# WATER RESOURCES AND ENVIRONMENTAL ENGINEERING: EDUCATIONAL PROBLEMS AT UNDERGRADUATE-GRADUATE LEVEL

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## Summary

In the present article, educational problems connected with the organization of university courses in environmental engineering and water resources both at graduate and undergraduate level are tackled. In this context, water resources courses are considered as a component of the wider area of environmental engineering education. Problems relative to the teachings to be included into university curricula have also been analyzed. Furthermore, the Italian situation is described and used as an applicative example: Italian curricula in environmental engineering of the eighties and their transformations during the next years have been taken into consideration.

## 1. Introduction

At present, environmental implications permeate most of the engineering problems. Assessments relevant to environmental impact are considered as a fundamental stage for the design of works, and the conditions imposed by environmental sustainability tend to influence more and more also economic profit choices.

Environmental issues tend therefore to become an integrating part of the engineering culture, enough to provide for special teachings in the university curricula of engineering schools. These aspects concern all engineering areas, but in particular Civil Engineering applications. Today, environmental questions have largely penetrated the world of the engineering profession: apart from structural applications, nowadays, environmental problems are prevailing in most of the Civil Engineering applications.

Moreover, some environmental aspects are so connected with the designing procedures as to look like a new engineering sector: in particular, those bound to natural resources and their exploitation and to territory use, security, road and communication infrastructures. In many engineering schools, curricula more or less concerned with environmental problems have appeared in the last two decades. These new environmental engineering schools were initially proposed in the United States and then have appeared in many countries having university structures similar to the American one. Anyway, in many European countries environmental engineering does not have have its own identity, but appears as a series of teachings included in civil or hydraulics engineering curricula.

## 2. From Hydraulic Engineering to Environmental Engineering

*Environmental Engineering* comes out of *Hydraulic Engineering*: think about the fact that one of the first attempts to give systematic procedure to the environmental impact assessment was proposed and developed within river engineering [Leopold, 1971].

*Sanitary Engineering* itself arose in the field of *Hydraulic Engineering* and was firstly mainly concerned with wastewater treatment.

The environmental problem appears mainly as a problem of protection of resources and of their sustainable and rational use. Among the resources to be protected, water resource seems to be the most relevant element both for its world-wide diffusion and for its role in any degree of development, both of human society and of any ecosystem. In relation to this aspect, *Hydraulic Engineering* and *Hydrology* share the same interests of *Sanitary Engineering*.

Apart from this, from an educational point of view, it seems necessary to acknowledge environmental engineering's autonomy as a formative curriculum, having basic and applicative tools more and more different from those of civil engineering.

Historically, *Hydraulics* was essentially concerned with water supply systems and water bodies control: as a discipline in the university curricula it arose as *River Hydraulics* more than one hundred years ago.

The coming of hydropower shifted the interest of *Hydraulics* to plants and to relevant hydraulic structures; at the same time most of the fundamentals of *Fluid Mechanics* are substantially borrowed from aerodynamics: think, for example, about the theory and applications of the boundary layer, about turbulence theories and most of the theories of potential flow. Only in the last decades, has *Hydraulics* begun again to be concerned with natural systems, after having achieved the development of the hydro-electrical power plants. Today, natural systems tend to be identified with the natural environment, as a consequence of the environmental issue. *Environmental Hydraulics* is nowadays considered as a new research area and a self-standing discipline.

In the near future, *Hydraulics* will be more and more concerned with issues directly related to the natural environment and to the connected protection and defense problems.

A Task Committee on Hydraulic Engineering Research Advocacy of ASCE has recently faced the problem of the new vocations of hydraulic research, listing a series of problems and ideas, but pointing out natural systems as being the research outlet for our scientific community [ASCE, 1999].

*River Hydraulics* represents an emblematic example of the evolution of the new disciplines in the hydraulic field.

Up to a few decades ago, *River Hydraulics*, like other disciplines connected with it (such as *River Restoration*), was mainly concerned with *Hydrology* as the prediction of the design discharge and considered the river as a duct, essentially as a fixed bed channel: sediments transport theories were simply a list of sediment transport formulas, the use of which was not clear to most of the students.

Today, *River Hydraulics* is becoming in contrast a mobile bed hydraulics with strong morphology and morphodynamics bases.

A transformation process took place with *Sanitary Engineering* nearly ten years ago. The water bodies quality had been becoming an autonomous teaching within *Sanitary Engineering* for a few decades: *Fluids Mechanics* and *Applied Hydraulics* aspects are well connected with chemical engineering and chemical plants.

There is evidence of growing common interests between Engineering and Applied Ecology which are asking for more attention in applications and research.

In the cited ASCE report [ASCE, 1999], *Ecology* comes before *Sediments Transport* in the list of teachings to be included into the university curricula of hydraulic engineers. *Ecology* presents aspects which must be known by an engineer working on natural systems: the engineer must know fundamentals and principles of this discipline and must also be able to foresee the effects on the ecosystem of an engineering work. Biologists will have to resolve and investigate thoroughly these aspects, but it is fundamental for engineers to know the scientific language necessary to interact actively with the experts of the ecological sector.

The problem is actually also educational. From the educational point of view, the question is whether it is necessary for the student of engineering to have a deep knowledge of *Ecology* and *Biology* and in what measure these fields should influence our scientific culture. As a consequence of the arguments following the birth of sanitary engineering, it is possible to foresee that *Ecology* and *Biology* will gain more and more importance in the future within the engineering culture. In other words, why shouldn't a hydraulic engineer, even with his mechanical background, eventually take on problems, methods and tools belonging to sectors that today seem relatively far from him? This happened for example for *Chemistry* and *Economy* and before for *Mathematics* and *Theoretical Mechanics*. Maybe, it is only a matter of time.

## 3. Possible Structure of an Environmental Engineering Course

It is quite evident that an Environmental Engineering curriculum must be structured, taking into account educational and professional objectives of the future graduate.

Furthermore, it is quite evident that Environmental Engineering comprises a wide number of skills: some of them are more related to traditional Civil Engineering, while others, less design oriented, are bound to management and monitoring.

The problem is not only of contents, but also of university system structure. This is a very real problem, mainly within the European Community. One of the most debated questions among the Countries of the European Community regards the university structure, which is actually very different, but, thanks to an agreement called *Bologna Declaration* (1999), signed in Bologna by European Education Ministries, this scenery is changing: most of the European countries enforced this agreement, proposing a two-level structure made of a first level, the duration of which must not be less than three years, followed by a second level, so that the total duration will be five years [Bologna Forum, 1999].

This organization of *Bachelor-Master* type will certainly affect present and future university curricula. Nowadays a five-year university education, according to a recent ASCE report, is considered as fundamental for a design engineering profile [ASCE, 2001].

In the environmental area and mainly in the management and resources areas, there are occupational opportunities for which a three-year curriculum might be enough. On the contrary, there are intervention areas needing a more complete formation, lasting five years.

Anyway, according to ASCE proposal, as far as the environmental infrastructures design is concerned, a four- or five-year curriculum, similar to the *Civil Engineering* traditional one, is necessary. It should be organized in an organic way, without foreseeing a Bachelor type structure. A curriculum of the same type should be proposed also for environmental resources planners. A wide transversal culture is actually necessary for this sector, being the issues related to very heterogeneous environmental resources.

On the other hand, there are some occupations for environmental engineers for which a shorter university curriculum might be enough. Think, for example, about environmental control and resources and environmental quality monitoring.



## 4. New and Old Teachings

What distinguishes the formation of an engineer from that of other graduates in natural disciplines is the ability to solve practical matters with rigorous methods. Therefore, it is fundamental to keep that physical and mathematical culture which has characterized the engineering formation for a long time. It is thus necessary to give a strong base of *Mathematical Analysis*, *Calculus* and *Experimental Physics*. As far as Environmental Engineering is concerned, it is necessary to remember that, at present, *Mathematical Modeling* furnishes a professional tool which is largely used by engineers. The mathematical models available on the market devoted to environmental problems are often much less widespread than in the traditional civil engineering sector. It might happen that an environmental engineer is called to judge non-validated mathematical models or to produce or modify numerical codes: all these aspects must be therefore taken into consideration, while structuring an engineering curriculum.

*Chemistry* and its *applications* represent a more useful knowledge for the environmental engineer than for traditional civil engineering. Therefore also these ingredients should not be lacking in his university curriculum.

As already said, *Ecology* and *Biology* should be well known by the environmental engineer. The teaching of these disciplines is problematic as far as both educational method and contents are concerned.

From a methodological point of view, students of engineering approach these disciplines in a substantially different way from students of natural sciences, since the students of engineering are used to quite schematic and organic approaches. Therefore, a systemic approach should be privileged, pointing out functional relationships rather than a classifying type view.

From an academic point of view, it is fundamental to remember that these disciplines have always been missing in the formative curriculum of engineers. Therefore, it will be necessary to train a teaching staff able to teach disciplines typical of natural sciences with engineering language and methods.

As far as the basic engineering teachings are concerned, the most important for Environmental Engineering will be fundamentals and applications of *Thermodynamics* and of *Solids and Fluids Mechanics.* In particular it will be necessary to focus on *Fluids Mechanics,* since two fluids are the principal elements of the environment: water and air. They are actually the most important vehicles of life, because they are not only its greatest resource, but also its most frequent application field.

Once these fundamental notions have been given, the other teachings to be included into the curriculum will depend on the specialization.

A curriculum directed to water resources must include *Hydrology*, *Hydraulics* and probably also elements of *Sanitary Engineering* and *Water Quality,* as well as the design of works for *Water Control, Transport, Storage and Distribution.*

A curriculum more devoted to environmental quality problems must take into consideration the problem of liquid, solid and gaseous wastes, as well as their disposal and treatment. It must also include some elements of *Atmospheric Physics.*

A curriculum directed to safety must contain elements of *Geotechnics* and *Geomorphology,* as well as *River Hydraulics.* And so on.

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**Bibliography**

Armanini A. (1999). Environmental Engineering Courses in Italy. *Technical Work on Education and Training on Ecohydraulics.* Proceedings of the XXVIII IAHR Congress, Graz, 1999, pp. 1-7. [This work provides data concerning the Italian situation for what environmental engineering courses are concerned].

ASCE Task Committee on the First Professional Degree (2001). Engineering the Future of Civil Engineer. *Report of the Task Committee on the First Professional Degree to the Executive Committee Board of Direction, American Society of Civil Engineers,* May 2001. [This report focuses on the importance of a master's degree as a prerequisite for the practice of civil engineering at a professional level].

ASCE Task Committee on Hydraulic Engineering Research Advocatory (1999). Environmental Hydraulics: New Research Directions for the 21$^{st}$ Century. *ASCE Journal of Hydraulic Engineering* **122**(4), 180-183. [In this report, the problem of the new vocations of hydraulic research is faced].

Confederation of European Rectors (1999). Trends in Learning Structures in Higher Education. Background paper for the Bologna Forum, Bologna, 1999. [In this work a two level structure of Environmental Engineering Courses is proposed].

Leopold L.B. (1971). A Procedure for Evaluating Environmental Impact. *Geological Survey Circular n. 645*. [This work is one of the first attempts to give systematic procedure to the environmental impact assessment].

**Biographical Sketch**

**Aronne Armanini,** born in Padua, Italy, in 1948, graduated at the University of Padua in Civil Engineering. He developed his academic career at the University of Padua, where he was Assistant Professor of Hydromechanics first and then Associated Professor of Hydraulics. In 1986 he became Professor of Hydraulics in the Faculty of Engineering of the University of Trento, where in 1997 he was elected Dean of the Faculty of Engineering.

Prof. Armanini has taken on different responsibilities in the field of research and education: Head of the Environmental Engineering School and the Forestry Engineering School of the Faculty of Engineering, University of Trento, 1986-1996; Chairman of the National Project Research of Fluvial Morphology (Ministry of University Education), 1989-1994; member of the Scientific Committee of the Italian National Group of Hydraulics (Ministry of University Education and Scientific Research), 1992-1994; National Co-ordinator of the National Committee of Environmental Engineering Schools; member of the steering committee of the boards of the Deans of the Italian faculties of Engineering; member of the Council of the International Association of Hydraulic Research, 1997-99; and Chairman of the Committee of the Section "Continuing Education and Training" of the International Association of Hydraulic Research.

His main fields of interest are river engineering, sediment transport and debris flow hazard and mitigation.