Will "environmental" be replaced by "extrasensory"?

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Abstract: The paper explores the concept of environmental science, as a science of complex interactions (physical, chemical and biological) that are very difficult to understand and quantify. This complexity is very often underestimated by the community, decision-makers and what is worst, scientists themselves. This leads to the danger that practical solutions developed may fail to achieve expected outcomes. Examples of very frequent underestimation of the complexity of environmental issues are discussed in the paper as well as approaches of university undergraduate and postgraduate teaching in this area. The conclusion presented is that the future depends on the ability of environmental science and technology to provide solutions to environmental problems.

The aim of this paper is to discuss some general directions and challenges faced by environmental science and technology and to provide a perspective on the future developments and trends. This somewhat global vision could be of assistance to all those who have professional interest or responsibly in any aspects of the environmental field including scientists, practitioners, computer software and hardware engineers, medical professionals, decision makers, etc.

The main title of the paper is puzzling and requires explanations before its meaning, and thus the focus of the paper can be understood. Rather than providing the explanation upfront, the concepts introduced in the title will be explored to build a picture from which the meaning will emerge.

The original version of this chapter was revised: The copyright line was incorrect. This has been corrected. The Erratum to this chapter is available at DOI: 10.1007/978-0-387-35503-0_29

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Firstly, the concept of REPLACEMENT and the need for it will be discussed. To do this, I will take a few steps back in the history of science and technology, to the sixties and seventies of this century. One area that was at the time developing very rapidly and appeared to be very promising, was nuclear physics and its application towards generation of energy. At the time when the demand for energy was rapidly growing and when it became clear that fossil fuels would not last for ever, a new source of energy from fission of heavy elements and possibly fusion of light elements appeared to have the potential to resolve world energy problems. At the time "nuclear" inspired the imagination of young people, many of whom became nuclear physicist or engineers. "Nuclear" was also a synonym for scientific and technological challenges and thus for progress relating to addressing these challenges.

Later, in the eighties and the nineties, it become clear that nuclear energy is not necessarily the solution for the future. The unsolvable problems related to generation of nuclear energy resulted in a gradual decrease of interest in this source of energy and increased attempts in identifying energy sources that would not be linked to the problems of nuclear energy. The main problems have been ensuring safety at every stage of the nuclear power generation process, and disposal of radioactive waste. Satisfactory solutions of these problems have not been identified and "nuclear", especially after the Chernobyl accident, became the synonym for radioactive pollution and risk. There has been less and less research and development funds available for nuclear programs and the world has started looking in new directions. Some of the final chapters of this process included reorientation of programs of organisations initially oriented at nuclear programs, to the extent of changing the names of the organisations. One organisation in Europe discovered that replacing "nuclear" in the title by "national", allowed them to keep the well known logo, while changing the technical and scientific foci. This is obviously a somewhat simplified view, as there are many nuclear power plants operating across the world, and for example France derives more than half of its energy from nuclear fission, but the expectations were much bigger.

In summary, "nuclear" did not fulfil the expectations, did not quite work, and thus was REPLACED.

A question can be asked at this point as to what inspires the imagination of young people nowadays? There certainly is not just one area which is currently in focus, and which is a choice of study for many young people. One of the areas, however, is related to environment: environmental science, environmental engineering, environmental technology, etc. Preserving the environment, cleaning the environment and protecting it, is what the current young (and not only) generation believes should be a priority when thinking about progress and development. But when asked about the meaning of "environmental" many university students and even academics struggle to define or explain it. References are being made to the need of preserving the environment, to endangered species and pollution, but usually in a vague and roundabout way. My first encounter with the problem related to understanding of the meaning of "environmental" in relation to applied science was when the Head of School of Geology, who managed to obtain funds from the university for a new academic position, asked a close group of academics, what actually was *environmental geology* in which he was about to make an appointment. Recently a first year student in his essay on the greenhouse effect described those who are dealing with environmental issues as either "doom and gloomy scientists" or "tree hugging hippies".

So what is environmental science?

One definition states that: Environmental science is a professional application of knowledge from many existing disciplines to the study of the environment. While this definition is very broad and does not necessarily explain a lot, it introduces the interdisciplinary aspect of the scientific work conducted. A definition that I have been promoting is that: Environmental science is a discipline aiming at quantification and explanation of physical, chemical and biological interactions between environmental systems that include the biosphere, geosphere, hydrosphere and atmosphere. The concept of environmental science, as a science of interactions is presented schematically in Figure 1.

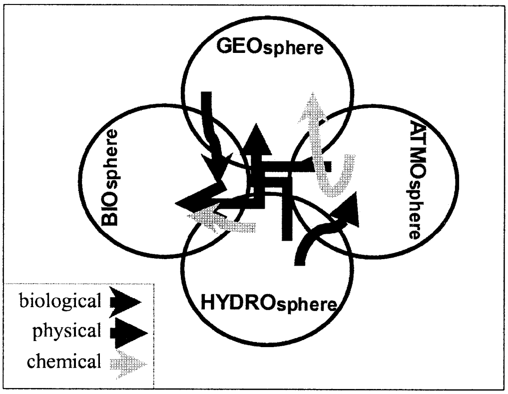

Figure 1. Environmental science - science of interactions between systems

Environmental interactions (physical, chemical and biological) are the most difficult ones to understand and to quantify and the complexities of environmental science stem from:

- A very large number of parameters which need to be taken into account
- A very large number of interactions and processes which have to be considered
- Need for an interdisciplinary approach.

Consequently it is not only that we cannot really answer many big questions, such as: what will be the progress of global warming, but even much smaller ones, such as: what will the weather be like tomorrow, or what will be the impact of pumping water from an underground well for local agricultural needs.

The complexity of environmental processes is usually underestimated by everybody: community, decision-makers and what is the worst, scientists themselves. I will illustrate the scientists' approach later when talking about development of a university curriculum. From the underestimation of the complexity comes a tendency to assume or expect that one environmental expert should be capable of dealing and solving all environmental issues. Therefore the number of "environmental" experts or organisations dealing with "environmental" issues, without specifying any particular area is very large. This approach often results in inability of those broadly oriented experts or organisations to solve specific problems, requiring expertise in the first instance, in one specific area.

Let us now take a hypothetical example of the following organisations carrying names that are relatively common, and ask a question what these organisations do:

- Centre for Environmental Studies
- Centre for Atmospheric Environmental Studies
- Centre for Environmental Aerosol Studies

While the name of the first organisation is too broad to identify the focus, if any of the organisation's activities, the name of the third organisation on the list may imply a very narrow area of studies. Let us then focus for a while on this area and use it as an example to show where the complexities come from.

Aerosol is another term for airborne particles. For example a task of an environmental consultant could be to characterise particles in the atmospheric environment of an office building or in urban air. The complexity comes when the following aspects are brought into the picture:

- The particles can be generated by a large number of sources: motor vehicles, power plants, wind blown dust, volcanos, photochemical processes, cigarette smoking, quarry operation, etc.

- After generation the particles undergo a large number of physical and biological processes and interactions: sedimentation, deposition on surfaces, coagulation, changes by evaporation or condensation, etc.
- Smaller and larger particles behave almost as different entities and for example:

  For small particles:
  - Their number is large, but the mass is small
  - They contain most of the toxins/trace elements
  - They remain in the air for a long time
  - They penetrate deep to the respiratory track
  - They penetrate through filtration systems

  While for large particles:
  - Their mass is large, but the number is small
  - Fibres and pollens are in this range
  - They do not remain in the air for a long time
  - They deposit mainly in the nose
  - They are removed by filtration systems
- The choice of different instruments, operating on different principles and measuring different particle characteristics, with different sensitivity in a different size range is very long.

What to measure then, how to do it and how to interpret the data? Recently an environmental consultant asked me for help in developing a sampling design for an environmental impact assessment of a large coal processing plant. The available budget was ten thousand dollars and the duration of the project one year. The design outline was supposed to be ready by the same afternoon. The consultant had very little understanding of airborne particles, did not know what particle characteristics to measure or what instrumentation to use. Neither the industry purchasing the services of the consultant, nor the consultant had the realisation that with the budget made available for the project it would be impossible to obtain any meaningful results.

Some of the other complexities in this area include:

- Need for considering particles in systems consisting of gases and vapours as well;
- Need for bringing scientific (physical, chemical, biological, etc), engineering (filtration engineering, motor vehicle engineering, etc) and medical (respiratory physicians, epidemiologists, etc) to properly set the objectives of investigations, to design and conduct the project and to interpret the data.

Let us review now some of the current difficulties experienced by applied environmental aerosol science:

- *Standards*: incompatibility of air quality standards which are expressed in terms of mass of certain particle sizes, with motor vehicle emission standards which are expressed in terms of total mass.
- *Problem*: There are no simple methods of measuring the mass size fraction from motor vehicle emissions to enable routine measurements.
- *Particle inventories in airsheds*: contributions from different sources to concentrations of different size ranges and different properties are unknown.
- *Problems*: for fine and ultra fine particles emission and post formation changes yet to be quantified
- *Particle effects on health*: we know that there are strong correlations but we know little about the exposure-response relationship or even the mechanisms by which particles induce health effects

After listing of all these difficulties, problems, and unknown areas, it should be pointed out that the discussion above has been focused on one "narrow" area of environmental aerosols. What if we went up one step to atmospheric environment issues, or whole environmental problems?

The example of problems encountered in one specific area, such as environmental aerosols was discussed to illustrate the dangers facing environmental fields in general. These dangers could be described as follows:

- Underestimation of the complexity of environmental issues
- Rushed and superficial approach towards solving environmental problems (environmental impact assessments)
- Missed control and mitigation actions

From unsuccessful control and mitigation actions the final conclusion can be drawn: IT DOES NOT WORK.

If it does not work it should be REPLACED - like "nuclear". Some signals of replacing trends are already evident. For example when choosing a name for a new School at one University in Australia, which was to deal with a spectrum of environmental issues, "environmental" was not considered in the title as it was perceived that this was an overused term. Another example is a comment made by a government affiliated person, that when making new appointments in environment related departments of the government, there is more demand for *scientists*, than for *environment scientists*, as the later are often unable to understand the depth of the problem.

If "environmental" does not work what to replace it with? The current trend and the current direction are sustainability.

What is the meaning of sustainability? A commonly used definition states that: sustainable development means to meet the needs of the present without sacrificing the ability of future generations to meet theirs. Thus, the concept of sustainability is even broader that the concept of environment. In fact it is sustainability of the environment. If, however, we cannot solve environmental problems, it will be even more difficult to do so in relation to sustainable issues.

A very important challenge which is facing the future of sustainable development and a sustainable approach, is how to link the general understanding for the need of sustainable development with the specific goals, targets and responsibilities of individual disciplines and professionals. In other words, how to provide in practice an interface between the outcomes of specific undertakings, so the overall outcome is sustainability in development and progress. At the moment there is often a gap between the outcomes of real actions and the requirements of sustainability. I suspect that many professionals asked what exactly sustainability means in relation to their professional areas, and what exactly to do towards achieving sustainability, would not be able to provide an answer.

Thus the nature of the problem is: How to provide an interface between a global approach and vision, and understanding of the details of science and practice. Without this understanding the area of sustainable development will face the same dangers as environmental fields. These are:

- Underestimation of the complexity of sustainability issues
- Rushed and superficial approach towards actions aimed at achieving sustainability
- Missed control and management actions

Development and progress has always been made on the foundation of teaching and education. Returning to the area of environmental science, undergraduate and postgraduate programs in this area have been developed at many universities. Students undertaking postgraduate environmental science programs would have obtained education in one specific area in which they graduated and thus, before venturing into broader environmental areas, they gained deeper expertise in one particular field. The dangers come when environmental studies are undertaken at the undergraduate level, when without gaining depth in any particular area, students venture straight to global problems.

Environmental science is one example of interdisciplinary science, and as such, undergraduate teaching in this area can be discussed in more global terms of interdisciplinary teaching at the undergraduate level. As a general trend, students' demand for new and interesting areas, linked to Universities' needs to attract students results in the tendency to create interdisciplinary undergraduate programs. The key questions arising in relation to this trend are:

- should interdisciplinary teaching be conducted at the undergraduate level, and
- how to do it right, so that graduates are not disadvantaged by this trend in terms of the quality and quantity of knowledge, and society is not disadvantaged by receiving half cooked graduates.

A large body of knowledge from many areas needed to address interdisciplinary problems leads to misconceptions about the need for teaching of various elements from many areas, without focusing in this process on any specific area. As a result, the graduates from interdisciplinary undergraduate programs, while having broad horizons may not have the ability to solve any real interdisciplinary problems, the complexity of which is usually very high and requiring a high level of expertise.

To avoid this, the recommendation for an approach to university interdisciplinary teaching such as environmental science is that:

- students should obtain a high level of education in one specific discipline, and
- a broad understanding of interdisciplinary issues.

From university undergraduate and postgraduate students grow professionals undertaking work in various areas of the environmental field. In relation to professional expertise it is very important to realise that:

- Professionals should be experts in one discipline and have a good understanding of global issues, and
- It should not be expected that one environmental expert would be capable of addressing all environmental problems.

One obvious recommendation here is that, environmental experts should work in multidiciplinary teams covering a broad range of expertise needed to address all aspects related to specific projects. While this is the most logical solution, it is only rarely followed and the reasons for this are multiple, including:

- Lack of realisation by experts themselves (scientists, consultants, medical professionals, etc) that they do not posses the required depth of expertise.
- Expectation from funding agencies (government, industry) that an environmental expert or an environmental group should be able to address all environmental problems.
- Economical factors due to which particular teams or consultancy firms cannot afford salaries for additional personnel to cover the required range of expertise but in order to generate funds they are forced to undertake projects outside their expertise range.

In summary, the concepts that have been discussed above include:

- The need for developing new areas, directions and approaches if the existing ones do not provide solutions. In other words, the need for replacement if what is in use but does not work.
- The complexity of environmental science and the danger that if this complexity is underestimated, the practical solutions developed may fail to achieve expected outcomes.
- Examples of very frequent underestimation of the complexity of environmental issues and, potentially also in areas related to sustainable development, by scientists, practitioners and university educators.
- The recommended approaches to university training of environmental experts.

What about the "extrasensory" which is in the title of this paper? While to most readers this is a term related more to science fiction, rather than to any real science or practice, one extrasensory area, which is intuition, has been acknowledged as a tool in some European management training programs.

In the title of this paper, this word has been used however, as an abstract term to illustrate the concept of REPLACEMENT, preferably by a word starting with the same letter to "keep the logo" if necessary.

It should also be pointed out here, after the challenges and trends in environmental field have been discussed, that while failure of nuclear technology to provide solutions to global energy problems was brought up the beginning of the paper as an illustration of the replacement concept, the parallel with replacing of "environmental" cannot be taken too far. Application of nuclear processes towards energy generation is a human invention, and because of this humans have choice whether to use it or not. Humans do not, however, have a choice whether to live in the earth environment or not, and as such this environment cannot be replaced by something else, which means that replacement relates in this case more to terminology rather than to the field itself.

In conclusion, the future depends on the ability of environmental science and technology to provide solutions to environmental problems.