy	Heath	3	F 79	38
Courses outside the Department					
BIOS 105	Principles of Statistical Infer.	Grimson	3	S 80	46
BIOS 135	Probability and Statistics	Taulbee	4	F 79	14
BIOS 145	Principles of Exper. Analysis	Grizzle	3	S 80	16
EPID 162	Epidem. for Envir. Occup. Hlth.	Shy	3	S 80	62

UNIVERSITY OF OKLAHOMA

COURSE WORK Designation	Title	Instructor	Last Pres.	Enrollment
CE 3213	San. Engr. Anal. & Unit Oper.	Reid	S'80	73
CE 4233	San. & Hyd. Systems & Proc. Des.	Streebin	F'79	63
CE 5863	Environmental Impact Assessment	Canter	S'80	43
CE 5600	Envir. Quality Mgt. Fld. Training	Streebin	Su'78	10
CE 5613	Urban Env. Systems	Reid	S'80	32
CE 5703	Marine & Est. Water Quality Mgt.	Schornick	S'80	11
CE 5843	Hydrology	Harp	S'80	26
CE 5853	Groundwater and Seepage	Tauxe	S'80	10
CE 5923	Air Pollution Control Engr.	Canter	F'79	26
CE 6980	Research for Doctor's Dissert.	Staff	Su'80	-
ES 5113	Advanced Environmental Chemistry	Klehr	S'80	5
ES 5133	Advanced Environmental Biology	Robertson	S'80	22
ES 5223	Chemical Aspects of Env. Science	Klehr	F'79	23
ES 5323	Biological Aspects of Env. Sci.	Robertson	F'79	30
ES 5473	Soil Science	Laguros	Su'79	5
ES 5500	Public Health Fld. Prac.	Robertson	Su'80	11
ES 5624	Food Protection, Sys. & Analysis	Guyer	F'79	14
ES 5663	Noise Environment	Murphy	S'80	15
ES 6210	Occupational Safety	Murphy	F'79	5
ES 6210	Industrial Hygiene II	Murphy	S'80	18
ES 6210	Envir. Science Special Topics	Staff	Su'80	-
CE/ES 6703	Water Quality Management	Streebin	S'80	10
CE/ES 5032	Radioisotope Technology	Klehr	F'78	4
CE/ES 5041	Radioisotope Technology Lab.	Klehr	F'78	4
CE/ES 5244	Water & Waste Treatment Proc. & Operations	Streebin	F'79	11
CE/ES 5653	Industrial Hygiene Engr.	Murphy	F'78	13
CE/ES 5803	Solid Waste Systems Planning	Canter	S'80	11
CE/ES 5980	Research for Master's Thesis	Staff	Su'80	-
CE/ES 6603	Sanitary Design & Water Resources	Reid	S'80	18
CE/ES 6613	Water Resources System Analysis	Reid	F'79	10

UNIVERSITY OF MICHIGAN

COURSE WORK Designation	Title	Instructor	Credits	Last Pres.	Enrollment
CE 405	Civil Engineering System	Bulkley	3S	79-80	39
CE 420	Hydrology I	Brater	3S	79-80	50
CE 421	Hydraulics	Wylie	3S	79-80	-
CE 480	Environmental Chem & Proc.	Weber	3S	79-80	36
CE 481	Water Quality Measurements	Weber	1S	79-80	25
CE 484	Sewage Treatment	Borchardt	2S	79-80	10
CE 485	Water & Wastes Engineering	Glysson	4S	79-80	28
CE 520	Hydrology II	Brater	2S	79-80	12
CE 536	Critical Path Methods	Harris	3S	79-80	17
CE 523	Open Channel Flow	Wright	3S	79-80	17
CE 524	Advanced Hydraulics	-	3S	79-80	-
CE 525	Turbulent Mixing Processes	Wright	3S	79-80	11
CE 526	Design of Hydraulic Syst.	Wylie	3S	79-80	10
CE 529	Hydraulic Transients	Wylie	3S	79-80	12
CE 531	Cost Analysis & Estimation	Bidwell	3S	79-80	42
CE 542	Physiochemical Principles in Soils	Gray	3S	79-80	12
CE 580	Microbio-Engr./MIC 434	Kempe	3S	79-80	50
CE 581	Physiochemical Process Dynamics	Weber	3S	79-80	26
CE 582	Sanitary Engr. Design	Canale	3S	79-80	15
CE 583	Water Purification & Treatment	Borchardt	3S	79-80	24
CE 584	Waste Water Treatment	Borchardt	3S	79-80	31
CE 585	Solid Waste Engineering	Glysson	3S	79-80	9
CE 586	Ind. Waste Treatment	Borchardt	2S	79-80	20
CE 587	Wtr. Res. Pol. & Admin.	Bulkley	3S	79-80	32
CE 588	Wtr. Resource Systems & Economics	Armstrong/ Heidtke	3S	79-80	10
CE 589	Pol. Fac. Envir. Water Res. Engr.	Bulkley	3S	79-80	15
CE 590	Stream, Lake, & Estuary Analysis I	Canale	3S	79-80	20
CE 592	Stream, Lake, & Estuary Analysis II	Canale	3S	79-80	10
CE 624	Free Surface Flow	Wylie	3S	79-80	9
CE 685	Prob. Envir. Wtr. Res. Engr.	Staff	'	79-80	9
CE 690	Design for Water Quality	Canale	3S	79-80	9
CE 880	Sanitary Engr. Seminar	Canale	1S	79-80	16
CE 881	Water Resources Seminar	Weber	1S	79-80	10
CE 885	Wtr. Res. Mgt. & Sci. Seminar	Bulkley	2S	79-80	10
CE 980	Envir. Wtr. Res. Research	Staff	'	79-80	10
CE 990	Dissertation/Precandidate	Staff	'	79-80	5
CE 995	Dissertation/Candidate	Staff	'	79-80	10
AOS 401	Large Scale Geophys. Motion	-	3S	-	-
AOS 402	Phys. Proc. in the Atmosph.	-	3S	-	-
AOS 417	Geology of the Great Lakes	-	2S	-	-
AOS 423	Biological Oceanography	-	3S	-	-
AOS 442	Oceanography	-	4S	-	-
AOS 444	Geophysical Fluid Models	-	3S	-	-
AOS 449	Marine Geology	-	3S	-	-
AOS 451	Atmospheric Dynamics I	-	4S	-	-
AOS 461	Meteorological Instr. for Air Poll.	-	2S	-	-
AOS 463	Air Pollution Meteorology	-	3S	-	-
AOS 478	Chemical Oceanography	-	3S	-	-
AOS 479	Atmospheric Chemistry	-	3S	-	-
AOS 531	Marine Ecology	-	3S	-	-
Biostat 500	Introduction to Biostat.	-	3S	-	-
Biostat 510	Data Processing	-	3S	-	-
Chem 447	Physical Methods of Analysis	-	2S	-	-
CCS 573	Automatic Programming	-	3S	-	-
Econ 480	Public Finance	-	3S	-	-
Econ 481	Government Expenditures	-	3S	-	-
Econ 587	Urban-Regional Economics I	-	3S	-	-

UNIVERSITY OF MICHIGAN

Econ 588	Urban-Regional Economics II	-	3S	-	-
EIH 500	Environment & Health	-	2S	-	-
EIH 502	Principles & Env. Health	-	3S	-	-
EIH 504	Computer Applications	-	2-4S	-	-
EIH 506	Elements-Env. Biology	-	4S	-	-
EIH 508	Radiation-Environment	-	2S	-	-
EIH 531	Environmental Chemistry	-	3S	-	-
EIH 533	Instrum. Meth. of Analysis	-	3S	-	-
EIH 542	Industrial Toxicology	-	2S	-	-
EIH 543	Ecological Toxicology	-	3S	-	-
EIH 544	Methods in Toxicology	-	3S	-	-
EIH 570	Water Quality Management	-	3S	-	-
EIH 571	Water Quality Management Prac.	-	3S	-	-
EIH 573	Water Pollution Biology	-	3S	-	-
EIH 575	Water Bacteriology	-	2-3S	-	-
EIH 576	Microbial Ecology	-	2-4S	-	-
EIH 579	Analysis of Water Res. Systems	-	2-4S	-	-
EIH 580	Envir. Systems Engineering	-	2-4S	-	-
EIH 631	Chemical Analysis of Water	-	3S	-	-
EIH 634	Methods of Chemical Analysis	-	3S	-	-
EIH 635	Physicochemical and Biochemical Methods of Separation	-	3S	-	-
EIH 670	Advanced Water Science Engr.	-	2-6S	-	-
Geol 461	Introductory Geochemistry	-	3S	-	-
IPPS 472	Quant. Meth. for Pub. Admin. II	-	3S	-	-
IPPS 555/ Econ 555	Economic Analysis for Public Admin. I	-	3S	-	-
IPPS 556/ Econ 556	Economic Analysis for Public Admin. II	-	3S	-	-
IPPS 573	Public Sector Systems Analysis	-	3S	-	-
IPPS 585	Public Organization & Admin. I	-	3-4S	-	-
IPPS 586	Public Organization & Admin. II	-	3-4S	-	-
IPPS 614	Legal Envir. of Public Admin.	-	3S	-	-
IPPS 629	Quant. Methods for Public Admin.	-	3S	-	-
IPPS 861	Legal Problems of Natural Res.	-	3S	-	-
Law 731	Legal Problems of Envir. Qual.	-	2S	-	-
Law 792	Legal Problems of Envir. Qual.: Water Resources	-	3S	-	-
NR 402	Conservation of Nat. Res.	-	3S	-	-
NR 411	Ecology of Aquatic Res.	-	3S	-	-
NR 412	Wetland Ecology	-	4S	-	-

Appendix B

SCOPE OF ENVIRONMENTAL HEALTH

1. ACCIDENT PREVENTION
    - Home Accidents
2. AIR POLLUTION
3. ANIMAL DISEASES TRANSMISSIBLE TO MAN
    - Rabies control
    - Brucellosis control
    - Tuberculosis control
    - Aviary inspection
4. EMERGENCIES
    - Civil defense
    - Epidemics
    - Fire, flood, drought
5. FOOD ESTABLISHMENTS
    - Restaurants
    - Taverns
    - Soda fountains
    - Bakeries
    - Grocery stores
    - Food processing plants
    - Frozen food lockers
    - Honey production and packing
    - Cider mills
6. HOUSING
    - Conservation
    - Rehabilitation
    - Clearance
7. INDUSTRIAL ESTABLISHMENTS
    - General sanitation
    - Gases
    - Dusts
    - Fumes
    - Other industrial hazards
8. INSECT AND RODENT CONTROL
    - Breeding places
    - Infestation
    - Control measures
9. MEAT
    - Slaughter houses
    - Meat inspection
    - Poultry inspection
10. MILK
    - Pasteurization plants
    - Milk products plants
    - Producer farms
11. NOISE
12. PUBLIC, QUASI-PUBLIC, RECREATIONAL, BUSINESS & COMMERCIAL ESTABLISHMENTS
    - Trailer parks
    - Hospitals
    - Sanitariums
    - Nursing Homes
    - Homes for the aged
    - Maternity homes
    - Country clubs
    - Hotels
    - Jails
    - Boarding homes
    - Day care centers
    - Nursery schools
    - Churches
    - Bowling alleys
    - Roller skating rinks
    - Theaters
    - Ball parks
    - Dance halls
    - Clubs
    - Fairs
    - Carnivals, circuses, and public exhibitions
    - Barber shops
    - Terminals
    - Tourist courts
    - Motels and cabin camps
    - Resorts
    - Camps
    - Recreational areas
    - Parks
    - Roadsides
13. RADIATION
14. REFUSE AND SOLID WASTES
    - Collection
    - Transportation
    - Place of disposal
    - Method of disposal
    - Areas served
15. SCHOOLS & INSTITUTIONS
    - Planning
    - Operation
    - Maintenance
16. SEWERAGE AND LIQUID WASTES
    - Sewerage systems
    - Promotion of sewer extensions
    - Treatment plants
    - Septic tanks
    - Privies
    - Stream pollution
    - Aid in development plans

SCOPE OF ENVIRONMENTAL HEALTH

17. SUBDIVISIONS AND PLANTS
    - Water supply
    - Sewage disposal
    - Drainage
    - Land Development

18. SWIMMING AND BATHING
    - Public swimming pools
    - Private swimming pools
    - Bathing places

19. WATER
    - Municipal distribution
    - Promotion of water main extensions
    - Source of supply
    - Treatment plants
    - Pressure problems
    - Semipublic supplies
    - Private supplies
    - Geological problems
    - Surface water availability
    - Aid in development plans
    - Toxic and hazardous substances

REFERENCES

1. Patterson, J.W. & Minear, R.A. (1980) Proceedings, Fourth Conference on Environmental Education, Association of Environmental Engineering Professors, p. 116.

2. Vesilind, P.A. & Minear, R.A. (1981) Register of Environmental Engineering Graduate Programs, Association of Environmental Engineering Professors, Ann Arbor Science Publishers.

Annex 3

FIELDS OF ACTIVITY RELATING TO THE TASKS OF THE SANITARY ENGINEER

1. Supplying palatable and wholesome drinking water
2. Supplying water for non-domestic purposes
3. Collecting, treating and disposing of liquid domestic waste
4. Collecting, treating and disposing of liquid trade waste
5. Managing quality of fresh surface waters
6. Managing quality of coastal and estuarine waters
7. Collecting and disposing of solid domestic wastes
8. Collecting and disposing of solid industrial wastes
9. Managing quality of the soil
10. Managing quality of underground waters, springs and wells
11. Collecting and treating gaseous discharges
12. Managing quality of the atmosphere
13. Integrated rural sanitation
14. Managing habitats of disease vectors
15. Sanitary inspection of dwelling houses
16. Sanitary inspection of city planning
17. Sanitary inspection of public buildings (for example: schools, prisons, barracks, markets, places of entertainment)
18. Design and control of swimming pools
19. Control of noise
20. Managing of consequences of natural and man-made disasters
21. Integrated management of environmental health in a city or region
22. Control of slaughterhouses and meat processing
23. Sanitary control of milk processing and distribution
24. Sanitary control of foodstuffs and food storage and processing
25. Radiation control
26. Toxic wastes control
27. Management of sanitation of touristic complexes

Annex 4

CURRICULUM COMPONENTS RELATING TO HUMAN HEALTH

Biostatistics

Determinants of health and diseases related to air (air hygiene)

Determinants of health and disease applied to sanitary engineering (applied hygiene)

* Epidemiology

Environmental determinants of health and disease (environmental hygiene)

Food determinants of health and disease (food hygiene)

Health (of public) control on working premises

Housing determinants of health and disease (housing hygiene)

Human ecology

Industrial determinants of health and disease (industrial hygiene)

Industrial toxicology

Noise control

* Parasitology

* Principles of human ecology

* Principles of toxicology

* Public health and environmental legislation

Public health education

Public health organization and administration

Radiation protection

Rural sanitation

* Sanitary biology and microbiology

Toxicological chemistry

Tropical determinants of health and disease (tropical hygiene)

Urban determinants of health and disease (urban hygiene)

Urban ecology

Urban sanitation

* Vector control

* Waterborne diseases

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* Topics which occur the most frequently in curricula.

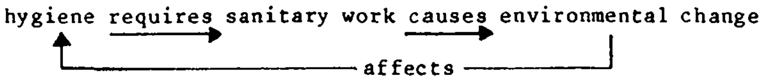
Definitions:

"Hygiene" = Concern with physical, chemical, biological, geographical and social environmental determinants of health and disease.

"Sanitary" = Relates to installations or processes, therefore has a technical content, implying hardware.

"Environment" = Global and local surroundings including nature.

These may be linked in a cyclic, or feedback manner:



"Applied" = Must be used as applied to something, for example microbiology applied to sanitary engineering, *not* applied microbiology.

"Control" = Management, in some cases, for examle environmental quality management, *rather than* environmental quality control.

Annex 5

LIST OF PARTICIPANTS

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