About Nature, Science and Society : the example of Environment
- A new deal for Scientists and Engineers -

Alain Pavé
Professor at the University Claude Bernard (Lyon 1)
Director of the Programme « Environment, Life and Societies » - CNRS

and

Marcel Jollivet
Research Director at the CNRS
Scientific Advisor of the Programme « Environment, Life and Societies » - CNRS

Summary

Environment gives good examples of actual problems, with scientific, technical, economics, and social aspects, posed at different time and space scales. Moreover, the relationships between society, nature, sciences and techniques seem to change rapidly during the last times. In fact, if it proceeds from an evolution, surely accelerated but not new. Now it poses new questions in the manner to envisage scientific approach and engineer practice, therefore academic and engineer training : working in a large interdisciplinary context, understanding, controlling or managing complex systems, dealing with new techniques and methodologies, for example modelization,…

We present a short analysis of actual environmental questions and their genesis and how these questions have been and have to be considered in a scientific and technical context and then in a social one. We examine also the related difficulties and the consequences on scientist and technician practices. Replaced in an historical context, we show how the environment problem concerns progressively more and more operating actors and how the functions and skill and therefore training of classical ones are changing, or will have to change in the next future.

Introduction : an historical background

Interest for Environment and specific questioning about it come from a double origin : the first is social, the second is scientific. The term "Environment" itself, as it is accepted today, is new. This term has been added to the words : nature, surroundings and in a sense has generalized them.

The social origin of the Environment problem dates from about the sixties with the awareness of a certain number of issues, set out by the development of our societies : pollution, damage to areas, the limitation of natural resources, a badly made or even chaotic accelerated urbanization, the global view of disturbance from anthropic origin, etc. Since the beginning of the seventies, this social awareness has been leading to the writing of a great amount of reports[1] whose purpose was essentially to make the necessary assessment ; to make some important urgent questions emerge and to make immediate recommendations to political powers.

The scientific origin is older and comes from the apprehension of nature, of "the natural surrounding". It was anticipated by the progressive consciousness of the need of a natural resource management and agriculture development. The background has emerged from practical responses given to these questions. For example, the history of “water and forests” management at which, in France a specific engineers corps was and is attached[2].

The scientific origin comes from question posed by scientists and we will remember that some up-to-date of them have been clarified for a relatively long time. For example :

- The Buffon's remark about the negative effect of man action : "*Nature works to restore what man does not stop to destroy*"
– Since 1824, J. Fourier was wondering about "*the forming and the progress of human societies*", "*natural forces*" and their respective effects at the global level of the Planet,
– A century ago Arrhenius was asking the question of the *great balances of the Planet* and in particular the question of the influence of the CO_2 accumulation in the atmosphere,

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

It would be interesting to examine how some scientific questions are transmitted, adapted, translated understood and become social ones, and then come back as social questions posed to scientific community.

Today, it is a matter of crucial questions because the **expansion**, the **generalization** of problems and the awareness of their **interdependence** are emerging more and more distinctly. However, until a recent past, the technical and scientific approaches of environmental problems was rather pragmatic. It is also true for education and training.

(i) Environment and Research : research operations have been launched on precise subjects as soon as they were identified. Numerous reports which have been made since the beginning of the seventies have contributed to this identification at the level of general problems[3] as well as specific ones (studies of various pollution and in particular of the air and the water and their effects, the evolution of various environments and ecosystems, the future of stratospheric ozone layer, the destruction of tropical forests, …)[4]. The running of these fundamentally multidisciplinary operations often amounted to a juxtaposition of monodisciplinary work. In this way, scientific and technical research on Environment was and remains a matter for a list of more or less organized themes and not for a constructed and consistent unity but with a still weak interdisciplinary practice. Little by little, groupings were made which enabled to launch great international scientific programmes such as "Man and Biosphere" (MAB), "International Geosphere-Biosphere Programme" (IGBP) or national programmes such as, in France, "National Programme for Climate Study" (PNEDC), "Interdisciplinary Programme of Research on Energy and raw material" or still "Interdisciplinary Programme of Research on Environment" (PIREN) of the CNRS. The emergence of these programmes, their making, the results they found, tends to wonder whether today it is possible to suggest a coherent presentation of scientific programmes and its expected technical consequences dealing with every sides of Environment (Jollivet and Pavé, 1991, 1992 [5]). Nevertheless, in the same time, some immediate and coherent technical solutions can also be envisaged on actual scientific knowledge and know-how.

(ii) Environment, education and training : for a long time Environment was not distinguished from Nature or rural zones and curiously avoid urban zones. At less in France, the education in primary or secondary schools was more or less naturalist with a biological or, now, ecological dominance. However, in academic or high technology training, if students in biological sciences or in bioengineering have to know a minimum of mathematics, physics or chemistry, conversely students from these last domains have generally not a minimum knowledge in life sciences. Curiously, some efforts are made to make sensitive all students to some social sciences, particularly in high-tech ways (e.g. economy or the learning of foreign languages), but in a strong operational point of view. Today, if some efforts are observed there is to do some progress to introduce particularly life sciences or other human and social sciences in the basic culture of scientists and engineers[6]. We have also to replace scientific knowledge within an historic perspective.. Another remark is relative to common *basis of knowledge and skill* , it refers precisely to common tools or common methodologies which are available in many disciplines (system analysis, data analysis, modelization, computer simulation…). It would be also interesting to show to students, even to researchers themselves, how the scientific community, how the science itself, appropriates and reformulates complex questions and conversely how these subjects have influences on scientific practices and on scientific evolution. In this context, the case of Environment is particularly interesting and demonstrative.

How global questions emerges and may structure the scientific and technical activities

Questions about Environment come from various origin. If it is possible, as above, to give some historic references, there is, in fact, a lack of global history of questions which today are put together under this term and which form what we can call "the question of Environment". We proposed a first organisation of the field (Fig.1, Jollivet and Pavé, *op.cit.*) :

The "problem of Environment" could be imagined as the result of the implementation of three interrelated paradigms deduced from this first analysis (cf. fig. 2) :

- the one of planetary states and dynamics,
- the one of renewable resources and biological diversity,
- and the one of mutual dependence upon men.

It leads first to detect and to understand involved mechanism and relationships and then to search new solutions in many fields of human activities : at least technical and economical but also social and juridical…

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

Simultaneously, an action scheme can be proposed to envisage practical solutions (fig. 3). Then an iterative process between knowledge acquisition and action is progressively establishing. In two cases it appears clearly that studies must be conducted in an interdisciplinary framework. But as corresponding sets are interrelated, in major cases to solve an Environment problem leads to put together the specific approaches. This leads to practical consequences on the work of involved scientific and technical teams, but poses the problem of future ways of teaching for young engineers and scientists.

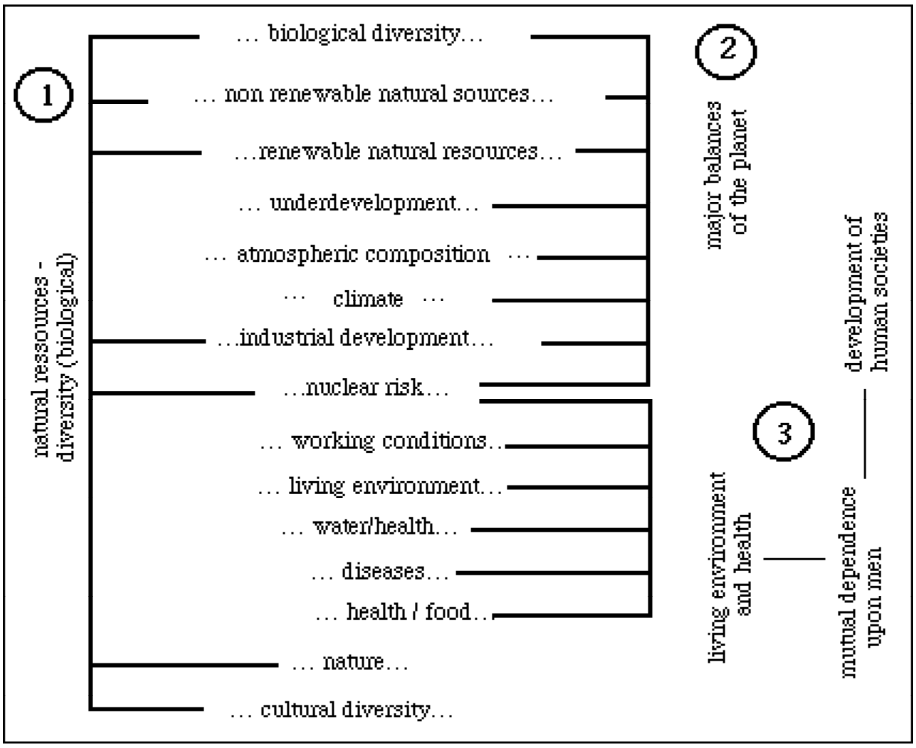

Figure 1 - First moving-closer of the questions as they come from concrete problems. Three groups of questions can be identified ; the problems of the development of human societies are at the background of these questions.

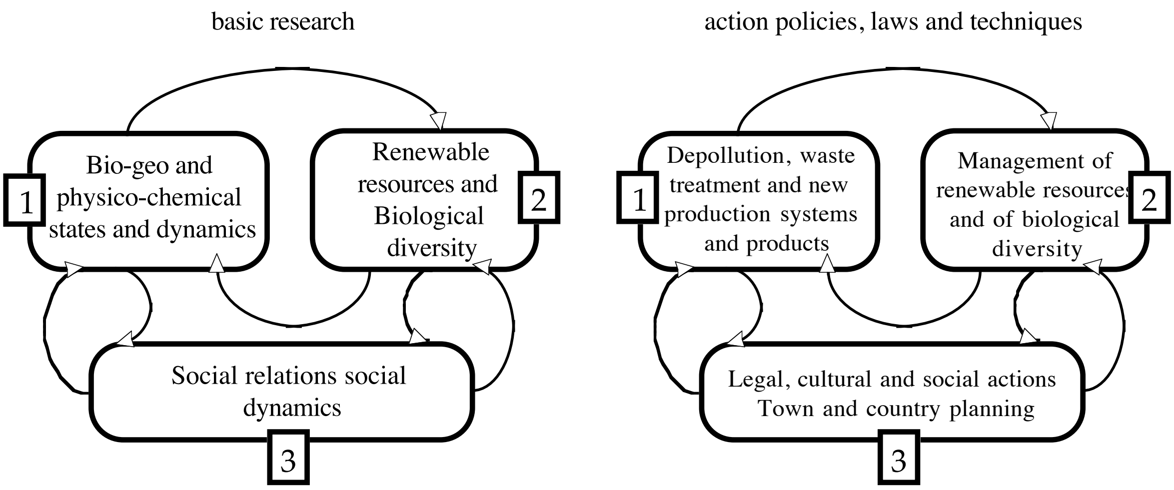

Figure 2- Left side : the actual main paradigms which govern the basic research on Environment. These paradigms are interrelated. Right side : actions which can be proposed to solve Environment problems can also be arranged in interrelating subsets.

Specific theoretical and methodological issues

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

The preceding developments evoke theoretical and methodological problems. Simply, we would like to identify the major ones. In a first analysis, we can distinguish five problems :

- the definition of what is exactly Environment,
- the analysis of the relations between the different integration levels of space and time,
- the systemic approach
- the modelization,
- the interdisciplinary, particularly between nature sciences, social sciences and engineering sciences.

Environment as a scientific object

For everyone of us - and that is a first naïve and intuitive definition - Environment is what surrounds us as human beings, at a time set and in a place given. In fact, this notion of Environment is hard to understand, indeed :

› It is **relative** to a central object. This object depends on the centre of interest of the scientific work and it differs according to each discipline. For a biologist of populations, the central object is the population and the Environment is what surrounds this population. For a sociologist, the Environment can be the family environment, the social class, the working environment, etc.

› It is **complex**.

› It is **polysemic**. For example, some scientific and technological areas have taken it with different meanings. For instance, ***Environment*** in computer science has a very particular meaning.

› It is **recent**. The Environment as a subject for studies was only identified as a result of **the problems** asked by the **human activity**

› It is **changeable** in time and space.

› It involves some **phenomena** with characteristics which are scientifically and technically hard to define, to identify and to estimate.

Which point of view is to be adopted ? It is desirable to look at it with a double prospect : on one hand from an heuristic point of view and on the other hand from an active point of view, including both scientific action and action on the real field. So after analysing some current definitions we proposed the following one :

The Environment is the whole of natural or artificially made environments of the ecosphere, on which man settled, which he exploits and which he develops ; and it is the whole of non-anthropised environments which are essential for its survival. These environments are characterized by :
◊ their geometry ; their physical, chemical, biological and human components and the space distribution of these components,
◊ the process of change, action or interaction which imply these components by attiring them in space and time,
◊ their numerous dependencies in front of man's actions,
◊ their importance for the development of human societies.

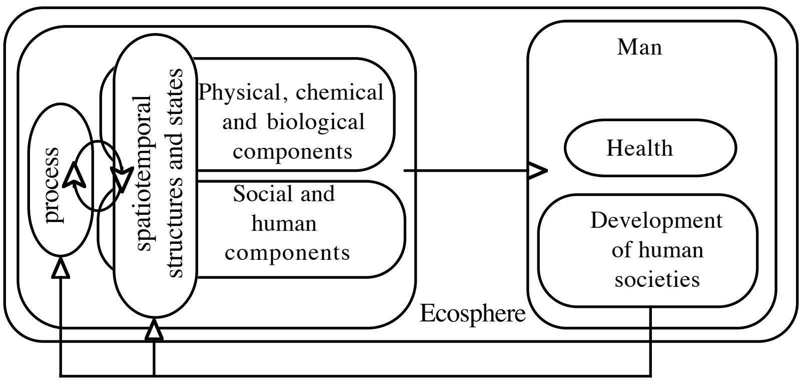

Figure 4 - This diagram illustrates the temporary definition of the Environment notion.

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

Organisation levels , relations between different integration levels of space and time

The planetary level has a central place in the unifying process of research on Environment. And thus, we can interpret the fact that the term "global change" at the international level has progressively replaced the term "Environment" in the language of a part of the scientific community. But, the favored reference at the planetary level may be reducing if it becomes a rule according to which any question must be brought back to a single level or originated in it only. Further to these first developments, we can conclude that while stating us in the planetary scope which gives them their final reason, the research on Environment must take as a goal to report the extreme diversity of cases and to particularly of the organization levels and of the different scales of space and time produced by the various questions. In fact, the understanding of the phenomenon which happen at the inferior levels, takes part in a better knowledge of processes at the planetary level.

Systems Analysis

The Systems Analysis has completely changed the classical way to think. The integration of the putting into **models** and of the **experimental process** in the systemic vision make this analysis a great operating approach.

The Environment as an object, a complex and diversified system, is a selected ground on which these schools were in confrontation. There is no doubt that the analytic method on one hand and the systemic analysis on the other hand, bring some determining results. Besides they are not **contradictory**, they are even **complementary** and effective if they are used well and if we avoid their "perversions".

Basically systemic approach was devoted to analyses stock variations and fluxes of matter or of energy between elementary structures (boxes) The laws governing the fluxes are more or less based on modified mass action laws principles. The problem of information flow and processing is poorly considered in the system framework and is generally studied in the context of information networks (e.g. neuronal networks, multi-agent systems…). Models of information flow are quite different than material ones. today we have to consider simultaneously “system-information network” sets to represent both aspects : material and information fluxes, transformation and processing because each of them can act on the other.

Modelization

Practically, and for these reasons, modelization is more an more used in environmental research and techniques to understand fundamental processes, to forecast future states of environment at different scales and to give some new ideas about possible behavior of environmental components (eg. global, regional and local climates, ecosystem changes, managing static[7] and dynamic[8] geographical information, variations of pollutants, relations between time and spatial scales, testing hypothesis, aid to paradigm formulation, ecosystem and social dynamics[9] [10]., etc., and model as common language and tools for an interdisciplinary approach). It is also a necessary approach to many technical problems (test of alternative policies, effects of techniques applications, etc.). So modelization has to be introduced both in the research process and in the technical aspects. But some methodological progress has to be done (constructing and managing large models, software design, test and validation, connection to observed and experimental data, etc.)

The interdisciplinarity

The research on Environment is interdisciplinary by nature. It deals with all disciplines at various degrees. This interdisciplinarity must be considered under two forms :

– as a participation of numerous disciplines in a common field of research,

– as a research work makes in common by some disciplines.

This does not mean that some monodisciplinary research cannot be pursued on subjects coming from the Environment problems. Nowadays, we are able to build good research in this field only with a strong disciplinary medium. This disciplinary support materializes at two levels :

– the one of proven techniques and methods which are more a matter for service than for a scientific research,

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

– the one of a real research in the discipline which makes this discipline progress in its scientific dynamic or even brakes with this dynamic and opens new horizons. And that is why we are able to mobilize good scientists, excellent teams.

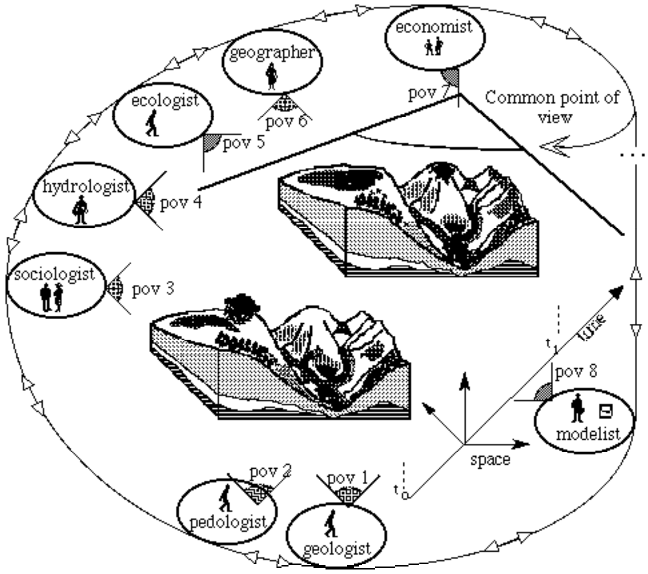

Figure 6 - The interdisciplinary work needs the cooperation between specialists of different disciplines. Elaboration of a common point of view seems to be more efficient than separated approaches.

Conversely, are the research on Environment the simple result of the sum of disciplinary research ? In other words, are these research reducible to the string : Environment problem, disciplinary division, disciplinary research and results and then gathering of the results and synthesis ? There is no absolute answer, and an important part of the research on Environment more or less comes from this diagram.

Today, we can wonder whether the interdisciplinary approach is possible in the everyday practice. This practice involves to make a division of the object of the research which is different from the sequential approach mentioned above : then the interdisciplinary practice leads to a quite permanent contact between the researchers of the various disciplines. There are several examples which show that this practice is possible and even it is one of the major acquisition of the preceding years.

Scientific fields and disciplines, Environmental problems

Life sciences : ecology and biology

The ecology plays a particular role. First, for social reasons : the social grouping which intentionally raised the Environment problems are the political groupings of ecologists. It was often made on anecdotal, local, emotional and less scientific bases but they were nevertheless real and concrete. This social and political appropriation of this scientific discipline has no facilitate things for it. And secondly and mainly for scientific reasons

- the ecology considers on one hand the relations between living people and on the other hand the relations of these living people with the environment they live in. (biological and physico-chemical components);
- the ecology uses largely some other disciplines in order to solve its own problems ; so the ecologists have an experience of the interdisciplinarity;
- at last, it is not enough known that the ecology has a sound theoretical approach and a great practice of the putting into models.

Thus, it tries to appropriate the research on Environment but now as a real scientific discipline[11]. Of course, this scientific discipline is hard involved by the nature and the quality of its process and research ; but it only gives, however, its view on the object that we want to be scientific and which is the Environment.

The other disciplines of the life sciences are also involved

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

If the ecology is the first discipline to be implicated in the research on Environment, other discipline are also implicated : systematic, animal and plant physiology, biology of evolution, human biology, microbiology, molecular biology, biomedicine, etc. An important effort, dealing at first with the Environment, must focus on the deciphering of the fundamental mechanisms which govern : biological organization, the emergence of the organization levels and their properties, the definition of the functional units, of the origin, of the evolution and of the role of the biodiversity. etc.

Moreover, the relations between organism and environment are very important to consider, for example :

- to sharpen the analysis of the contributions of living people to the great biogeochemical cycles and their reactions to the cycles alterations.
- to study the relations between Health and Environment
- or to forecast the behavior of recombined and modified organisms in the Environment, etc.

The questions related to the photosynthesis and to its fundamental mechanisms are topical questions and in particular to understand better the reactions of the photosynthetic organisms to the global modifications of the Environment. At last, problems studied in the fields of "ecotoxicology" or "toxicology of the Environment" pose questions at all levels of organization and in particular at the cellular and molecular levels.

Chemistry at the parting of the ways

Chemistry is one of the discipline which is the most involved in the Environment problems, and this for three reasons :

- The first from social origin put the chemistry if not in an accused position, at least in a suspicious one as it represents the origin of the pollution.
- The second from economic origin is stated by the production sector : elaboration of new products which pollute very little or not at all and which are biodegradable, study of cleaning problems in industrial and natural environment.
- The third is from scientific origin. Nowadays, the analytic chemistry may have new developments : the chemistry of compounds in traces ; the chemistry of the complex reactive systems in solid, liquid, gaseous phases, at the interfaces ; dynamic of complex systems…, as many problems for a new chemistry of the "natural environments"

To sum up, the chemistry is one of the disciplines which may evolve very rapidly thanks to the Environment problems and in it the scientific problematic will probably be fundamentally renewed.

The sciences of the engineer : some lessons, some tools and some requirements

These sciences already bring much to the Environment (applications of the hydrodynamics, of the acoustics, of the aerodynamics…). They largely participate to the elaboration of the Universal Tool based on the Trilogy "Model, Analysis, Control" (J.L. Lions op. cit.). The technological aspects and in particular the device genius that they develop, are putting them on the first line for numerous industrial and environmental problems (new device linked with the technologies themselves, device for waste processing, restoration of the Environment, fight against noise, etc.). Two fields which are not involved yet : computer science and automation, should be rapidly involved in the Environment problems :

In short, the sciences of the engineer intervene already largely in the Environment problems. A more and more important implication of the computer science and the automation is to be foreseen more anticipated and solicited. However, it is traditional to consider that Sciences of the engineer are essentially devoted to industrial non living processes. It becomes necessary to include all engineer domain connected to agronomy, management of natural systems and so on

The sciences of the Universe : necessary but not sufficient

The sciences of the Universe are "naturally" involved in the Environment problems. Anyway, their status must be brought closer to the ecology. They also risk to reduce the Environment, problems to their problematic. Principally, Earth sciences, soil sciences, sciences of the atmosphere, oceanography are invoved in the study of :

- the physical environment of our Planet (geosphere, hydrosphere and atmosphere) ;

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

- some biological aspects in particular in the marine environment that is to say where the dynamic inner to the physical environment is fundamental. In fact, the major part of the marine biology classically is attached to the Sciences of the Universe;
- the natural history (palaeontology, paleoclimatology, study of paleoenvironments, ...).

The researches are bringing not only a fundamental contribution to the knowledge of our past and present environment but they are also leading to methodological and instrumental developments, which are important and usable by other disciplines. For example, we cannot deny the effort made in the field of the space and air remote detection or in the field of the modelization of numerous phenomena.

Man's sciences and sciences of the society : the centre of the debate

As we have seen, the human dimension has a central position, the Environment notion on which we work is related to Man and human societies. So it is clear that Man's sciences and sciences of the society are directly questioned. They took an interest in the Environment problem more tardily than Earth sciences or Life sciences, or at least if we refer to the "natural Environment", and so they are unequally and insufficiently involved. As for the "built Environment" in concerned, Man's sciences and the sciences of the society conversely have a precedence on the Nature sciences (about towns). A great number of disciplines are concerned : mainly demography, geography, economy, law, sociology, politics, but also history, anthropology, archeology and philosophy.

The important thing is to understand fundamentally how Man sees his Environment according to his history, to his culture ; how Man reacts towards his Environment, how he exploits it, how he disturbs it gravely or on the contrary how he protects and manages it ; what are the regulating actions he can implement. All this must be examined according to the social tensions, to the evolution of human societies but also according to the evolution of the Environment itself due in particular to the damage of environment, to the climatic changes and their consequences[12].

Mathematics and basic Physics : new ideas and new methods

Mathematics is still apparently less concerned by the Environment problems, or indirectly by the study of mathematical objects coming from disciplines involved in the study of Environment problems (for example, in the phase of mathematical and numerical analysis of models). Nevertheless, some original questions could be tackled in connection with :

- the emergence of properties in the organized systems,
- the treating of space and temporal scales problems,
- the analysis of mathematical objects with complex behaviors ,
- the treating of the uncertainty, for example, of the theoretical study of decision process in an uncertain future,
- the definition of indicators able to announce brutal changes of states (behavior of the trajectories of a dynamic system near a special point, with noise...),
- more generally, the properties of dynamic systems.

These themes are given only as examples : surely it would be easy to complete this list and to make it precise and more attractive for the community of mathematicians.

The engineers and Environment and the engineers of Environment

First we propose to consider the engineer as a sort of mediator (figure 12). Engineer has to response to questions posed by socio-economic world, then he (she) elaborates the technical principles and tools of actions which are assumed to be adequate to the wished response. In this process he uses both scientific and technical knowledge but also some practical know-how. Sometimes, he (she) needs to consult scientific community because the corresponding basic knowledge is not available then he (she) poses problems. In the best case these problems can be solve by scientists and then participate to knowledge accumulation and to the practical solution of technical question.

Today if all engineers are more or less concerned by environment, it becomes quite important to have specific training for specialized engineers on environment, although in some way, for natural and rural zones, foresters, engineers in agronomy or rural engineers can already take into account many questions.

Training problems

The development of the research on Environment will not happen without the training of young researchers. The concrete implementation of the knowledge and of the technological developments must also have some specialists that is to say engineers and technicians of the Environment. It seems also necessary to suggest in the other degree courses, some education or activities of consciousness-raising to the Environment problems. How to promote some training actions to meet the purposes ? We do not pretend to give an immediate answer, this is a question which is worth thought and in particular on what already exists either in the Environment field or in some equal fields like the one of health. Several prior thoughts and several tracks nevertheless can be suggested :

- First we must agree on the following principle : the field is vast and the first danger is to dilute such a training in too vast generality, that is to say to create some generalists without real professional competence. Conversely it is necessary to ensure a true scientific culture and a practice of common work in an interdisciplinary context.

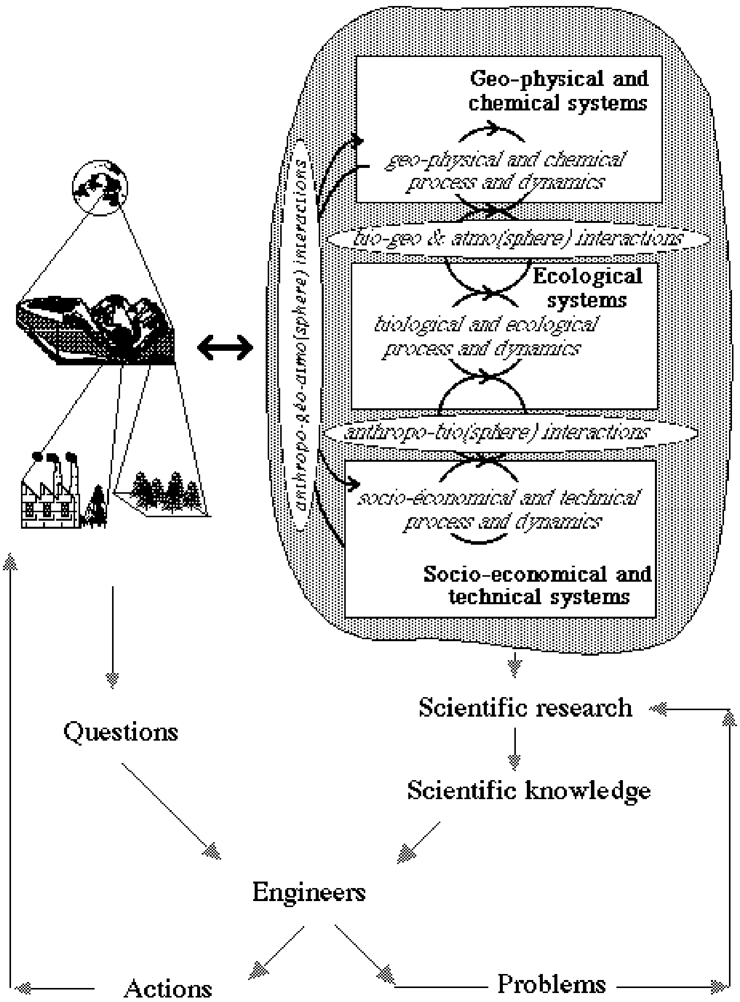

Figure 12-- The engineer can be considered in position of a mediator between technico and socio-economic questions and scientific domain.

- So we can suggest **for the initial training** to lie on a strong disciplinary content that is to say first to train some good mathematicians, physicists, chemists, geologists, pedologists, biologists, ecologists, sociologists, economists, etc., before plunging them in Environment problems. The specialization as regards Environment will happen at the end of the degree course - and notably for the engineers and the technicians. The educational report orthogonal to the preceding one, will be centered not on the discipline but on the object "Environment". So, from identified questions, it will be a matter for specifying the spatialized contribution of his discipline to the solution of some of these questions and for presenting the point of view of other disciplines on this object "Environment" and their contributions to the answer to these questions.
- We can think that within the "classical" phase of a degree course which is centered on the control of a discipline and apart from the aims of this degree course ; the point of view on the Environment problems of this discipline must be stated.

For example for a chemist the fact to underline the problems of the chemistry of compounds in traces, the heterogeneous reactions in phases, the chemistry of the atmosphere, the device of "own" processes, ..., and for the biologist the fact to talk about the ecology, the ecotoxicology, the biological diversity, ..., all these are not out of study.

- But, it seems nevertheless desirable, as we have already mentioned, that a bit synthetic education of consciousness-raising to Environment problems be proposed to the whole of young training people. To this end, the approach at the global level, if we pay attention to specify that it is not the only one,

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

may be able to answer such worry. At a local scale, the study of concrete cases which are immediately comprehensible may be used as a support, as a beginning point to a more general report.

- **For the bombastic training**, the diagram can be transposed. We think that a bombastic training first must lie on a discipline and must specify the point of view of this discipline on the object of the study that is to say the Environment. So, we think that it is better to see emerging some training like "the chemistry for the Environment", "Environment sociology", ... "Environment law", than training which only specify the term "Environment".
- At last, what we say about the research activity at the methodological level must be taken into account in the training actions ; in particular we must introduce or develop the education of the data, systems and network analysis and of the modelization. Moreover, it seems also desirable that young researchers can get very early into the way of the interdisciplinary practice (although this practice is not well structured yet, we must admit that it is true for numerous engineers training but much less in the academic training in Universities) ; particularly they must learn how to speak clearly about their discipline and how to read the results of the other disciplines.

These several remarks were only mentioned to open the debate which should be sited, according to us, at a national level and this all the more as the local initiatives multiply without any co-ordination or even a clear view of the means and the goals. For example, if we can criticize some weaknesses of the number of research subsidies which is dramatically low for the subjects dealing with the Environment. Conversely, it is not always easy to find one's bearings in this "environmentalist" nebula and so to promote a scientific training policy which is serious and ambitious.

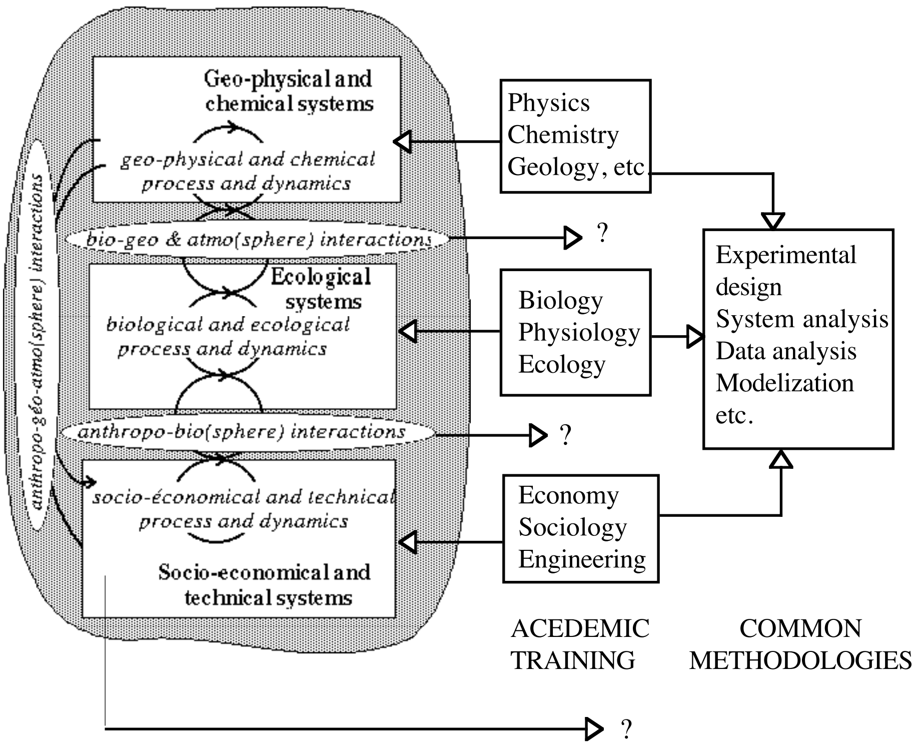

Figure 12- Environment systemic representation and classical academic training : the scientific disciplines are the center of classical training, progress have to be made for general methodologies and principally for presenting interfaces problems.

By way of conclusion

So, the environment questions lead to a new scientific and technical practice which, in the great majority of cases, need : (1) a shift work in an interdisciplinary context, (2) in complement to disciplinary research and technical approaches, to develop studies of, and at, the interfaces, (3) to consider complex systems and situations, (4) to develop common languages and methodologies, specifically modelization (and not only applied mathematics, (5) to adapt scientific and technical training.

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

And eventually, to develop conceptual and theoretical constructions. In fact the necessity of theory is obviously related to the limited capabilities to store knowledge in the human brain : then structuring this knowledge and bringing out general concepts, models and "laws", if possible…

Notes and references

[1] For example, we can note :
-Man's impacts on the global environment : Assessment and Recommendation. MIT, Cambridge (Mass.), 1970.
-The famous "Meadows Report" (The limits to Growth, 1972).
-Development and Environment (preparatory report to the United Nations, June 1971).
-Use and preservation of the biosphere (UNESCO, 1970).

More recently,

-The Brundtland report (1984).
-L'effet de serre et ses conséquences climatiques - évaluation scientifique - Rapport à l'Académie des Sciences, 1990.
At last, some questions related to possible major disturbances like a nuclear conflict have troubled the scientific community these last years, cf, for example, the book :
-C. Sagan and R. Turco : l'hiver nucléaire. Seuil, Paris, 1990.

[2] Cf. for example :"l
Les Eaux et Forêts du 12e au 20e sciècles" Editions du CNRS, 1987.
[3] I*bid* [1]

[4] For example,

La pollution de l'air en France (la documentation française, 1973), or "the reports of the programme DEFORPA" which studies the effects of the acid rains on the forests.

[5] [Jollivet M. et Pavé A. - L'Environnement un Champ de Recherche en Formation. *Nature-Science-Société*, 1,1, 1993, 6-20.
Jollivet M. et **Pavé A.** - L'Environnement : Questions et Perspectives pour la Recherche. *Lettre du Programme environnement du CNRS*, n°6, 5-29, 1992.

[6] We speak of human and social science more than "humanities". It refers to sciences curricula, it would be also convenient to propose to specialists of human sciences to have a natural science culture : the humanity and the culture of the ones are the skill and the science of the others…

[7] Ashdown & Schaller S. GeographicInformation Systems and their applications in MAB-Projects. UNESCO. Man and Biosphere Program, German National Committee, Bonn, 1990.

[8] Coulson R.N., Folse L.J., LOH D.R., Artificial Intelligence and Natural Resource Management, *Science*, 1987, 237, 262-267.

[9] Bousquet F., Cambier C., Mullon C., Morand P., Quensière J. and Pavé A. - Simulating the Interaction Between a Society and a Renewable Resource. *Journal of Biological Systems*. 2, 1993, 199-214.

[10] Représentation, Modélisation, Développement. Actes de l'atelier "Recherche Opérationnelle et Développement - 1990" (Org. P. Matarasso). Centre d'Échotechnique du CNRS, 1991.

[11] However we will remark that in some recent work, the authors distinguish the Ecology and the Environment, at least in the terms if not at the base. For example :
Sharma P.D., Ecology and Environment. Rastogi Public Meerut (India), 1990.

[12] For broader developments on the implications of Man sciences and of the sciences of the society, one can consult :

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993.*

M. Jollivet. La prise en compte de la société dans les recherches sur l'environnement. *Lettre du Programme Interdisciplinaire de Recherche sur l'Environnement,* 4, 13-16, 1991.

Reprint from : *Proceedings of the International Symposium « The Culture of Engineering in a Rapidly Changing World » (University of California Berkeley, Conférence des Grandes Ecoles and Massachussetts Institute of Technology) Berkeley november 1993*.