EAWAG

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EAWAG news

Swiss Federal Institute for Environmental Science and Technology (EAWAG), CH–8600 Dübendorf, Switzerland

Science's Duty to Ask Questions and to Express Doubts

Dear Readers

To date, environmental protection has rested on two pillars: reckoning the dangers and adopting standards to mitigate the damage. This dual approach is now reaching the limits of our technical capabilities and is being jeopardized by the growth in consumption. It is a source of conflict and is subject to particularly fierce criticism during periods of economic distress.

The Rio de Janeiro Environment Summit held in June 1992 established a third pillar for environmental protection. By using the generic term "sustainable development", it showed the need for integrating environmental protection into economic strategies.

We are still far from our goal, but a powerful movement has been set in motion. It allows us to harness economic and political energies so that the sustainable use of resources, the reduction of pollution to acceptable levels for ecosystems, and health and respect for life in all its diversity become part and parcel of every human endeavour.

Environmental protection is no longer on the defensive. It is becoming an engine of global progress. It is calling on all scientific, economic, social and cultural forces to create a civilization in which humanity and nature, the present and the future, and people from all over the world are in harmony.

To accomplish this task, each and every one of us must come out of his or her shell to think, act and participate in one of the grandest projects ever faced by humankind.

Scientists, overprotected by their encrypted speech and a too generous interpretation of the freedom of research, have to step down from their ivory tower. They must find a simple language in which to express their findings – and of course their questions and doubts – so that all of us understand our responsibility to work towards the goal of sustainable development.

EAWAG offers fertile ground for this urgent task.

Philippe Roch, D.Sc.
Director of the Federal Office for the Environment, Forest and Landscape

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Title page picture
Aerial view of an alluvial river with its floodplain (Nyack Flats, Middle Fork of the Flathead River, Montana, USA) demonstrating the complex mosaic of aquatic and terrestrial habitats which is characteristic of such systems (see article by Tom Gonser).

Alexander J.B. Zehnder

Environmental Development: the Way Forward

We live in an age that demands fundamental changes in the way science, technology and society interact. A great deal of thought is being given to the reasons for these changes and the steps that must be taken to cope with the problems of our future. The social and economic turmoil and political upheaval of recent decades have no doubt contributed to these changes. The problems which confront us stem mainly from the large-scale consumption of resources in the industrialized world and from predictions of continued population growth. The primary concern is sustainability – the preservation of natural resources and the environment.

« *We cannot put resources in a museum. We have to learn to harness them in such a way that they are still there for us and our descendants.* »

The Earth's Population in the Next Century

Population growth in this century has been so spectacular that it is one of the most striking aspects of modern history. We are now seeing the culmination of a process which has been building up over centuries. We can be sure that the population will not always grow at the same rate, but this phenomenon will remain a source of great concern over the next century. It is not merely the fact of growth itself, but how and where the population is growing (Fig. 1). Growth is fastest in the less developed regions of the world, especially in South and East Asia, Africa and Latin America. Population expansion is stagnating in North American and Europe (including the countries of the former Soviet Union). This imbalanced development is a cause for concern since:

- Rapid population growth threatens both the poor countries' own development and global well-being.
- The huge disparities in income, coupled with population pressure, are leading to political turmoil and violence. The upshot is increased international and transcontinental migration. The coming years, it is feared, will bring us new and bigger waves of migration. While some countries fear a "brain drain", others are worried about being overrun by the less well educated.

Demographic imbalances generally tend to right themselves, though unfortunately this may take some time. Female children who, as grown women, will bear children in the next century have already been born. The results of active family planning will not be seen for a generation or two. In the meantime, the population is growing inexorably. Only to a very limited extent is population size a political variable which governments can manipulate at will. Politicians, like business people and scientists, should not concentrate on limiting population growth, but rather on developing concepts and technologies which will enable us to promote and industrialize the less developed areas while combining the desire of a growing number of people for individuality, mobility, more personal security and comfort with protection of the environment and preservation of resources; in short, sustainable growth.

From Environmental Protection...

The sheer scale of the mounting problems has paralyzed us too long, and we have done little to find innovative solutions. There are two main reasons for our relative passivity:

First, we have assumed that we have to think exclusively in global terms. The demographic and ecological problems do call for worldwide solutions, but we do not yet have the instruments to develop such a global approach. There are a number of reasons for this. It is relatively easy to define global problems, but exceedingly complex to solve them. A concerted approach is ideal but is stymied by short-term special and national interests. Though the environmental conference in Rio sent clear signals, practical implementation is hesitant or even non-existent and has so far taken place only where the effects are relatively painless. Time is running short, and we can no longer wait for a worldwide consensus. What we can do is tackle the global problems at the local and regional levels. Local and regional solutions are possible; they allow those directly involved to make their personal contribution and identify with it. They enhance everyone's personal sense of responsibility.

Secondly, many people still believe that there is an inherent contradiction between ecology and business. For more than 20 years, a clear dividing line has run through ecological politics. At one end of the spectrum, we have the environmentalists who demand that pollution be eliminated and ecosystems protected, whatever the cost. In their view, big business is raping

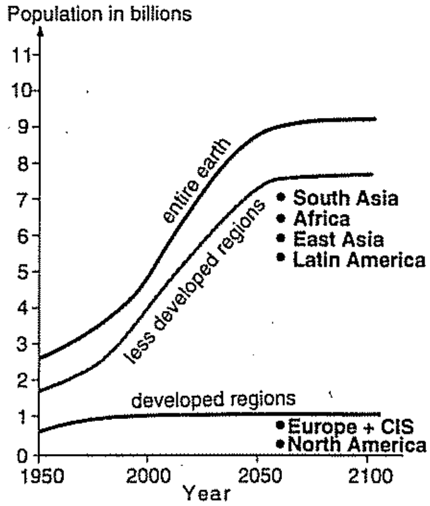

Fig. 1
Forecast for population growth in the next millenium. Source: The World Bank (1992)

the environment for the sake of profit and bears the blame for all environmental damage. At the other end, we have the business "lobby" – with their various supporters – who believe that any legislation to protect the environment hampers economic growth. In their view, environmental protection is wasting financial resources which are then lacking for economic growth. In the late 1980s, farsighted representatives of both camps began to cross the line and are in the process of erasing it. Both sides discovered that sound business practice and a sound ecological approach are not mutually exclusive. By harnessing the mechanisms of the free market, pollution can be minimized, environmental protection maximized, and economic growth realized. Recent developments in the automotive industry, for example, show that the innovative combination of business and ecology can lead to products with interesting markets (e. g., fuel-saving engines and the new technologies developed in response to the California law stipulating that as of 1998 at least 2% of motor vehicles must no longer use fossil fuels). The ecological approach is thus by no means a shackle on the economy. On the contrary, it is increasingly clear that ecological thinking can act as a catalyst for innovation, development and economic expansion.

The fact that the synergies between the free market and environmental protection are still only barely visible on the horizon is due in part to the disappointing results achieved in recent years with environmental legislation in various countries. Legislation has not always produced the anticipated effect, since it has leaned excessively towards command-and-control regulation. In the initial phase, this approach is no doubt unavoidable, and it does serve to reduce pollution. Because it is inflexible, however, it also hampers innovative efforts which are then lacking when problems have to be confronted at a later date.

...to Environmental Management

Reactions to (demographic) problems are usually defensive. The first response is protection, and this is probably the right reflex. But protection is not enough. We must go on the offensive. We cannot put our resources in a museum. We have to learn to harness them in such a way that they are still there for us and our descendants. That is why sustainable development is not a static process. The Brundtland Report's definition of sustainable development is neither static nor dynamic. The interpretation is open. Until now, environmental protection has focused on limiting and minimizing damage; in the future, we will have to avoid unnecessary damage and learn to manage our resources. It is essential that the resources do not go into irreversible decline. Obviously, once certain resources are used up, they are gone forever. Sustainable development does not mean preserving a specific resource, but finding a replacement that is at least equivalent. Roughly speaking, sustainability may be considered to be the total amount of resources which remains constant over time in a steady state (Fig. 2). Human activities will consume part of the resources. It is neither possible nor even desirable to completely prevent this consumption. What must be prevented is excessive exploitation, which is now unnecessarily high in the industrialized world. We must find novel ways of converting resources that have been used up into equivalent resources. A model of this kind will allow consumption as well as development and growth. The scale and speed of growth depend not only on consumption but also on new ideas in technology and innovation; that is, our own inventiveness. The process described here is actually common to all natural cycles of the elements. The elements too are simultaneously mineralized and incorporated into complex molecules. Sustainable development should, therefore, be defined as a cycle of all resources. We, as human beings, have to learn to reintegrate ourselves into this cycle, even though the conditions today are more difficult because the growth of the world's population is continually throwing this resource cycle out of kilter. We must counter the population explosion with an innovation explosion in order to close the resource cycle as quickly as possible.

The Question is How

Up to here, most readers will have found it easy to agree with me. What steps must be taken, however, to insure effective resource management? I would like to put forward three proposals which will enable us to make the transition from environmental protection to environmental management.

Thesis 1
Environmental and resource management must become central to decision-making; it must no longer be considered a "necessary evil".

Improvements in our decision-making will hinge on our ability to develop processes for regulating prices in such a way that they accurately reflect the actual costs of pollution or resource consumption. The challenge for science is to develop the appropriate criteria and methods for this purpose. In Switzerland, we are on the right path with environmental compatibil-

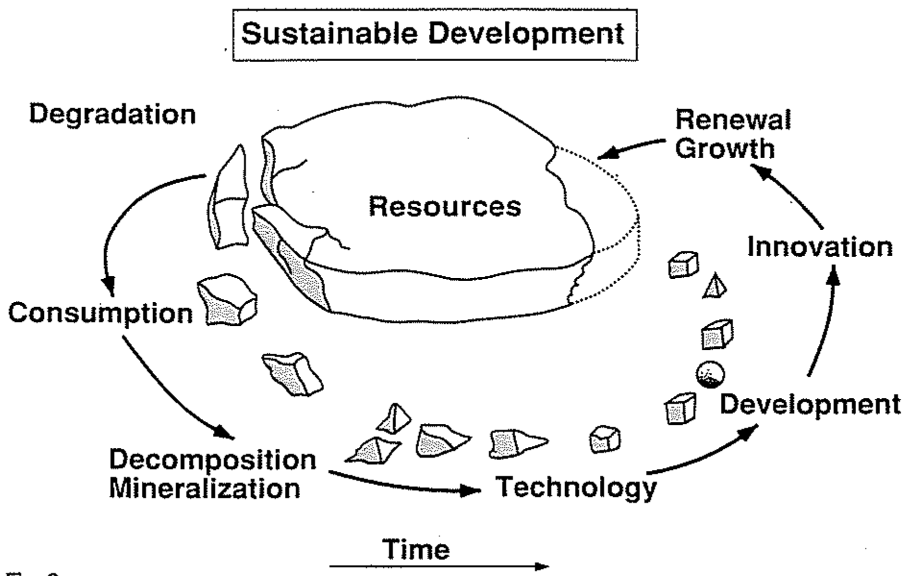

Fig. 2
Schematic diagram of sustainable development as a steady state over time.
The total amount of resources remains constant. Resources which have been used up or degraded are replaced by technological gains, development and innovation, thus allowing renewal and growth.

ity testing and eco-audits for substances and products. However, if we fail to come up with clearer and more incisive economic incentives, these tests and audits will continue to be regarded as just a necessary evil. Progressive charges levied on the use of resources and their direct recycling to stimulate innovation with the aim of reducing consumption or developing alternatives are original contributions to an ecology-driven economy.

Thesis 2
Each individual is personally responsible for his or her own use of resources and intervention in the immediate environment.

We often tend to consider environmental protection – and to a growing extent environmental management – as "somebody else's problem". If we want to be successful in environmental management, each and every one of us must consider environmental issues, in particular the use of resources, a personal issue. A targeted and coordinated education, information and taxation policy is essential for making people aware of the problems involved.

Thesis 3
As inhabitants of this country, each and every one of us must reduce his or her current level of resource consumption to an average of one third of the present consumption in the next thirty years.

This last proposal is, in fact, the quantification of the first two. The time horizon is long enough to allow technical developments in a wide range of areas to reach the production stage. A coordinated policy on taxation and innovation stimulation is the key to achieving this aim. Many developments and improvements in the past two decades have shown that this goal can be met. The articles in this issue by Peter Baccini and Roland Schertenleib illustrate the point.

What Remains?

Even if these three proposals are put into practice, the problems of scale and distribution of resources among the earth's inhabitants remain to be solved. We still have to answer the question of how large a global economy can become and yet still be ecological balanced, particularly with reference to the industrialization of the less developed regions of the earth.

Population growth is greatest in regions that have a dearth of food and land resources. The growing demand for food can be met locally only for the next few decades at most, a relatively short timescale. This is already taking place at the expense of soil quality. It is thought that in the last forty years as much as 11% of cultivable soil has been destroyed, and the rate of soil degradation is increasing with population growth and industrialization. In the near future, the less populated industrial nations will have to produce the bulk of food for the densely populated areas. Most of this food will have to be transported between and across continents in order to reach consumers. As yet, it is difficult to put an exact figure on the energy and transport costs, not to mention the additional consumption of resources, needed for this purpose.

Water is a key resource. The earth has sufficient fresh water, but its distribution and quality often do not meet actual needs. Economic growth in the less developed regions necessarily increases water consumption, thus exacerbating the pressure on this precious resource.

The driving force for the unremitting trend to transcontinental migration is the natural desire of people to enjoy prosperity – in other words, gain access to resources. In the long run, however, it is not possible to move huge numbers of people to the resources. In the future, the resources (or the products originating from them) will have to be transported to a larger extent across continents to the consumers. A major challenge facing our society is how we solve the problem of distributing these resources.

Biological resources are a special case. Organisms have developed over billions of years of evolution and selection. These two processes have created an infinite variety of genetic combinations. A network of systems has developed in the biological world to ensure adaptation, evolution and efficient selection. This network can be irreparably damaged and potentially valuable biological resources destroyed if species become extinct or nature's biodiversity is jeopardized. The upshot could be serious ecological imbalances.

EAWAG's Role

Putting these three proposals into practice is a challenge for all of us. It calls for a dynamic and innovative approach and for close cooperation between science, business and society. EAWAG accepts this challenge and would like to play its part in bringing about the necessary changes. As regards the first point, EAWAG will help develop concepts for an environmentally sound economy. As for the second point, EAWAG sees its role mainly in education and information. For the third point, we would like to make a contribution to improving the basic understanding of natural processes and ecology. We hope that this understanding will encourage the development of new ideas, social structures and technologies. The articles in this issue of EAWAG News illustrate how we see our role in selected areas.

Background information on the issues raised here can be found in the literature cited below:

- Alper, J. 1993. Protecting the environment with the power of the market. Science 260:1884-1885.
- Brown, L.R. et al. 1990. State of the World. A Worldwatch Institute Report on Progress Toward a Sustainable Society. Unwin Paperbacks, London.
- Göran, O. 1992. The population concern. Ambio 21:6-9.
- Gore, A. 1992. Earth in the Balance. Earthscan Publications Ltd., London.
- Lincoln, D.W. 1993. Reproductive health, population growth, economic development and environmental change. In Environmental Change and Human Health. Wiley, Chichester (Ciba Foundation Symposium 175) p. 197-214.
- Malone, T.F. 1993. Ferment and change: science, technology and society. Environ. Sci. Technol. 27: 1026-1031.
- Oldeman, L.R., R.T.A. Hakkeling, and W.G. Sombroek. 1990. World map of status of human-induced soil degradation: An explanatory note. Rev. 2d. ed. Wageningen, The Netherlands, International Soil Reference and Information Center.
- The World Bank. 1992. World Development Report 1992; Development and the Environment, Oxford University Press, Oxford.
- World Commission on Environment and Development. 1987. Our Common Future, (The Brundtland Report). Oxford University Press, Oxford.

Claudia Pahl-Wostl and Carlo C. Jaeger

Risk Communication:

The Example of Climate Change

In dealing with complex environmental systems, a substantial degree of uncertainty is unavoidable. This calls for new forms of dialogue between science and society.

The 1992 Rio climate convention demands that the production of greenhouse gases be stabilized at a level which represents no danger to the earth's climate system. Attainment of this target is not to be put off until considerable climate-related catastrophes have already occurred as a result of human influence, but is to occur fast enough so that the natural ability of ecosystems to adapt to anthropogenic climate change is not overtaxed. Continuity of food production and environmentally sound economic development should be guaranteed on this basis. Thus an upper limit for the production of greenhouse gases is postulated without being laid down quantitatively. Science is called upon to model and to quantify the dynamic causal chain, society → greenhouse gases → climate → ecosystems → society, including relevant feedback mechanisms.

Are Complex Systems Predictable?

The concrete implications with respect to the degree of uncertainty involved in predicting the effects of climate change are illustrated schematically in Fig. 1.

Our point of departure is a scenario with given amounts of greenhouse gases in the atmosphere. Our goal is to predict the climatic, ecological and social consequences which will result from the expected effects of these gases. The simplified illustration shown in Fig. 1 demonstrates the fact that the uncertainties involved within a causal chain multiply at each stage, and thus undergo an overall increase. In addition, this figure implies that the uncertainties inherent in the sequence climate → ecosystems → society increase on proceeding from physical systems through biological systems to human systems. It should be stressed that this illustration does not yet take into account the effect of feedback between the systems alluded to above. Thus it would appear that the synthesis of individual results, obtained under special conditions, to obtain an overall result becomes increasingly problematic. The uncertainties which occur are of various types. Apart from an inadequate state of knowledge, which can be improved by intensifying research efforts, the dynamic nature of the systems to be investigated gives rise to questions and gives cause for reflection.

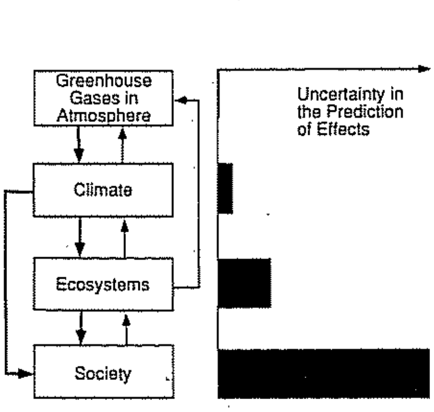

Fig. 1
Cascade of uncertainties within a causal chain.

Complexity Does Not Imply Continuity

As a contribution to research in this area, the Department of Environmental Physics at EAWAG is studying environmental archives such as lake sediments and Greenland ice cores. These studies have shown that changes in climate, as well as in ecosystems, do not occur continuously, but rather in discrete jumps. A clear illustration of this is given by the abrupt change in lake sediments from an oxic to an anoxic condition. This can be seen in Fig. 2 in the color change from light to black of Baldeggersee sediments.

Such discrete changes are a general characteristic of non-linear systems. They often set narrow limits on predictive capability. An instructive example of this is the difficulty involved in predicting the weather in Alpine regions. The occurrence and collapse of Föhn conditions represent a discrete change that drastically limits predictive capability. Such limitations of predictive capability with respect to the changes in climate now threatening us are being investigated in "CLEAR" (CLimate and Environment in Alpine Regions), a component project of the currently running Swiss "Priority Program Environment", to which EAWAG is making important contributions.

More Knowledge – More Decisions?

When estimating limits on predicting the future development of the climate, it is worth considering research results which

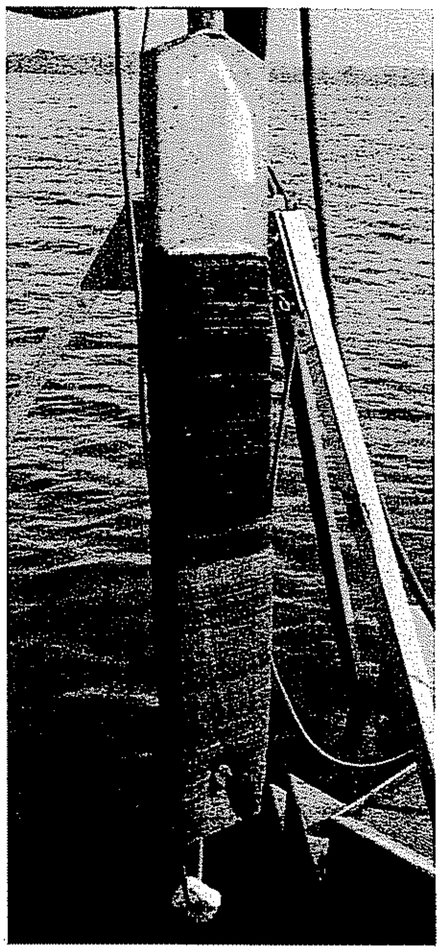

Fig. 2
Sediment core from Baldeggersee (CH)

imply that important properties of the oceans also experience discrete jumps (Fig. 3). The oceans play an extremely important role in long-term climate development, especially insofar as regional differences are concerned. An improved understanding of this role will necessitate conducting extensive measurement programs as well as developing complex mathematical models. However, one must come to terms with the fact that the progress attained is likely to result less in an improvement in predictive capability than in an improvement in our understanding of why – similarly to the situation in meteorology – predictive capability remains so limited.

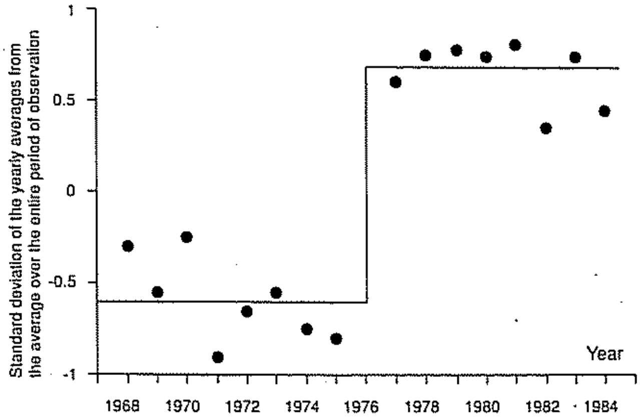

Fig. 3
Sudden change in climate in the North Pacific region shown in terms of an index composed of 40 environmentally relevant variables (after Kerr, 1992, Science, 255: 1508).

This does not at all mean, however, that scientific results bearing on the climate problem cannot form the basis for politically important statements. Research on Greenland ice cores shows that the global climate over the last few thousand years has remained relatively stable compared to earlier climate eras. The increase in greenhouse gases in the earth's atmosphere could change this, resulting in an increased frequency of extreme events for which no further predictions are possible. It can, therefore, be said with certainty that a threat exists globally, but concrete developments on the regional level are largely open.

Such results fit badly into the traditional picture of science as the agent by which well-founded knowledge is obtained which can be employed as the basis for environmental decision-making. It is questionable whether the communication structure which has evolved between science and politics in other contexts can be taken over unchanged in this new situation. This structure can be outlined as follows (Fig. 4):

The Role of Science in Determining the Politics of Climate Change

Scientific research is funded by government, which also decides on which questions to focus resources. An example of such a question might be: "Up to what concentrations is a certain substance non-toxic to humans and other forms of life?" Science works out answers to this question and trains specialists who are able to understand the answers and to make practical use of them. To do this, science has recourse to its accumulated store of knowledge, which is continually being cultivated and extended through basic research. Based on the scientific answers which they receive to the questions they pose, the politicians then decide on measures to solve the problems which occur. An important example of this is the question of threshold values, a topic which dominates large areas of environmental politics.

As far as the politics of climate change is concerned, such an approach does not seem particularly promising. The idea that the results of scientific research will allow determination of the development of maximum global greenhouse gas emissions in the future does not appear to be very plausible. Even less plausible is the idea that national limits for such emissions can be set on the basis of such results.

In the future, science will increasingly have to involve itself in an open social dialogue on the subject of innovative responses to the dangers of anthropogenic climate changes. The goals of the climate convention cannot be attained in a top-down fashion by fixing quantitative global emission limits based on the results of scientific research, and then by attempting to implement them politically on the national level. A complementary bottom-up process is needed in which innovative technological and social approaches to the problem of reducing the concentration of greenhouse gases are developed and their utility is tested. The function of science in this case would be not only to obtain answers to questions arising from within the context of environmental politics, but also, increasingly, to test political solutions

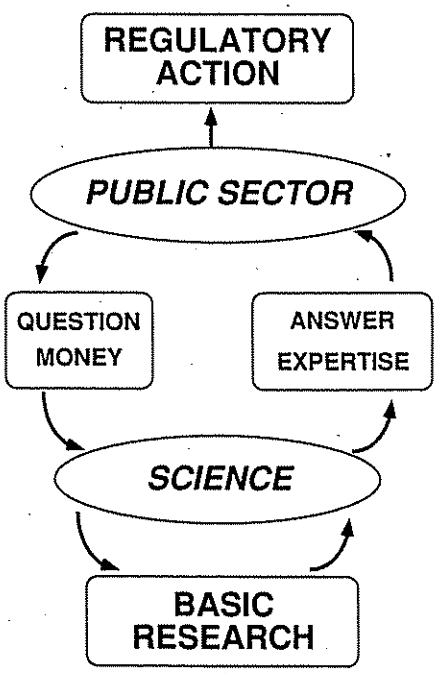

Fig. 4
Traditional structure of communication between science and politics

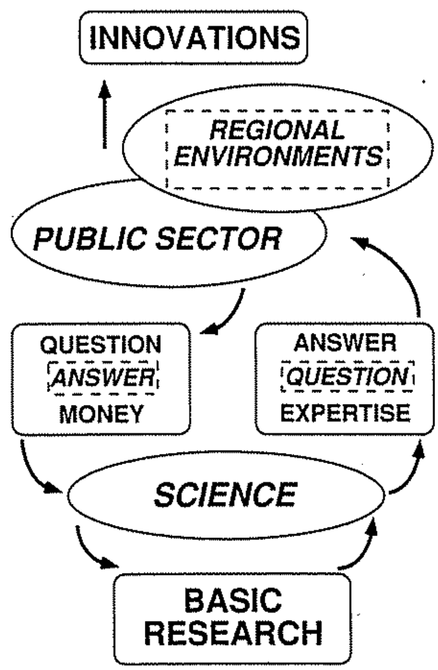

Fig. 5
Innovation-orientated communication between science and politics

to environmental problems critically, and if necessary pose questions requiring political, not scientific, answers.

New Impulses Must Come from the Regions

Recent contributions to research on innovation emphasize that innovations nowadays often originate in regional environments, in which know-how relevant to certain problem areas is collected in such a way that collective learning processes result. Important examples of this are Silicon Valley in California and various regions in central Italy and southern Germany; the watchmaking area of the Swiss Jura might also be included here. A conscious emphasis on such regional environments will probably be an important feature of innovation-orientated environmental politics (Fig. 5).

Within a framework such as this, approaches to a system of sustainable regional development (SRD) can be formulated. With regard to climate change, a system of SRD must fulfill three criteria:

- It must set per capita levels for greenhouse gas emissions which can be generalized to cover humanity globally.
- It must be economically competitive.
- It must function internationally as an example of a desirable state of affairs worthy of emulation, thus contributing to an effective reduction of greenhouse gas emissions regionally as well as globally.

In the Department of Human Ecology at EAWAG, some ideas relevant to the development of a system of SRD are being investigated with respect to new forms of transport (Swatch Mobil) and new forms of living requiring a lesser degree of mobility (decentralized places of employment). The possible role which could be played by taxes on CO_2 emissions and/or other forms of an energy tax is being given special consideration here. By opening a dialogue between science and relevant social groups, a discussion of global environmental problems on the regional level, under full awareness of existing uncertainties, can be facilitated and the capability to act innovatively promoted.

Herbert Güttinger

How Much Stress can Organisms and Ecosystems Tolerate?

Ecotoxicological Considerations

Organisms Under Stress

Stress in the medical sense means an abnormally high strain placed on an organism by external and internal stimuli. The term also encompasses the totality of the body's nonspecific adaptive and protective reactions. Typical stimuli include heat, cold, overexertion, oxygen deficiency, nutritional deficit, infections, surgical procedures and mental excitation. Three stages of stress can be defined as: 1. the immediate, short-term emergency phase; 2. the subsequent defensive phase; and 3. a repair phase with a concomitant adaptation syndrome. This definition of stress can be applied, by analogy, to the non-human part of the biosphere.

Environmental protection is primarily concerned with those external stimuli arising from human activity, and the consequent need for their reduction when they exceed "normal" levels. But what do we mean by normal? Let us take, for example, the simplest and ultimate effect: the death of an individual and the extinction of a species. In excess of five million different species of microorganisms, plants and animals have evolved over the course of the last 3–4 billion years. Even without any help from humans, a great many species have died out during this very slow evolutionary process, whether as a result of catastrophes or gradual displacement by more successful species. Evolution is a dynamic process in which the growth, reproduction and modification of organisms is limited by external forces, and it results in the selection of species. In recent decades, the natural limiting factors have been compounded by adverse influences, introduced by humans, which far exceed the adaptive possibilities of species in terms of power, diversity and variability (Fig. 1). Such effects cannot be ignored. According to expert estimates, several thousand species become irretrievably extinct each year [1]. The more highly developed organisms with long generation times and a complex genome are particularly affected. Simpler organisms are more likely to be able to adapt.

In the short-term at least, the ecosystem "earth" has managed to cope with this incredible, irreversible destruction of genetic information. Whether humans, as

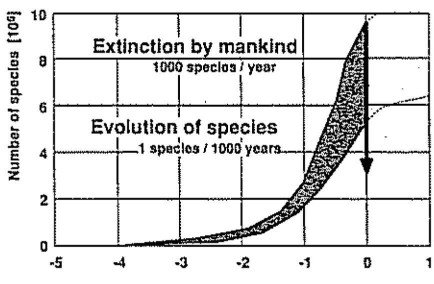

Fig. 1
Evolution and extinction of species.
The emergence of species is based on data concerning the first appearance of life in the earth's history and on estimates of the currently surviving number of species [1]. The rate of eradication by humans is shown as a trend without precise figures. The specified rates should be considered simply as orders of magnitude. The present rate of species extinction exceeds that during the greatest catastrophes during the history of evolution by several orders of magnitude.

"higher" organisms, will be able to tolerate cohabitation with nothing but insects, algae, bacteria and fungi remains to be seen. As a result of this adverse trend, more and more people are becoming uneasy, and more and more people are supporting the protection of species as an urgent national and global task. They no longer view the stress of species extinction as an acceptable price to pay. To reduce this stress, the requirements for the survival of threatened species must be satisfied, and no additional species should become endangered. Chemical, physical and biological needs, and requirements relating to habitat and diet all have to be fulfilled. The boundaries of the ecological niches of species should not be encroached upon by human activity.

Ecological Niches and Limiting Factors

Let us take a closer look at the concept of the ecological niche. According to Hutchinson [2], it is a multidimensional space incorporating all of the factors that affect a species (Fig. 2). For each individual factor, there is a range within which the species can exist. Within this range, the transition from ideal living conditions through harmful effects and extending up to acute lethal effects is gradual. As a one-dimensional concept, an ecological niche could also be considered as a dose-response relationship (Fig. 3). As far as nutrients and essential trace elements are concerned, for example, low concentrations/doses lead to harmful effects, an optimum balance is achieved at medium concentrations and high concentrations are poisonous. Toxic substances, by definition, produce only adverse effects on individual organisms by limiting growth and reproduction.

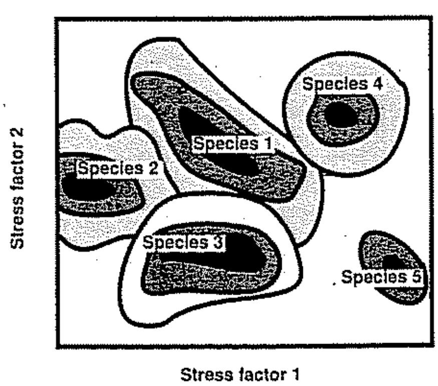

Fig. 2
Ecological niches.
Schematic diagram of the ecological niches of certain species in relation to two factors. The two-dimensional presentation is a considerable simplification of the actual multidimensional niche of a species.

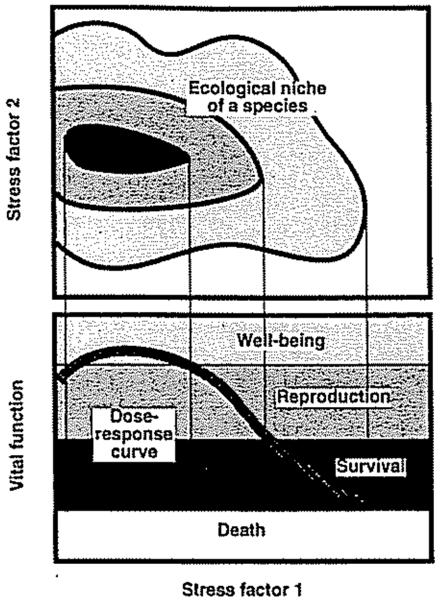

Fig. 3
Relationship between ecological niche and dose-response curve.
The projection of the two-dimensional presentation of a niche shows the relationship of a single factor to a vital function (growth, reproduction, change). The transition from harmful to harmless is gradual. Threshold values have to be set arbitrarily for a specific effect (generally the death of the individual).

The higher stages of biological organization, such as populations, complete biocenoses or ecosystems, should not, however, be treated simply as the sum of their individual species; they must, instead, be considered in their entirety. Within a single population, for example, lifecycle stages with differing sensitivities and genetic variants must be taken into account. For a population to remain in existence, specific individuals need not only survive but must be able to reproduce. The greatest differences between stress reactions, however, arise from the differing sensitivities of the various species involved. At the biocenosis level, therefore, stress almost invariably involves a shift in the quantitative relationships and interactions of the species [3]. Such quantitative changes can also lead, in time, to qualitative modification of the species structure. At the still higher stage of ecosystems, biogeochemical and physical status can also influence the fate, availability and effects of a toxin. The primary effect of stress at the molecular level is thus reproduced, via the individual and population, ultimately to affect the structure and function of whole biocenoses and ecosystems. Even the minutest of disruptions can change the direction of evolution and pose long-term limits on certain species. However, such relationships are at present almost impossible to quantify, and we, therefore, have to adopt a pragmatic approach in estimating tolerance limits. In this context, the short-term survival of the population of the most sensitive species in any biocenosis represents the minimum requirement. Satisfying this requirement in the best way possible is one of ecotoxicology's most important tasks.

A Yardstick for Measuring Toxicity

Before entering into circulation, therefore, chemicals (and other stress factors) must be investigated for their potential harmful effects and environmental impact. Naturally, experiments can only show whether a stress has a specific effect, or whether such an effect is not observed under certain circumstances. In other words, we can never definitely exclude the possibility that an adverse effect will occur somewhere or sometime. As a result, general safety or environmental acceptability is just as difficult to prove as general innocence. Toxicity is not a quantifiable parameter.

Instead of resigning themselves to these unpalatable facts and banning everything, or simply waiting until something happens, most countries have adopted pragmatic solutions. New substances have to be investigated for their toxic properties by means of standardized ecotoxicology tests [4]. Selected, representative laboratory organisms are tested for their sensitivity to the test substances. In aquatic systems, these mainly involve specific fish, daphnia and algae. These tests are complemented by investigations into degradation behavior and bioaccumulation. The concentrations at which a defined effect occurs after a predetermined period are measured. The following are the most commonly employed reference values: the concentration at which 50% of test organisms die within 48 hr (LC_{50}(48h), *lethal concentration*, Fig. 4), the concentration at which a 50% effect is observed after 96 hr (EC_{50}(96h), *effect concentration*), the concentration at which a specific effect is no longer observed (NOEC, *no observed effect concentration*). However, toxicity figures of this kind can never be totally reliable. They simply provide orders of magnitude at which certain (generally undesirable) effects occur. Consequently, thresholds and quality targets have to be set at a lower limit in order to be able safely to exclude such effects. The size of the safety margins used will depend upon political requirements and the available test data [5].

Science's task is to improve the meaningfulness of "toxicity" figures and to assist in the interpretation of such data in the light of political goals. Attempts must be made to reduce both the probability of error in the classification of substances and the number of laboratory animals required for the relevant tests. Important factors affecting reliability include: differing sensitivities of different species and different stages in the lifecycle, unreliable extrapolation of short-term effects to long-term effects, inadequate knowledge of synergistic effects of substance mixtures, scanty knowledge of indirect effects, lack of information about the relationship of effects on specific individuals to those on higher stages in the biological hierarchy, and generally poor applicability of laboratory findings to situations in the field. The criteria for enabling policy makers to set ecotoxicological requirements are to be found in the field of ecology, and they affect all stages of biological organization, from the health of a single organism to the integrity of whole ecosystems.

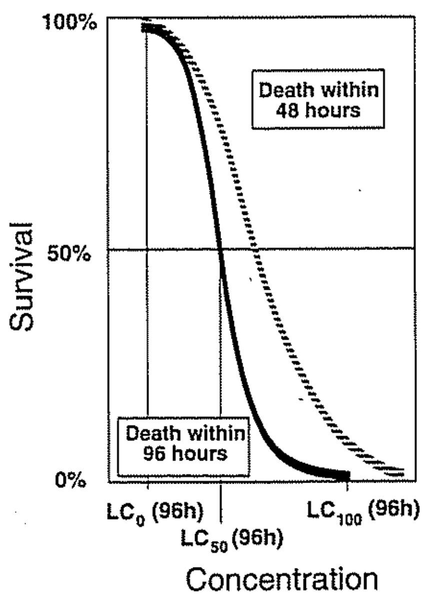

Fig. 4
Typical toxicity curve.
The graph shows reference values typically used in ecotoxicology: LC_{50}(48h) (lethal concentration or the concentration at which 50% of test organisms die within 48 hr). The ideal aim of an ecotoxicological test would be to find a value below which a negative effect no longer occurs. Unfortunately, such a value cannot be determined directly by experimentation.

So How Much Stress can Organisms and Ecosystems Tolerate?

One is tempted to answer "none", though such a response would be incorrect and unsatisfactory. The 16th century physician Philip Theophrastus Bombastus von Hohenheim, otherwise known as Paracelsus, was right when he said: *You wish to know what is and what is not poisonous? All things are poisonous and nothing is without poison; the dose alone makes a thing poisonous.* But Darwin was also right when he observed, in his theory of evolution, that the development of species involves an interplay of growth, reproduction, change and selection by external forces – a constant struggle for life combined with survival of the fittest, but resulting in stress for the weak. Thus, a certain amount of stress appears to be not just tolerable, but even essential, since it compels species to adapt constantly to the changing environment.

A second possible response would be: as much as would exist without the presence or activities of humans [6]. This would also be unsatisfactory. In the first place, it would be impossible to construct a satisfactory model of the situation on earth without humans. Secondly, putting this into practice would exclude humans from earth. Nevertheless, this type of approach can provide valuable insights into the tolerability of stresses.

In fact, the question cannot be answered in general and absolute terms, but rather has to be consciously posed for each individual factor and viewed within the overall context. The risks and benefits of substances should be assessed on a case-by-case basis. The borderline conditions for using a substance need to be determined and its fate and effects monitored. The irreversibility and extent of any harm should be considered in light of specific parameters (e. g., amount, spatial and temporal distribution, rate).

The multifaceted nature of the problem can be illustrated by the example of alcohol. Taken in small quantities by adults, alcohol produces positive effects on the mind and circulation. Long-term consumption, by contrast, generally proves harmful. It produces a disinfectant effect when applied externally at high concentrations, but the consumption of large doses can prove fatal. So while it would not be helpful to introduce a general ban on alcohol, it is certainly appropriate to rule on particularly critical areas such as alcohol for children or drivers.

The limit of tolerability of chemical stress lies somewhere between the natural background concentration and the experimentally determined toxicity values [5]. The range is very narrow and sufficiently well-known only for a few stress factors. It has to be determined for each individual factor through experimental investigation of its effects and improved models for reproducing natural conditions [7]. The natural range of variation in environmental concentrations and effects serves as a starting point for the evaluation of stress. Irreversible damage, such as the extinction of species or climatic changes, should be avoided or delayed for as long as possible.

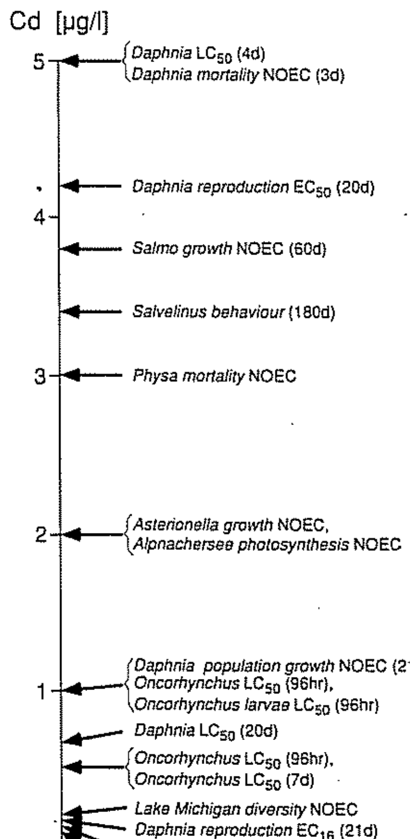

Fig. 5
Graph showing the ecotoxicity of cadmium [10].
For many substances a variety of experiments have been conducted, each producing differing results depending upon the trial design. In evaluating a given substance, results have to be selected from the wealth of toxicity data that are relevant to the problem in question.

However, as well as gaining a better understanding of, and satisfying, the requirements of species (their ecological niches and limiting factors), we also need to identify possible alternative approaches.

The great challenge is to identify and preclude future problems before they arise. Developments should no longer be left to chance; we have to manage our own planet [8, 9]. This means that we have to make a conscious decision, for each human activity, as to whether its consequences can be tolerated or not. In making this evaluation, we should take a holistic view of existing knowledge. The toxicity data in Fig. 5 illustrate the variety of investigated effects and effect concentrations. Instead of searching for a uniform measure for "toxicity", we need to quantify the relationships between cause and effect. These should be interpreted in a targeted manner (see also 5) and should also take into account production data, exposure analyses and characteristics of the receiving ecosystems.

I thank Renata Behra and Alexander J. B. Zehnder for their helpful comments, Heidi Bolliger for drawing the figures and Michael Bornstein for his good translation.

[1] Wilson E.O. (1989): Threats to Biodiversity. Scientific American 261, 3 (Special issue: Managing Planet Earth): 60–66.

[2] Arthur W. (1987): The Niche in Competition and Evolution. John Wiley & Sons Chichester, pp. 175.

[3] Lampert W. (1992): Der Stand der aquatischen Oekotoxikologie – aus der Sicht eines Oekologen. In DFG (1992) Beurteilung von Pflanzenschutzmitteln in aquatischen Oekosystemen. Rundgespräche und Kolloquien. VCH Weinheim; 146–161.

[4] OECD Guidelines for Testing of Chemicals. Paris.

[5] Behra R., Genoni G., Sigg L. (1993a): Festlegung von Qualitätszielen für Metalle in Fliessgewässern, EAWAG news (this edition).

[6] Baccini P. (1993): Erste Schritte zu einer nachhaltigen regionalen Ressourcenbewirtschaftung. EAWAG news (this edition).

[7] Güttinger H. (1993): Combined interpretation of biological and chemical field data to evaluate ecotoxicity of chemical substances. The Science of the Total Environment, 134 (in press).

[8] Cairns J., Jr., Todd V. Crawford ed. (1991): Integrated Environmental Management, Lewis Publishers, pp. 214.

[9] Clark W.C. (1989): Managing Planet Earth. Scientific American 261, 3 (Special issue: Managing Planet Earth): 18–26.

[10] Behra R., Genoni G., Sigg L. (1994): Revision of the Swiss Ordinance for Wastewater Discharge: scientific Basis for Water Qualitiy Criteria for Metals and Metalloids in Running Waters. Schriftenreihe der EAWAG Nr. 6, EAWAG, CH, 8600 Dübendorf.

Tom Gonser

The Significance of Stream Morphology for Ecosystem Functions

Originally, riverine landscapes were by far the most speciose areas in our biome. They formed an extensive network of corridors along which the majority of our indigenous flora and fauna could move and from which disturbed areas could be recolonized rapidly. These were the zones of the highest natural mass transport and mass turnover. Furthermore, natural river ecosystems and its adjacent lands demonstrate a pronounced stability against climatic changes as compared with terrestrial systems.

The Structuring of Watercourses and Interactions with their Surroundings

The structure of streams is decisive for their ecological functions and for their system characteristics as a whole. These characteristics are determined by factors such as gradient, width, grain size and activity of the sediments, discharge, bank structure, riparian vegetation, contact to ground water and the possibility of exercising a self-structuring activity. Through human manipulations of structural elements, drastic changes in the system characteristics have resulted which in turn raises two important questions. Which ecological functions have been lost due to these structural changes? Which management policies need to be implemented so that natural ecosystem functions are sufficiently guaranteed?

The formation of the structural characteristics is determined by the geologic/geomorphologic development of the entire catchment of which the stream is an active participant. The "embeddedness" of a river in a landscape and its interactions with the environment are of such overriding importance that lotic ecosystems[1] are characterized by their "edges" more than any other ecosystems. Boundaries or transitions to other ecosystems or habitats are generally termed "ecotones".

Fundamentally, three different situations must be distinguished [1]: (1) the water flows directly on an impermeable layer; (2) when sediments are deposited on an impermeable layer (e.g., bedrock), a system of pore spaces beneath the streambed is formed that is generally termed the hyporheic zone (gr. "under the flow"; see also Fig. 6). If sediment deposits are limited in scale, only river water flows through the hyporheic zone; (3) In wider valleys and lowland plains, a stream may flow over extensive sediment deposits (alluvium) in which a groundwater body is developed. Under such conditions, the hyporheic zone forms an exchange and transition zone between ground water ("phreatic zone") and surface water.

Longitudinally (Fig. 1b), we usually find a series of transitions between these situations [2]. In montane headwaters, all three conditions are often present relatively close to one another. The small basins, filled with coarse material, are well permeated and receive a major portion of the water through subterranean input from coarse debris slopes. When rivers flow through narrow valleys and gorges, where

[1] running water systems

the bedrock reaches the surface, both situations 1 and 2 are present. Further downstream, a large alluvium may be formed out of finer material. For alluvial reaches, the wide lateral connectivity with the land (Fig. 1c) and interactions with the phreatic zone are typical. Two distinct types of stream reaches can be differentiated by their transsectional profiles (Fig. 1a): (1) constrained reaches, in which the stream flows through a narrow valley; (2) unconstrained reaches, where the river is flowing over an alluvium and has the possibility of expanding laterally and interacting with the ground water.

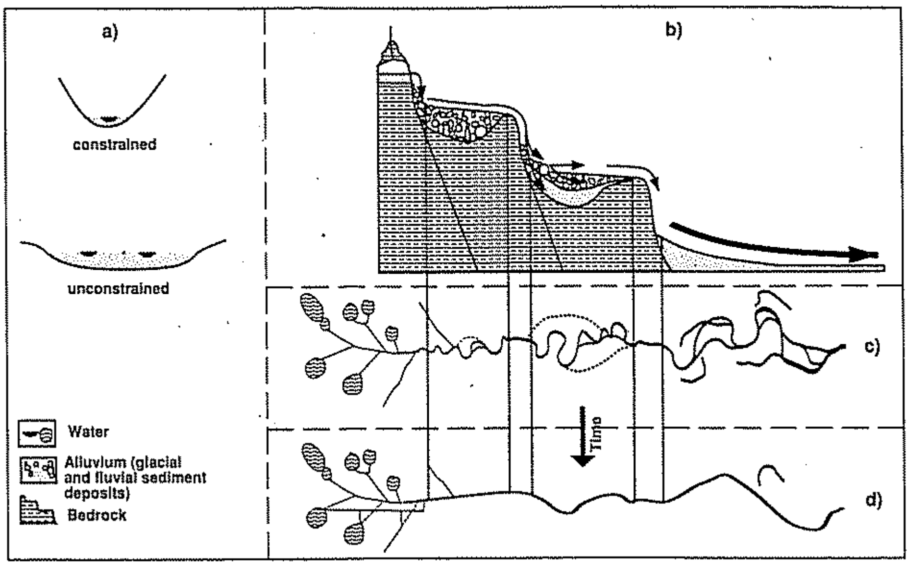

Fig. 1
Schematic longitudinal and cross-sectional representation of a river continuum.
a) Constrained and unconstrained transectional profiles.
b) Longitudinal profile.
c) Natural surface flow course.
d) Surface flow course after engineering alterations (adapted from [2]).

Watercourses: Past and Present

Naturally structured, unconstrained alluvial reaches are of highest biological importance; high aquatic and terrestrial habitat diversity is created and are zones of high material retention and turnover [2]. They may be considered "biological hot spots". In constrained reaches, on the other hand, there is little interaction with adjacent areas, and material retention and turnover are relatively low.

With few exceptions, the alluvial reaches in Switzerland have been completely transformed into constrained reaches (Fig. 1d). Below 1500 m, there are only a few biologically functional, unconstrained stream reaches left (e.g., the Rhine at Rhäzüns and Mastrils, the Rhone above Sierre and the Maggia between Bignasco and Avegno). However, all of these reaches are subject to the influence of hydroelectric power generation. Faced with this drastic and thoroughly structural and hydrological impairment of the lotic ecosystems, one must ask the following questions: Which factors sustain high biodiversity? Which factors affect the energy and nutrient budgets?

Diversity of Structures in Time and Space

Because of the importance of the transitions to other zones, lotic ecosystems can be conceptualized as four-dimensional systems [3]. They demonstrate longitudinal changes and connections, lateral transitions to terrestrial zones, and vertical transitions to the groundwater zone. These three spatial components exhibit differing temporal variabilities.

The aquatic-terrestrial ecotone is dominated by the discharge regime. Communities in the areas between high and low discharge levels ("varial zone") are continuously disturbed in their successional development [4] (Fig. 3). This disturbance is not homogeneous but, rather, very heterogeneous in its effect, creating a complex mosaic of patches of different successional stages and species compositions. Through the "interwovenness" of aquatic and terrestrial areas, both have strong effects on each other's structures and functions, and hence a very heterogeneous landscape is formed (see Figs. 2 and 3). It must be emphasized that this structural diversity is not temporally constant or "fixed", but rather extremely dynamic (Fig. 4). The areas that are flooded often, (i.e., exposed to high disturbance frequencies), are colonized by pioneer communities. These are mostly plants and animals with high reproduction rates that can recolonize disturbed areas rapidly and are able to survive under extreme conditions. On the other hand, areas that are subject to low distur-

Fig. 2
Alluvial river with floodplain and typical mosaic of patches of differing successional stages and habitat due to aquatic-terrestrial interaction.

[2] benthal = the bottom of water bodies, in this case, the streambed. Benthic: relating to the streambed.
[3] benthic stream organisms that penetrate into the sediments and true groundwater organisms that enter the hyporheic zone.

bance frequencies are dominated by competitive species. In an alluvial varial zone, there is a mixture of patches developed under the influence of the entire spectrum of disturbance frequencies; therefore, not only the structural heterogeneity as such is important for sustaining high biodiversity, but also the temporal variability of this heterogeneity. In a similar way, discharge dynamics affect the biota in the stream itself, resulting in a complex patchwork of different macrozoobenthos[2] communities [5].

The structure of the varial zone is a dominant factor in determining the nutrient budgets of lotic ecosystems. Under high discharge conditions, the vegetation lowers current velocities and is retentive for drifting organic material. Plant roots stabilize soils and sediments against erosion. Logs, branches and roots in the stream retain drifting material and are responsible for the formation of deep pools which act as sedimentation zones and shelter for fish under low discharge conditions. The retention in periodically flooded areas is much higher than that of permanently inundated zones [6]. In summary we can state that the discharge dependent lateral interactions in alluvial aquatic-terrestrial ecotones with their high retention capacities are responsible for the high biological diversities associated with natural riverine ecosystems.

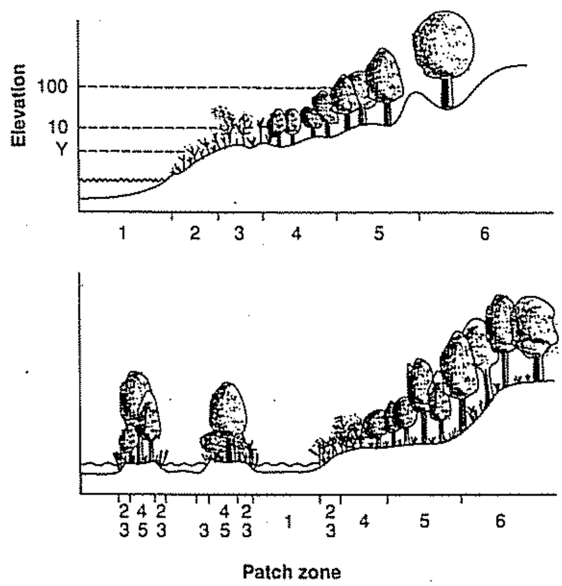

Fig. 3
The varial zone as a dynamic ecotone.
Patches of differing successional stages and their boundaries change continuously in time and space. Dashed lines refer to ecologically important flood levels:
y = yearly, 10 = 10 year, 100 = 100 year events.
Numbered patch zones refer to distinct biotic assemblages (from [4]).

The Significance of Surface Water/Groundwater Interaction

The observation of water levels in wells drilled into intermontane floodplains has shown that these closely copy the water levels of the river. The river is hydrologically connected to the ground water of the alluvium; however, this connection is not to be conceptualized as a continuous transition, but rather as a network of "arteries" and as a mosaic of lenses of different particle size composition. In the course of the genesis of the alluvium, the old river channels consisting of relatively coarse material are rearranged and/or covered over; thereby, zones of very different porosities are created. If these old, porous river channels (paleochannels) are tapped into, pumping may produce river organisms which may be encountered up to several kilometers away from the stream channel [7]. In these paleochannels, and in less porous zones, there are also true groundwater organisms. Functionally, a "combined biocoenosis" consisting of epigean and hypogean organisms[3] is present. This combined biocoenosis lives off of the biofilm on the stones where microorganisms metabolize dissolved organic material. In particularly porous alluvium, its biomass can exceed the benthic standing crop. This shows that the river is connected not only to the groundwater zone hydrologically but also biologically. The hyporheic zone of alluvial rivers is a complex surface-groundwater ecotone, whose expanse is dependent upon the porosity of the sediment deposits. Material and energy inputs are determined by the hydrogeologic exchanges and the biocoenotic composition results from the active immigration capacity of the individual taxa.

Longitudinally, streams show marked structural changes and discontinuities depending on the geologic formations which they traverse. On the other hand, inside of a stream reach, or an alluvium, there are characteristic longitudinal connections with the riparian and subterranean zones. Natural stream reaches normally demonstrate pool-riffle sequences. Particularly at

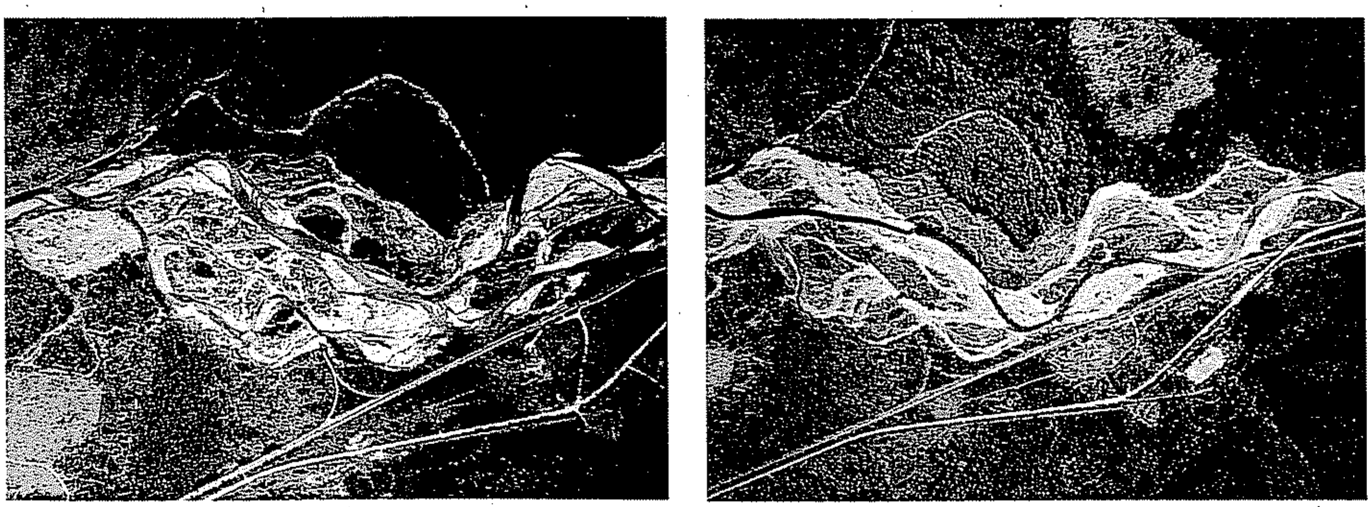

Fig. 4
Two aerial photographs of an alluvial floodplain taken 11 years apart (Middle Fork of the Flathead River, Montana, USA)

the riffles, river water flows through the streambed and the hyporheic zone (Fig. 5). Rivers that meander in alluvial deposits often show typical downwelling zones in the meander's upper portion and upwelling zones in its lower portion. Through these conditions transported particles are retained and the river water passes through a porespace system, which is lined by a microbial biofilm, where dissolved nutrients can be taken up and metabolized.

Lotic ecosystems also have large scale interactions with the groundwater zone. As rivers enter an alluvial basin, there is predominant downwelling (infiltration) into the ground water, while at the lower end of the basin, where the valley becomes narrow, mainly upwelling (exfiltration) out of the ground water takes place (Fig. 5). Due to the surface water-groundwater interactions, water with varying temperature regimes and nutrient concentrations reaches the surface. Thereby a large range of water temperatures can be measured on an alluvium, especially during the summer months.

Maintenance of Aquatic Habitat Diversity: Conclusions

The interplay in development and dynamics of these ecotones leads to varial zones with very diverse aquatic habitats such as oxbows, side channels, springs, springbrooks, groundwater-fed ponds, and a very heterogeneous stream morphology (See Fig. 6). In order to take into account the aquatic-terrestrial interactions and the functional significance of the surface water-groundwater ecotone, our understanding of lotic ecosystems must literally be greatly "expanded".

Through structural alterations of the alluvial stream reaches, their retention capacity for water, solids and nutrients, their internal mass turnover, their formation of

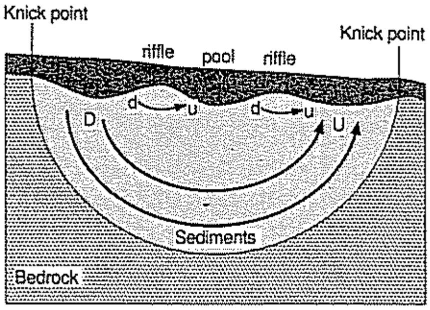

Fig. 5
Schematic representation of large and small scale up- and downwelling zones in the riffle-pool-sequence of an intermountain floodplain. D, d=downwelling zones (infiltration); U, u=upwelling zones (exfiltration).

aquatic habitat diversity, their interaction with the ground water, the creation of wet and dry sites for plants and the mutual influence of aquatic and terrestrial zones has been reduced to a minimum. The importance of the river's activity for the creation of semiaquatic and terrestrial habitat has been especially neglected, which is expressed in the almost complete absence of biologically functional floodplains.

Ecologically sound management strategies of lotic ecosystems must pursue the following objectives:

- Create a high degree of connectivity with the terrestrial and ground water zones
- Provide for the creation of biologically functional varial zones
- Use spatio-temporal heterogeneity as a basis for high biodiversity and high resilience capacity after disturbance events. Permit the self-structuring activity of the stream
- Protect oxbows, sidearms, springbrooks, groundwater-fed ponds, and adjacent wetlands
- Assure a significant natural input of large woody debris as structuring elements
- Protect sediment permeability

However, management strategies cannot be focused only on the streams themselves, but must also take structural changes in the catchment into consideration [8, 9]. The future management of running waters must be oriented towards the regeneration of the associated ecotones as functional units in which streams are naturally embedded [10], and thereby assure the interactions with riparian and ground water zones. The structuring function of the discharge dynamics must be especially taken into consideration. As a whole, in both research and management, we must move away from viewing streams as pipes separated from the adjacent land and ground water, and instead move towards viewing streams as integrated components of a hydrologic continuum, which are tightly connected and intricately interwoven with the adjoining zones [11].

I would like to thank Dr. Jack A. Stanford for the stimulating discussions leading to the development of this lecture.

[1] White, D.S. (1993), Perspectives on defining and delineating hyporheic zones. J. N. Amer. Benth. Soc. 12(1): 61–69
[2] Stanford, J.A. & J.V. Ward (1993), An ecosystem perspective of alluvial rivers: connectivity and the hyporheic corridor. J. N. Amer. Benth. Soc. 12(1): 48–60
[3] Ward, J.V. (1989), The four-dimensional nature of lotic ecosystems. J. N. Amer. Benth. Soc. 8: 2–8
[4] Naiman, R.J., H. Decamps, J. Pastor & C.A. Johnston (1988), The potential importance of boundaries to fluvial ecosystems. J. N. Amer. Benth. Soc. 7(4): 289–306
[5] Pringle, C.M., R.J. Naiman, G. Bretschko, J.R. Karr, M.W. Oswood, J.R. Webster, R.L. Welcomme & M.J. Winterbourn (1988), Patch dynamics in lotic systems: the stream as a mosaic. J. N. Amer. Benth. Soc. 7(4): 503–524
[6] Bretschko, G. & H. Moser (1993), Transport and retention of matter in riparian ecotones. Hydrobiologia 251: 95–101
[7] Stanford, J.A. & J.V. Ward (1988), The hyporheic habitat of river ecosystems. Nature 335: 64–66
[8] Turner, M. G. (1989), Landscape ecology: the effect of pattern on process. Ann. Rev. Ecol. Syst. 20: 171–197
[9] Holland, M.M. (1993), Management of land/inland water ecotones: needs for regional approaches to achieve sustainable ecological systems. Hydrobiologia 251: 331–340, 1993
[10] Holland, M.M., M.P. Risser & R.J. Naiman (eds.) (1991), Ecotones: the role of landscape boundaries in the management and restoration of changing environments. Chapman & Hall, New York
[11] Bencala, K. (1993), A Perspective on stream-catchment connections. J. N. Amer. Benth. Soc.12(1): 44–47

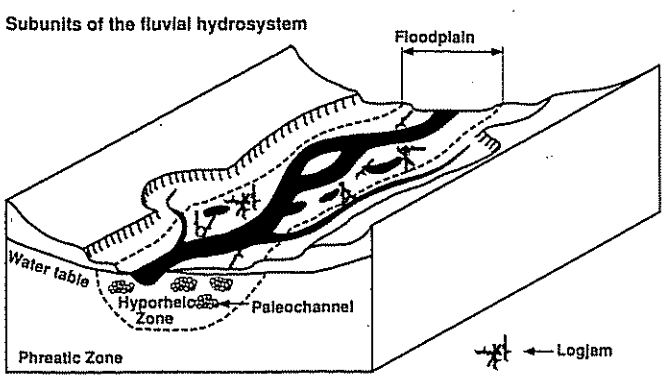

Fig. 6
Subunits of the fluvial hydrosystem in rhithron segments of river ecosystems.

Peter Baccini

First Steps Towards Sustainable Regional Resource Management

What does the "Sustainable Management of a Region" Mean?

The terms "regional resource management" and "sustainable development" are empty phrases that usually evoke vague ideals instead of delivering concrete advice. Environmental policy, which has only existed for a few decades is, nevertheless, a rich source of experience which can be utilized in taking the first steps in this direction. The phrase "sustainable development" was coined during the course of the Rio Conference in 1992 (UNCED) and was meant to encompass the following issues:

- a global plan for a combined, concerted effort in tackling environmental and development issues (called Agenda 21)
- an urgent appeal to the First World to reduce its consumption of nonrenewable resources (presently amounting to 80% of global consumption)
- an aid program for developing countries supporting them in the sustainable use of resources

For the resource management of regionally sovereign societies, the transition to sustainability entails the introduction of certain "rules of conduct" which can be summarized as follows (acc. to Donella and Dennis Meadows, Herman Daly and others):

- Replace nonrenewable resources by renewable ones.
- Carry out the same amount or more of an activity, process or job using less energy and less material.
- Plan ahead for several generations.
- Reduce reaction times.
- Maintain quality standards regarding the environment.
- Take the next steps towards a possible solution without any certainty of the outcome; make the steps small, however, in order to minimize the consequences of making mistakes.

Sustainable management of regional resources means to start out by introducing these rules of conduct in your own community; that is, in your own "house".

What is the Function of Development Planning and Environmental Protection?

First we should ask ourselves whether the existing regulations for the use of resources are not already adequate. In Swiss legislation (e.g., the law relating to development planning and the law for the protection of the environment) are possible instruments for applying the principle of sustainability. The Federal law relating to development planning (RPG 1979, Art.1) states the following objectives:

The federal, cantonal and community governments have the responsibility of implementing soil conservation. They have to coordinate their activities within a region and shall see to it that the land be settled according to the objectives that were originally stated for its development. In this they take into account both the natural factors and the needs of the population and the economy.

This means that the soil can only be used conservatively if the "development objectives" stated above are respected; the pursuit of these objectives entails a socio-political process with particular consideration for "nature", "population" and "economy".

The report on the situation of Switzerland's development planning at the beginning of the 1990s (Swiss Fed. Dept. of Statistics, Development planning Report of 1987, Baccini et al. 1993) suggests that (see Tab. 1):

1) The forested area is "taboo" ("untouchable") until today. The forestry law (1905) grants the forest a unique position and only allows for a separation between agricultural land and settlement areas.
2) If the degree of self-sufficiency with regard to foodstuffs should be increased or should at least level out (today this degree lies at 65%), then:
   - the yield per area has to be increased and/or
   - the nutritional behavior of consumers (i. e., their nutritional "needs") have to be changed and/or
   - forested area has to be converted into agricultural land
3) The consequences of growing settlement areas used to be:
   - growing demands for resources (per capita) (exceptions are the consumption of heating fuels and water as a result of increased efficiency)
   - increasing emissions (of pollutants per volume)
   - an increase in the use of purification technologies ("environmental technology")
4) The key activities are "living" and "transportation"
   - they consume most of the energy (>80%)

type of land	area (km^2)	fraction (%)
relevant total area (excluding alpine meadows, forests, waters)	**13'500**	**100%**
agriculture	10'000	74%
settled (populated) area	2'400	18%
land reserved for construction (future)	1'100	8%

Table 1
Land use in Switzerland (in the early nineteen nineties)

Growth rates of settled areas in m^2/ c y:
1950–1990: 30 km^2/y $\rightarrow$ 5
1990–2030: 20 km^2/y $\rightarrow$ 3

Typical land use in the lowlands of Switzerland (right)

	fraction (of total area)	fraction (left close to the natural state)
agriculture	55%	4–5%
forest	30%	1–2%
settlements	13%	
"unproductive"	2%	

	P	Cu	Zn	Pb
Loading	20	0.2–0.8	1–4	0.1–0.5
amounts in%				
• fertilizer	**90**	**50**	**45**	10
• sewage sludge	8	25	15	**45**
• deposition	2	25	**40**	**45**
lag time (years) until increase noticeable	20–60	10–50	20–90	20–60

Table 2
Quantitative changes in the elements in agricultural soils (acc. to Baccini and von Steiger, 1993). Annual net increase in kg/ ha y.

• they contain the largest amount of resources

The paragraph stating the purpose of the Federal Law relating to the Protection of the Environment states that (USG 1983, Art. 1):

1 The purpose of this law is to protect persons, animals and plants, their biological communities and habitats against harmful or annoying effects and to conserve the fertility of the soil.

2 Early preventative measures shall be taken in order to limit effects which could be harmful or annoying.

Several principles contained in this law are already based on sustainability, such as the requirement for the conservation of the soil which is very difficult to define scientifically, and the principle of precaution which has been applied tentatively if at all until now. Investigations on the metabolism of a region (Brunner et al., 1991) suggest that the application of ordinances which are derived from the law for the protection of the environment do not guarantee the sustainable protection of the soil or the ground water regarding their use. The conclusions can be summarized as follows:

1) Development planning and environmental protection could and still can affect the anthropogenic fluxes of resources in the following ways. They can:
   - channel them,
   - decrease their growth rates,
   - stabilize them at a high level,
   - but not reduce their amounts.

   These laws do not suffice for initiating the introduction of the aspired efficiency in the use of resources.
2) The strategy of setting up pollution standards in the ordinances of the USG permitted a *de facto* "loading" of soils, surface and ground waters (i. e., detection of pollution instead of early warning). It contradicts the above-mentioned principle of prevention.
3) There are both simple and more difficult areas within the whole to which the principle of sustainability can be applied.

In the following section, three examples are given: waste management, agriculture and construction.

Waste Management is a Relatively Simple Illustrative Example (for Applying the Principle of Sustainability).

Its main function is to produce environmentally compatible products (Swiss waste management guidelines, 1986). The final quality standards of wastes for permanent disposal is of key importance. This means:

- sustainability with regard to the disposal of wastes (i. e., no pending old toxic dumps for future generations to clean up)
- the treatment of mixed wastes is becoming expensive as it entails complex and expensive technology. As a consequence, recycling separately collected wastes becomes an economically viable alternative.

Which wastes have to be disposed of in Switzerland?

- slag from incineration plants: 100 –150 kg per capita and year (kg/c y);
- precipitation filter residues from treatment of exhaust fumes: 10–15kg/c y;
- the inorganic fractions of sorted construction wastes: 200–700 kg/c y.

The quantities and qualities involved (i. e., their suitability for use as raw materials or as anthropogenic sediment) are difficult to assess. The expense (about 200–700 sfr./ton of disposed wastes including all previous treatments) amounts to roughly 100 sfr per person per year. This amount practically equals 1% of the average annual net income per capita.

Circumstantial evidence suggests that the LRV and the TVA '91 ordinances have led to step-by-step improvements until now. Some setbacks are evident, however, as new dogmatic demands are being made on waste management which run contrary to the principle of sustainability. Waste management should also be socially and economically compatible.

Agriculture is an Even More Complex Issue than Waste Management

Using the phrase "multifunctional agriculture", the 7th Agricultural Report of the Federal Council defines an objective which calls for:

- a food supply at economically competitive prices
- environmentally compatible production
- landscape planning

Even Table 1 suggests that almost exclusively cultural landscapes are left to be tended and reshaped. Demands that more should be done for the good of the community are growing stronger. This work will also have to be paid for by the community; e.g., agricultural land would be converted step-by-step into communal meadowland. Making sustainable use of the soil also means that the ecological quality of the pedosphere must be conserved (USG 1983). In order to meet this objective, balanced materials fluxes are necessary. This is not the case at present, although the newly revised Water Protection Law requires such a balance regarding nutrients. Table 2 suggests that a broader view of the materials and time spans involved is needed. The implementation of such an agricultural policy would be economically acceptable, as financing this kind of agriculture would cost about 1000 sfr./c y, which lies in the same range as the present financing through government subsidies.

The relative annual loss of nitrogen to the water and to the air amounts to 50–80%. This is equal to about 9 kg of nitrogen per capita per annum and lies within the same order of magnitude as the flux of nitrogen oxides from combustion processes.

The Construction Industry is the Third and Most Complex Issue

The structures for living and working and the modes of transportation of people and goods determined by the nature of the so-called "national building structure" (i. e., the entirety of the constructed infrastructure of the nation, including all public utilities, buildings, roads, etc.) in turn determines the amounts and types of energy in the household of an economy. It reflects and contains important cultural values of its society. About 300,000 sfr per capita are contained in the buildings and roads of Switzerland. At the beginning of the 1990s, the total volume of construction amounted to about 50 billion sfr.

The constructional changes which are made each year to increase the efficiency of the use of resources and energy equal about 2–3% of the total construction volume. If we aim to reduce the expenditure of energy several times within 30–50 years, then we have to begin reshaping this national infrastructure. This expense amounts to 10^4 sfr./c y, which is in the same order of magnitude as the annual per capita income. Such an effort is not yet being considered concretely, let alone being tackled. Comparable to the previously mentioned examples, a long term strategy is also missing regarding construction. It takes this example to realize the purpose of sustainability when the main economic aspect of our society as well as our basic material values are involved which are anchored in the constitution.

Conclusions

Our first experiences with the implementation of development planning and environmental protection legislation suggest that we could already operate successfully within economically less important areas without introducing totally new limiting measures. These areas nevertheless are of importance concerning the ecology of their region, e.g., in agriculture (the pedosphere and parts of the biosphere) and waste management (efficiency in use of resources and prevention of uncontrolled disposal of toxic materials). These efforts can only be successful if the political commitment is present to implement the principle of precaution and the pollûter pays principle (having the originator pay for environmental damages).

If the key entities of energy and mass goods (water, stone, metals) are to be managed sustainably, then a basically new orientation of the entire development of the society with its structures is necessary. For this purpose we need to revise our constitution, firmly anchoring it within the principle of sustainability.

[1] Baccini P., von Steiger B (1993), Die Stoffbilanzierung landwirtschaftlicher Böden – Eine >Methode zur Früherkennung von Bodenveränderungen, Z.Pflanzenernähr.Bodenk., 156, 45–54
[2] Baccini P., Daxbeck H., Glenck E., Henseler G. 1993, METAPOLIS, NFP 25 Stadt und Verkehr, Bd. 34A

Renata Behra, Giulio P. Genoni, and Laura Sigg

Setting Water Quality Criteria for Metals in Running Waters

The discharge of metals into running waters and their concentration are regulated by the Swiss Ordinance on Wastewater Discharge (1975) which defines quality criteria as upper limits to allowable concentrations in an effort to protect organisms and ecosystems. The study described here was prompted by revision of the Swiss environmental protection law, and in particular, that part of the ordinance dealing with wastewater discharge.

We consider with the following elements: arsenic (As), lead (Pb), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), nickel (Ni), mercury (Hg), selenium (Se), silver (Ag), zinc (Zn) and organotin compounds (Sn). We recommend new quality criteria on the basis of known toxic effects and of naturally occurring concentrations of these metals. We illustrate the procedure for the case of copper and compare the revised quality criteria with concentrations found in moderately polluted streams in order to assess current levels of metals contamination in Switzerland.

Ecotoxicological Values

To formulate water quality criteria, we conducted a literature search on toxic effects of the above mentioned elements in aquatic organisms, populations and ecosystems. From the literature on toxicity, we retained data on species and systems that are endemic to Switzerland, but also on others that are comparable in their ecology. We calculated from these data "ecotoxicological values" (EV), corresponding to concentrations below which toxic effects may not be expected to occur. We did this by dividing the effective concentration by an extrapolation factor. Such factors are often included in risk assessments because of knowledge gaps on the applicability of data from laboratory experiments to the environment [1]. There are, however, uncertainties in the use of extrapolation factors. When extrapolating chronic from acute toxic effects, a large factor is applied. Conversely, when information is available on subacute or chronically effective concentrations, smaller factors are applied. These extrapolation factors are arbitrary, which is one of the main concerns in ecotoxicology. In this way, EVs can be estimated from the various relevant studies. Since it would not be sensible to take into account a single EV, we rather took several low values with which to compare the data on chemistry. The EVs for Cu are listed in Table 1. Lethal or sublethal effects in various organisms occur in the µg/l range, and the lowest EVs range from 0.05 to 2 µg/l. The complete ecotoxicology data and the references will be published elsewhere [2].

Concentrations in Unpolluted Streams

For deriving water quality criteria, we also considered background concentrations occurring in pristine streams using data both from the literature and from EAWAG studies [2]. Since the quality criteria refer

effective concentration µg/l	Effects	EF	EV µg/l
1	Green algae, inhibition of photosynthesis	1	1
6.4	Tube-dwelling worm, 48 hr LC_{50}	100	0.05
4–6	Water flea, 48 hr LC_{50}	100	0.05
2–10	Rainbow trout, larvae, infection	1	2–10
>2	Rainbow trout, inhibition of growth	1	>2
0.1–10	Rainbow trout, avoidance behavior	1	0.1–10

Table 1
Selected toxicity data and calculated ecotoxicological values (EV) for Cu. Effective concentration: dissolved (µg/l); EF: extrapolation factor; LC_{50}: concentration at which 50% of the organisms died during a given time.

Location	Dissolved Cu µg/l
St. Lawrence	0.6–1.1
Mississippi	1.5
Amazon	1.5
East coast rivers, USA	1
Rhône (France)	0.4–1.2
Lake Zurich	0.4–0.8
Lake Greifen	0.3–1
Lake Alpnach	0.6–1.1

Table 2
Selected Cu concentrations in unpolluted waters (total dissolved concentration, µg/l).

to the dissolved concentrations, we mostly retained data for filtered samples. From the literature, we chose data for which a careful sampling and analysis had been carried out. Table 2 shows Cu concentrations in a number of representative water bodies, including some large, moderately polluted streams. Streams that are comparable to Swiss streams include the Rhône in France and various streams on the eastern coast of the U.S.A. The concentrations measured in lakes and their outflows (e.g., Lake Zurich, Lake Greifen) may be considered representative of moderately polluted streams. Recent measurements show concentrations similar to those previously found in Lake Alpnach [3]. Few measurements of moderately polluted streams (upper reach of streams), however, have been carried out in Switzerland. The Cu concentrations range from 0.3 to 1.5 µg/l. An overview of the chemical data shows that background concentrations are very low (i. e., in the range of nanograms to a few micrograms per liter; [2, 3]).

Quality Targets and Speciation

Water quality criteria ought to be based on the lowest ecotoxicological values, but should not be lower than naturally occurring concentrations. A comparison of toxicity and chemical data for Cu shows that the lowest EVs (0.05–2 µg/l) overlap the range of natural concentrations (0.3–1.5 µg/l). This is partly due to the aforementioned uncertainties in the estimation of EVs, but also to the differences in its speciation in laboratory tests vs. natural waters. We shall briefly discuss this latter aspect with respect to the relationship between the biological effects and the chemical form of the metals.

In a stream, metals may occur in various forms in sediments, bound to suspended particles or in solution. Since quality criteria concern dissolved concentrations, we shall only deal with the various forms (or "species") in solution. In addition to the free metal ion, inorganic and organic complexes may occur. The total concentration of the metal in solution then corresponds to the sum of all species, and the proportion of each form depends on the chemical composition of the water.

Since the biological reactivity of metals is related to the activity of the free metal ion, rather than to that of the complexed forms [4], the total dissolved concentration is of little help in assessing environmental risk. For a given total concentration, biological effects may vary, depending on the proportion of free metal ions.

Concentrations of Metals in Moderately Polluted Streams

For a given copper concentration, the proportion of free metal ions is orders of magnitude smaller in natural waters ($Cu^{2+}/Cu_{total\ dissolved}$ = 10^{-5}–10^{-7}; 6, 7) than in a laboratory system ($Cu^{2+}/Cu_{total\ dissolved}$ = 0.01–0.8). And while natural organic copper complexes occur in water bodies, they usually do not exist in toxicity tests.

A comparison of toxicity and chemical data with respect to the estimated free dissolved concentration shows, as expected, that the EVs are higher than the natural concentrations (Fig. 1). Considering the speciation of Cu, we recommend a quality criterion at the upper range of natural concentrations (2 µg/l). Quality criteria for the other metals regulated by the ordinance were revised in a similar fashion.

We also include selenium (Se) and organotin compounds (Sn). Selenium could become a problem in the future because of its use in agriculture. Organotin compounds are among the most toxic metal derivatives.

The revised quality criteria are compared to the current quality criteria in Table 3. With the exception of arsenic, a strong reduction with respect to the 1975 ordinance is to be recommended for all elements, particularly for cadmium, mercury and silver. The EAWAG has already made such recommendations for some metals [3, 5].

A consideration of the concentrations in Swiss waters shows that the recommended quality criteria for As, Pb, Cr, Se, and Ni are generally not exceeded (Fig. 2). Few data are available on dissolved concentrations of Hg, so it is difficult to estimate whether Hg concentrations in running

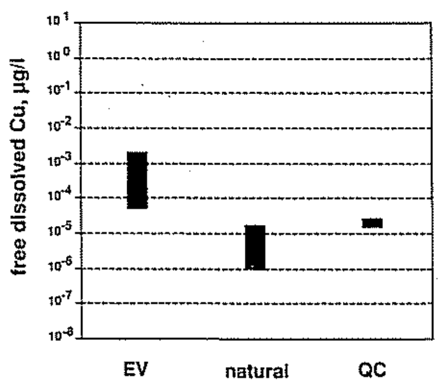

Fig. 1
Ecotoxicological value (EV), natural concentrations (natural) and recommended quality criterion (QC) (total dissolved concentrations, in µg/l) for Cu. The latter was calculated on the basis of the estimated dissolved free Cu concentration. The ratio of dissolved free Cu to dissolved total Cu is assumed to be 10^{-2} for the EV and 10^{-5} for the chemical data.

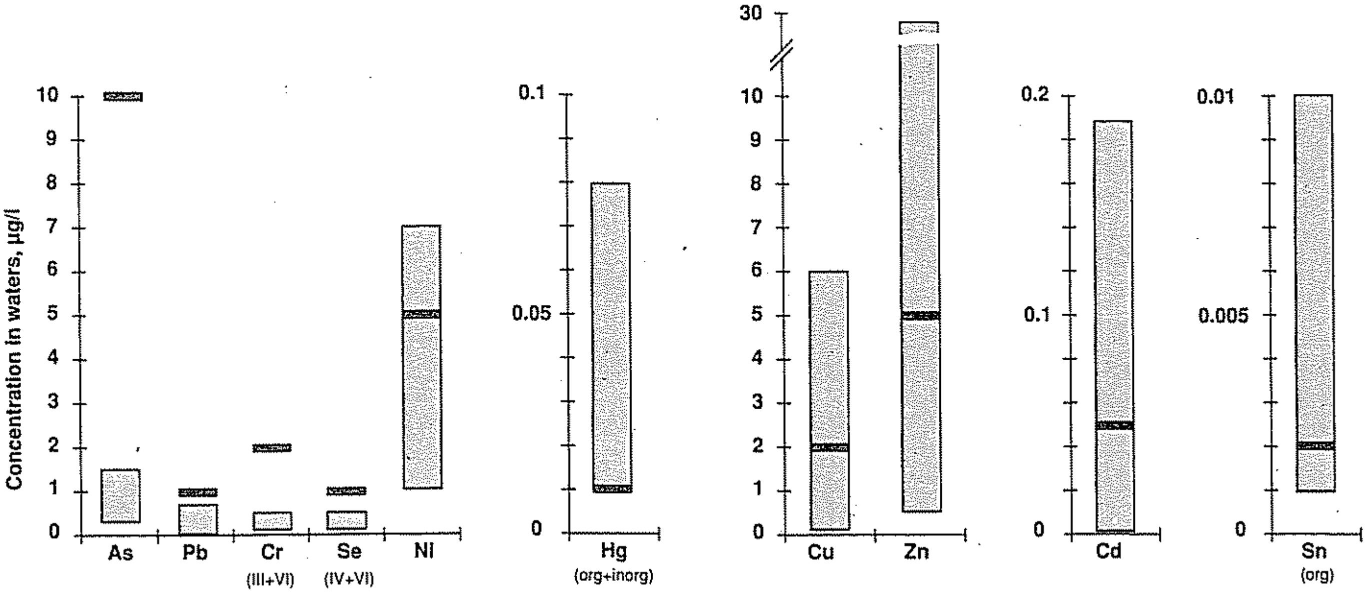

Fig. 2
Concentrations of various metals in moderately polluted waters and recommendations for new quality criteria (total dissolved concentration, in µg/l). Hg concentrations are given as the sum of dissolved and particulate Hg.

waters are lower than the proposed quality criteria. For Cd, Cu and Zn, the quality criteria are currently exceeded in small streams receiving significant wastewater inputs. For organotin compounds too, the proposed quality criteria are exceeded in some streams. For Zn and Cu, the main sources are presumably diffuse (pipes, etc.). Data from wastewater treatment plant outlets also show that in most cases very high concentrations do not occur [1].

In view of the variety of possible sources, no single approach can be recommended when quality criteria are exceeded. If concentrations are very much in excess, the points of emission in the catchment basin should first be identified, and inputs should be reduced if possible. If diffuse sources prevail, reductions are probably possible only in the long term. In cases of point source pollution, appropriate measures should be taken at the source. We believe that the problem of excessive concentrations should not be addressed at the level of the wastewater treatment plant.

To establish quality criteria, we estimated the environmental risk posed by metals. Our conclusions are based on scientific findings, but include some assumptions. Consequently, these quality criteria should not be viewed as a guarantee against long-term environmental effects of moderate metal concentrations. The regulatory criteria will need to be reviewed and revised periodically.

Finally, we would like to suggest that a long-term solution of environmental problems may require prevention – not merely restricting emissions of pollutants. Thus, little or no increase in metal concentrations in polluted waters should be strived for, even if they already lie below the water quality criteria.

Element	QT 1975 µg/l	Proposed QT µg/l
As	10	10
Pb	50	1
Cd	5	0.05
Cr(III)	50	2
Cr(VI)	10	(III+VI)
Co	50	10
Cu	10	2
Ni	50	5
Hg inorg	1	0.01
Hg org	–	(org+inorg)
Se(IV+VI)	–	1
Ag	10	0.1
Zn	200	5
Sn org	–	0.002 (TBT+TPT)

Table 3
Comparison of current and proposed quality criteria (QC) (total dissolved concentration, µg/l).
TBT: tributyltin; TPT: triphenyltin

[1] Behra, R., Genoni, G.P. and Sigg, L.: Wissenschaftliche Grundlagen für die Festlegung der Qualitätsziele für Metalle und Metalloide in Fliessgewässern, Gas, Wasser, Abwasser (1993) (in press).
[2] Behra, R., Genoni, G.P. and Sigg, L.: Revision of the Swiss ordinance for wastewater discharge: scientific basis for water quality criteria for metals and metalloids in running waters. EAWAG Publication Series No 6 (1994).
[3] Gächter, R.: Untersuchungen über die Beeinflussung der planktischen Photosynthese durch anorganische Metallsalze im eutrophen Alpnachersee und der mesotrophen Horwer Bucht. Schw. Z. Hydrol. 38, 97–119 (1976).
[4] Sigg, L.: Schwermetalle in Fliessgewässern. EAWAG news 32, 32–35 (1991).
[5] Frausto da Silva, J.J.R. and Williams, R.J.P.: The biological chemistry of the elements. Clarendon Press, Oxford, 1991.
[6] Gächter, R.: MELIMEX, an experimental heavy metal pollution study: Goals, experimental design and major findings. Schw. Z. Hydrol. 41, 169–176 (1979).
[7] Xue, H. and Sigg, L.: Free cupric ion concentration and Cu(II) speciation in a eutrophic lake. Limnol. Oceanogr. 38, 1200–1213 (1993).
[8] Oestreich, A.: Freie Kupferionen in Schweizer Fliessgewässern. M.S. Thesis, EAWAG (1993).

Jan Roelof van der Meer

Potential and Limitations to the Use of Microbiological Methods for the Treatment of Environmental Pollution

Degradation of Environmental Pollutants by Microorganisms

Microorganisms such as bacteria and fungi play a major role in the Earth's ecosystems in balancing the global cycles of the bioelements carbon, nitrogen, phosphorous and sulfur. Different oxidation and reduction reactions transforming these elements from one oxidation state to another (e. g., ammonium to nitrate or nitrate to dinitrogen), are carried out by bacteria. Microorganisms are responsible for the transformation of the largest fraction of organic compounds to carbon dioxide in the carbon cycle. These oxidative processes, called mineralization, help to maintain the delicate balance between the formation of complex organic molecules from carbon dioxide by plants and heterotrophic organisms and their degradation.

A large variety of different mineralization reactions has evolved in microorganisms. Degradation of organic material, however, is not always a process which is beneficial for man, plant or animal life. For example, pathogenic microorganisms invade and degrade cell tissues of living organisms, and there are other microorganisms which can cause spoilage of food by using the food organic molecules for their growth. Seen as a whole, however, microbial degradation reactions are important for sustaining life. Reactions carried out by microorganisms already have a large number of applications in biotechnological processes. Fermentations of raw plant and animal products are large scale processes currently used in the food industry, and microbially catalyzed reactions are involved in the production of specialized chemicals and pharmaceuticals. An important application that should not be overlooked is the use of microorganisms for the degradation of domestic sewage. This process, occurring in wastewater treatment plants, is now a common technology. Currently, there is an urgent requirement to find out whether microbial degradation reactions can be used in specialized waste management processes to treat toxic environmental pollutants. This article will discuss the potential and limitations for the use of microorganisms in the degradation of chemicals of environmental concern.

Pollutants of Environmental Concern

Contamination of our environment has reached such a scale that pollutants have spread to practically all environmental compartments (water, soil, ground water and air) and to living organisms themselves. The enormous variety of polluting compounds, as well as the large differences in their concentration and distribution between environmental compartments, has major consequences for the potential application of microbial degradation processes. The amount of a particular pollutant introduced into the environment is dependent on its source, and polluted sites can be found with large differences in concentrations of toxic chemicals. For example, industrial wastes and wastewaters, spills or leaks may cause very high local concentrations of toxic compounds. On the other hand, the use of chemicals in households will result in low concentrations of these compounds in wastewater treatment plants. Once polluting compounds have entered the environment, they will be distributed among the different compartments, depending on their physico-chemical characteristics and sorption, diffusion or dispersion processes. As a result, almost everywhere in the environment, very low chronic concentrations (less than 1 µg per liter) of pollutants can

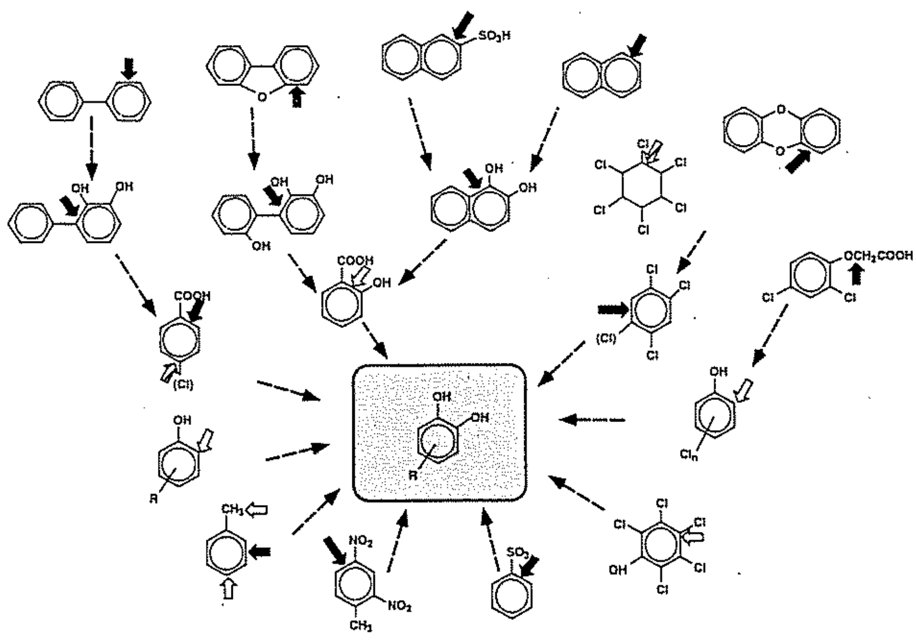

Fig. 1
Overview of enzymatic steps in the aerobic degradation of aromatic compounds by bacteria [2].
The different metabolic pathways lead to a central metabolite, shown in grey shading. The arrows on the molecules show the sites where enzymatic attack takes place. Combinations of enzymatic reactions leading from one compound to another are indicated by dotted arrows between the molecules. Black arrows: dioxygenase-type enzymes; white arrows: monooxygenase-type enzymes; striped: others.

be detected. Such low concentrations may be insufficient to support microbial growth or degradation metabolism. On the other hand, very high concentrations may lead to toxic effects. We will see below what the implications of this concentration effect may be for microbial degradation.

A large palette of enzymatic reactions is available over a wide range of different microbial species for the transformation of environmental pollutants. Organic compounds are used as food by the microbial cell, and the carbon, nitrogen, phosphorous and sulfur atoms find their way into cellular metabolism. Substituted groups on organic molecules, like chlorines or fluorines, however, are not used by the microorganisms and are released from the cell. Not all organic compounds are degraded at the same rates by microorganisms. Some molecules, such as halogenated organic compounds, are rather resistant to enzymatic attack. For example, only a few microbial species are able to degrade organohalogens compared to the number of species that can use nonhalogenated compounds. Furthermore, the degradation of these compounds becomes increasingly more difficult when more halogen substituents are present.

One important class of environmental pollutants are inorganic compounds such as the heavy metals. Chronic and acute toxic effects of heavy metals take place at relatively low concentrations. Many microorganisms have developed resistance mechanisms against heavy metals which enable them to transform toxic metal ions to less toxic elementary forms, or to actively pump the metal ions out of the cell. At present, it is not clear whether these or other types of microbial reactions can be applied to detoxify or to remove heavy metals from liquid waste streams; therefore, this article will focus primarily on the biodegradation of organic contaminants.

Microbial Degradation Pathways

For successful application of microbial reactions in environmental and industrial waste management, it is necessary to know in detail which pollutants can be degraded by microorganisms and how the degradation pathways proceed. The variety of degradation processes carried out by microorganisms appears to be enormous. Of major interest, of course, are those pathways which lead to complete detoxification of a contaminant. In general, these are the oxidative pathways of aerobic bacteria which use the organic compound as a carbon and energy source. An overview of the enzymatic reactions which have been found in different aerobic bacteria for the degradation of aromatic pollutants is shown in Fig. 1. The enzymes catalyzing the most essential steps in these degradation pathways are the dioxygenases and monooxygenases. Research has shown that the various di- and monooxygenases of different bacterial species are biochemically and genetically related suggesting that these enzymes became distributed during evolution among a variety of microorganisms and were selected to their present day diversity. Specific degradation pathways for transformation of aliphatic compounds under aerobic conditions have similarly been found in bacteria.

Although those metabolic reactions in bacteria that use oxygen often lead to a complete breakdown of aromatic and aliphatic pollutants, they appear to be less suitable for the degradation of highly chlorinated compounds. Recently, however, it was found that bacteria which live under conditions without oxygen (anaerobic bacteria) can catalyze reactions to remove chlorine substituents in a step-wise process. In laboratory experiments, researchers could demonstrate that dechlorination of tetrachloroethylene to ethane, or of hexachlorobenzene to monochlorobenzene was possible by using mixed bacterial populations living in the absence of oxygen. These less chlorinated compounds can then be further degraded by aerobic microorganisms. Researchers in different laboratories are now working on coupling such anaerobic and aerobic processes, to achieve a complete degradation of compounds such as polychlorinated biphenyls (Fig. 2).

Owing to the results of genetic experiments, we now know much more about the hereditary material of microorganisms that encodes the necessary information to degrade toxic compounds. The relatedness of the different enzymes carrying out the transformation reactions has clearly been demonstrated, and it has been found that evolution of novel metabolic pathways in bacteria is a still on-going process. Bacteria appear to have a variety of genetic mechanisms which enable them to adapt rapidly to, for example, novel food sources, by creating numerous changes in their genetic background that can then be selected for when circumstances are favorable. It is also now possible to develop in the laboratory specific microbial strains with combinations of degradation characteristics that are rarely found under natural conditions.

Environmental Factors Influencing Microbial Activity

Polluting compounds are rarely degraded at optimal rates (i.e., those possible under idealized laboratory conditions) under environmental conditions, even when suitable microorganisms are present. The reason for this is that the metabolic activity of microorganisms is determined to a large extent by environmental factors, like temperature, pH or salt concentration. Therefore, it is of utmost importance to optimize the conditions for the microorganisms when they are being applied in a biotechnological clean-up process. Clearly,

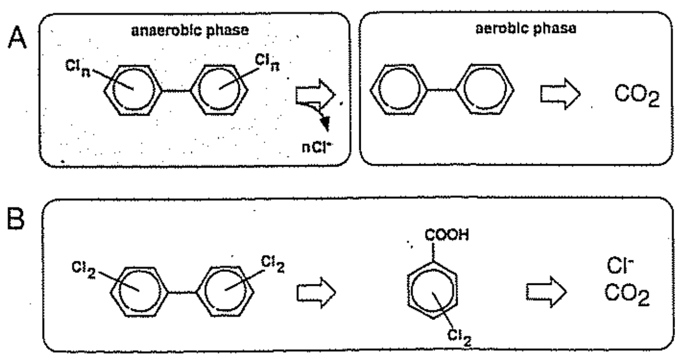

Fig. 2
Designed strategies for the degradation of polychlorinated biphenyls.

A: A two-step process, first using the activity of anaerobic microorganisms to dechlorinate chlorine atoms from the molecule, followed by an aerobic phase to degrade the non-chlorinated molecule completely.

B: A one-step process which makes use of specially constructed microorganisms in which different metabolic pathways have been combined. Degradation seems limited in this case to theless chlorinated biphenyls.

such an optimization will always be easier in closed systems like bioreactors than in soil or ground water.

Arguably, the most variable factor is temperature. In general, it appears that the lower the temperature, the lower is the metabolic activity. Furthermore, most bacterial species have a relatively small temperature range within which they will be optimally metabolic active. This temperature range can differ from one microorganism to another; for example, some microorganisms grow optimally at 10°C – others at 100°C. Therefore, it is very important to isolate the microorganisms at the temperature at which they will be applied in a later stage (Fig. 3). Nevertheless, in northern Europe groundwater temperature is approximately 10°C and degradation will proceed only slowly.

Microbial activity and growth under environmental conditions is further determined by a number of other biological and physiological factors. Predation by protozoa, for instance, leads to a reduced number of microorganisms in a natural population, which may significantly impact the observed degradation rate. The physiology of microorganisms is also dependent on the concentration of the food source and other nutrient molecules. When the concentration of the food molecules (in this case an environmental pollutant) is high, it will stimulate microbial growth, and subsequently the concentration of the compound diminishes. Some environmental pollutants, however, may be toxic to bacterial cells at high concentrations even if they are, in principle, degradable. When the concentrations of the compounds are very low, difficulties in uptake or inefficient use by the bacteria may result. Many pollutants in the environment are present at such low concentrations (<1 µg/L) that further microbial degradation does not proceed efficiently. Furthermore, at these low concentrations the "polluting" compound forms part of a mixture of food sources for the microorganisms in which other more easily degradable organic molecules like sugars, amino acids or fatty acids are present. How such mixtures of easily degradable food sources and environmental pollutants influence the degradation of the pollutant by microorganisms, is one of the present central research topics in the Department of Microbiology at EAWAG.

In most environments, microorganisms live in the presence of surface materials such as sand or clay particles. Microbial cells will in many cases attach to these surfaces, resulting in various physiological effects such as different substrate uptake, or biological effects, for instance, a physical protection against predation. It is thought that for uptake of most molecules, microorganisms rely on diffusion from the water phase to the microbial cell rather than direct uptake of molecules from a surface. For highly soluble compounds, attached microorganisms may face a diminishing flow of food molecules diffusing into the cell. For strongly adsorbing compounds, the desorption rates from the solid surface to the water phase may become the limiting factor for the rate of biodegradation.

The continuously changing conditions in natural environments causes a stress on the microorganisms, to which they respond with changes in their metabolic activity. Rainfall, for instance, may lead to a release of many nutrients in the soil and an increase in water capacity, causing microorganisms to become active. Other stresses for microorganisms are drought, rapid temperature changes, toxic compounds or pH changes. How these stresses affect microbial physiology is another current research topic in the Microbiology Department. A detailed knowledge of stress effects and stress resistance in microorganisms seems a prerequisite for both their activity in the natural environmental and their application in large-scale biotechnical systems.

Use of Microbial Degradation Processes for Environmental and Industrial Waste Management

Several techniques to apply microbial reactions for degradation purposes are presently available. Wastewater treatment plants to degrade domestic and industrial sewage have been successfully operated for a number of decades. In these systems, mixed microbial populations rather than individual microbial species, take care of the treatment process. Systems have been developed which operate under aerobic or under anaerobic conditions, depending on the nature of the organic waste to be degraded, the dimensions of the system or other special requirements. The microorganisms in these treatment plants or reactors may be in a free-living state or may be adsorbed to specific carrier materials, such as sand particles or polyurethane foam. In many cases, the free-living microorganisms build themselves into flock-like material or grains consisting of millions of microbial cells which often exhibit excellent settling characteristics. Research on improving treatment technologies for domestic sewage is no longer focused on the degradation of organic compounds, but on the removal of nitrogen and phosphorous. For industrial and toxic wastewaters, however, a greater effort is needed to accomplish degradation of polluting compounds. One important strategy will be to treat waste streams separately rather than

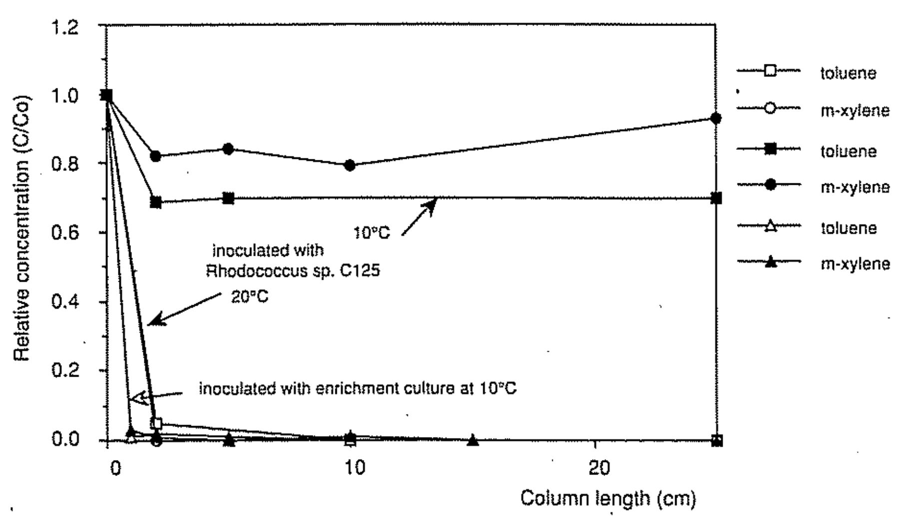

Fig. 3
Effects of temperature on the activity of microorganisms in the degradation of toluene and xylene. The figure shows the dramatic decrease in the performance of a *Rhodococcus* bacterium that has an optimal activity at 20°C when applied at 10°C in a soil column. In contrast, bacteria specifically isolated at 10°C still have good activity at that temperature. (Fig. taken from reference [1]).

mixing all wastes together. This will make it possible to use specialized microorganisms that can detoxify and degrade single pollutants in a mixture of different polluting compounds.

In environmental waste management, microbiological treatment technologies are available, although they are currently being applied in relatively few cases. For example, only 1% of the total amount of polluted soils and sediments which is yearly treated in The Netherlands is being performed by biological processes. The other part is cleaned up by physico-chemical processes (flotation, extraction, or heating); however, still by far the largest part is not treated at all, but rather stored at dump sites. It is clear that the characteristics of the soil and groundwater environment pose the greatest limitations to biological treatment technologies. In highly polluted sites where there is a serious public health risk, the polluting material will most often be removed. Polluted soil can be excavated and replaced by clean soil, polluted ground water can be removed from the subsurface by pumping. Possible biological treatment technologies for polluted soil include land-farming, composting or incubating in solid-phase bioreactors. Most of these processes, however, require considerable amounts of time for degradation of the pollutants to reach the desired concentrations (Fig. 4). Landfarming, for example, has been used successfully in the treatment of oil-polluted soils, although treatment periods range from half a year to several years. Biological activity can be optimized to a certain extent, such as by flowing air through the polluted material, by enhancing mixing or by increasing the temperature to the mesophilic range.

Contaminated groundwater can be treated biologically in a similar manner to wastewater, once it has been pumped up from underground. However, very often desorption of pollutants from the soil to the ground water occurs when cleaner water reaches the sites causing long-term pollution. Ground water treatment technologies, therefore, often involve a cycling system where ground water is pumped up, treated on-site, and after treatment reintroduced into the subsurface. This cycle is operated for so long as it takes to reduce the concentration of the pollutants in the ground water to acceptable levels. Biological processes are momentarily being applied in such cycling systems to treat polluted groundwater, e.g., with toluene and xylenes. Furthermore, the reactor effluent can be further oxygenated or replenished with nutrients prior to reinjection into the ground, to obtain stimulation of microbial degradation processes in the underground.

Biological treatment processes will take place spontaneously in natural systems; however, these processes occur very slowly. Very often the conditions for efficient biodegradation in the environment are far from optimal. Mixing techniques to improve the bioavailability of the pollutant, solubilization methods to overcome slow desorption rates, or addition of nutrients or oxygen can increase biological activity.

Future Prospects

Biological methods for cleaning up organic wastes in the environment or in industry have already shown their merits, and will form an essential part of future waste management strategies based on sustainability. Application of biotreatment methods in various polluted environments, such as soils, ground water, or river sediments, is possible in principle. Various techniques can be chosen, differing from intensive biological methods to extensive in-situ stimulatory measures. However, there are major obstacles for large-scale use of these methods at the moment, including the poor cost-benefit calculations for biotreatment methods and the low residual levels currently required for remediation. Inherent in bioremediation processes are the fast initial degradation rates, and then increasingly slower ones (Fig. 4). For example, in landfarming experiments with oil pollution, it was shown that it took half a year to degrade the first 90% of contaminants, and two additional years to remove the last 10%. However, in this case, it became clear that the lighter oil components were degraded completely, and that the polycyclic aromatic compounds were the ones that made up the last 10% which were more slowly degraded. Therefore, it is very important to evaluate measurements of biodegradation critically, which in soil may be rather difficult.

It is becoming increasingly more evident that the efforts and costs which will have to be made to clean-up all of the sites with severe soil- and ground water pollution are too high for most economies. The question will, therefore, arise as to which sites are going to be remediated and which sites are not. And for those which are, the next question will be if we are going to be restored to some natural background level, or will a treatment be applied which is cost-effective and technologically feasible. This will probably mean that in a large number of cases, natural biological processes will have to occur, even if this will take a long time. Precautions can be taken to prevent further spread of a particular contaminant, and extensive stimulation of biological activity on the site may be undertaken.

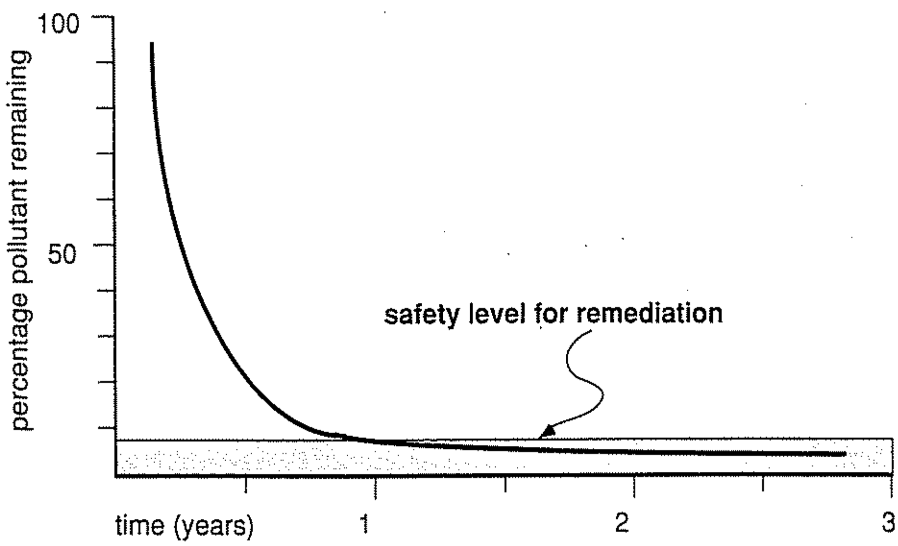

Fig. 4
Typical time course of the pollutant concentration in a biodegradative process.
Although 90% of a pollutant may be removed in the process within a short period of time, it may take considerably longer to reach a concentration which is below the safety levels set for remediation.

A more active waste management strategy can be followed to prevent further introduction of polluting compounds into our environment. Here, biological methods may be applied to reduce the amounts of toxic waste material before entering our waters, soils or ground water. A very useful integration would be to incorporate specific biotechnological treatment processes with individual chemical waste streams in industry. Such a direct coupling could prevent toxic waste streams from becoming mixed, which usually complicates treatment. Furthermore, the biological processes can be optimally designed and microorganisms specifically developed or selected for the individual waste stream characteristics. Already a number of companies exist in the USA which are developing "biocatalysts" (i. e., the microorganisms and the process technology) for use in industry to degrade common toxic chemicals like phenols, chlorinated benzenes and anilines. Knowledge on biologically mediated reactions will also make it possible to develop novel, perhaps less wasteful, industrial syntheses, which is essential for future environmental and industrial waste management strategies.

[1] van der Meer, J. R., Bosma, T. N. P. , de Bruin, W. P. , Harms, H. , Holliger, C. , Rijnaarts, H. H. M. , Tros, Maria E. , Schraa, G., and Zehnder, A. J. B. (1993). Versatility of soil column experiments to study biodegradation of halogenated compounds under environmental conditions. Biodegradation 3:265–284.
[2] van der Meer, J. R. Genetic adaptation of bacteria to chlorinated aromatic compounds. FEMS Microbiol. Rev., in press.
[3] Förstner, U. Umweltschutztechnik: eine Einführung. Berlin, Springer Verlag, 1990.
[4] Arendt, F., Annokée, G. J., Bosman, R., van den Brink, W. J. (Eds.). Contaminated Soil '93. Dordrecht, Kluwer Publ., 1993.
[5] Mason, C. A., Sticher, P., Hamer, G. (1992) Mikroben als Umweltsanierer. Über das Überleben und die Erhaltung der Aktivität von Bakterien im Rahmen von Reinigungsprogrammen für die Umwelt. Mitteilungen der EAWAG, 33: 11–19.

Walter Giger, Alfredo C. Alder, Pilar Fernández, and Eva Molnar

Laundry Detergents and Cleaning Agents: from Reactive to Preventive Environmental Protection

Introduction

The use of laundry detergents and cleaning agents has become an almost essential feature of modern civilization. Detergents with highly complex and variable compositions are used in huge quantities for fabric washing. Similar chemical products are employed for cleaning solid surfaces (dishwashing, cleaning of buildings, etc.) and for body care. Along with natural substances such as soap, technically manufactured surfactants are used on a major scale. Since detergents are usually mixed with water, these chemicals are generally discharged together with the waste water. It is vitally important, therefore, to evaluate the behaviour of these substances both in the narrower sense of the waste water treatment itself and in the broader sense of their environmental behaviour. Fig. 1 plots the course of annual detergent consumption over the last 50 years. The annual per capita consumption has risen steadily since 1940 from approximately 10 kg to about 25 kg. A new trend has been discernible since 1989–90, with a slight drop in overall consumption. This decline is due, at least in part, to recently developed compact detergents. In 1991, consumption in Switzerland was just above the European average, ranked sixth in a list topped by Spain, which consumed most (35 kg/head) detergents, with the thrifty Swedes (12 kg/head) bringing up the rear.

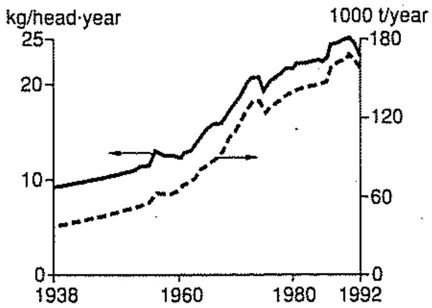

Fig. 1
Annual consumption of detergents in Switzerland (according to figures supplied by the Verband der Schweizerischen Seifen- und Waschmittelindustrie [Swiss Association of the Soap and Detergent Industry])

Four Generations of Detergent-related Environmental Problems

The detergent-related environmental problems, together with associated evaluation concepts and environmental protection measures, can be subdivided into four generations, as listed by keywords in Table 1. Generation or phase one is characterized by foam build-up in waste water and natural water bodies, a phenomenon produced by poorly biodegradable surfactants based on the multiple-branched alkylbenzenesulfonate (ABS). The extent of such environmental effects was at its worst in the 1960s, and the foam problem was subsequently resolved as a result of voluntary substitutions made by detergent manufacturers and legislation governing the biodegradability of synthetic surfactants. The highly branched ABS was eventually replaced by linear alkylbenzenesulfonate (LAS) which continues to play a crucial role as an anionic surfactant. In the second generation, the triphosphate component of detergents is responsible for excessive fertilization (eutrophication) in natural waters. Here, too, voluntary and legal measures were implemented; in Switzerland, these included a phosphate ban which was introduced in 1986 through the *Stoffverordnung* (Ordinance on Substances). A wide variety of solutions have been adopted in Europe and across the world to deal with these problems. The analytical monitoring of substitute substances in the environment played an important role in the control of these two generations. In particular, the phosphate substitute nitrilotriacetic acid (NTA) has been extensively investigated [1]. Recent studies have shown that another organic chelating agent, ethylenediaminetetraacetic acid (EDTA), is much less environmentally acceptable, and this substance is no longer used in detergents or cleaning agents. Unfortunately, environmental protection agencies often appear to be unaware of this fact.

In the third phase, toxic intermediate degradation products of surfactants were discovered in treated waste water and in digested sludge [2]. Other detergent chemicals have also been found to accumulate in digested sludge. Moreover, since LAS is poorly biodegradable under anaerobic conditions, high concentrations of this substance have been measured in digested sludge (approximately 1–10 g per kg of dry sludge).

Phase four covers the current situation and involves not only the evaluation of individual components but also consider-

Detergent-related environmental problems

GENERATION I
Poorly biodegradable surfactants
——> foam build-up

GENERATION II
Phosphate ——> eutrophication
of natural waters

GENERATION III
- Persistent metabolites
- Enrichment in sewage sludge (nonylphenol, LAS)
- Phosphate substitutes (NTA, citrate, polycarboxylate, phosphonate)
- EDTA

GENERATION IV
Preventive measures:
- optimum constituents
- conscious use
- ecolabel
- life cycle assessment

Table 1
The four generations of detergent-related environmental problems

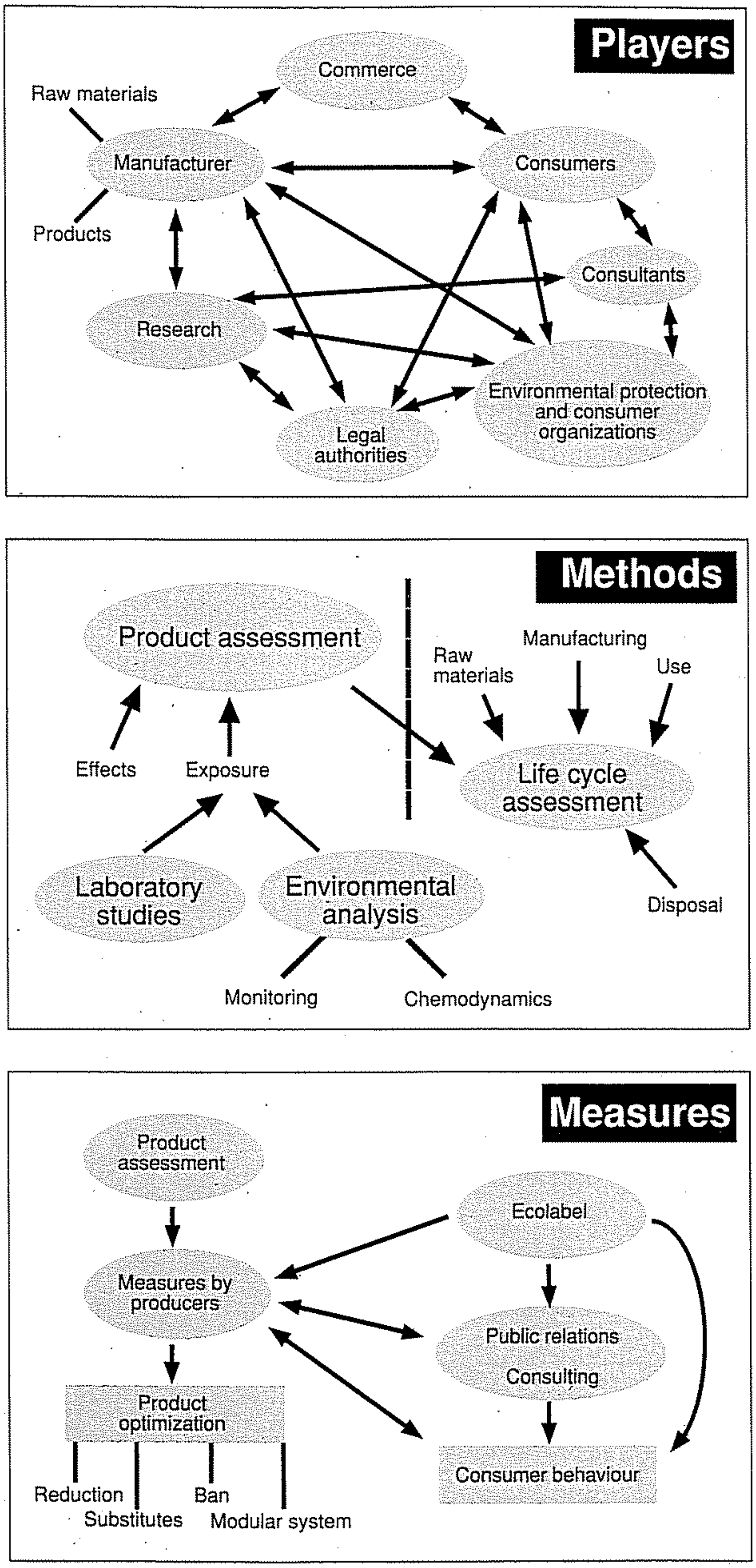

Fig. 2, 3 and 4
Players, methods and measures characterizing and influencing detergent-related environmental problems

ation of the overall picture. Ecological assessments, frequently referred to in English reports as "life cycle assessment", are now the order of the day. Fabric washing is performed by combining basic detergents with softeners and bleaching agents (component or modular system), the aim being to use only those chemicals that are really essential. Bleaching agents should not be employed unless actually needed. The use of water-softening automatic washing machines should be encouraged, though little success has been reported in this area to date.

The four above-mentioned phases differ in certain basic respects. In phases I and II, for example, measures were introduced to react to effects observed in the environment. In generation III, on the other hand, analytical measurements of residual concentrations in the environment formed the basis for subsequent measures and proposals. The current fourth generation, for its part, is characterized by the attempt to counter detergent-related environmental problems by preventive actions.

Current Situation: Players, Methods and Measures

In today's world, operations concerned with environmental chemicals involve the interplay of various individuals and institutions (here termed "players") that employ certain methods and eventually propose or implement specific measures (Fig. 2, 3, 4). The players (Fig. 2) include, at one end of the spectrum, the industrial chemical producers who manufacture and sell either raw materials or finished detergent

Ecolabel for detergents

- Modular system
  - basic detergent
  - softener
  - bleaching agent
- Substances
  - no unauthorized ingredients
  - no water-polluting substances
  - aerobic and anaerobic biodegradability
  - low toxicity
  - no bioaccumulation
  - no stable degradation products
- Dosage and washing performance
- Consumer information
- Packaging material

Table 2
Criteria for awarding the ecolabel for detergents in Germany (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, 1993)

products. At the other end, we have the consumers who use these products. Sandwiched between these two are the environmental protection agencies and commercial institutions. Scientific research and development can intervene at various levels. The producers, for their part, have at their disposal sophisticated research and development departments to investigate the environmental aspects of products. EMPA in St. Gall and EAWAG belong to the, unfortunately rather small, group of independent research institutes concerned with the evaluation of the environmental impact of detergents. Various environmental protection and consumer organizations also play an important role in publicizing the subject of textile detergents and cleaning agents. Private consulting firms, representing primarily the interests of the major consumers of detergents, have also recently appeared on the scene. All these players mutually influence each other in differing degrees and combine to form an integrated network. The methods employed by these players are listed in Fig. 3. Product assessment, largely consisting of an evaluation of individual components, is based on laboratory tests and analysis of the environmental behaviour of specific chemicals. These provide data on "exposure", i.e. the stress to the environment caused by the relevant substances. Together with an estimation of the possible ecotoxicological effects a product is evaluated in the conventional sense. The current trend favours the preparation of environmental audits, also called life cycle assessments, encompassing raw materials, manufacturing processes, consumption and disposal. One prominent detergent producer, for example, is currently making great efforts to manufacture surfactants based on regenerating, natural raw materials. A Swiss surfactant manufacturer has transferred part of his production from Switzerland to the Netherlands, thus avoiding the need to transport a high-risk starting material over great distances. EMPA in St. Gall is internationally renowned for conducting such eco-audits.

The range of possible measures (Fig. 4) includes steps taken by producers, changes in consumption behaviour and legislation. The producers aim to optimize their products, thus acting directly at the source of any possible environmental pollution. Certain components can be reduced, or even dispensed with altogether, though

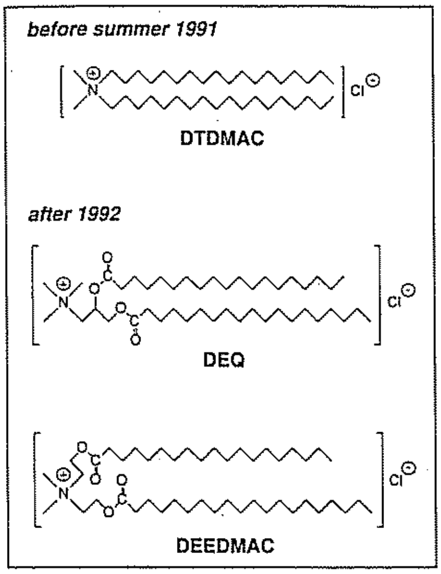

Fig. 5
Structural formulae of cationic surfactants in fabric softeners.
Because of its accumulation in sewage sludge and its toxicity to aquatic organisms, DTDMAC (ditallowdimethylammonium chloride) was replaced in Switzerland in the latter half of 1991 by more highly biodegradable substances known as esterquats. Typical replacement products include DEQ (a quaternary ditallowester of 2,3-dihydroxypropyltrimethylammonium chloride) and DEEDMAC (ditallowdiethoxyesterdimethylammonium chloride).

producers should always be on the lookout for possible problems with any substitutes. The development of innovative washing methods such as the above-mentioned modular system is also particularly important.

A more recent development has been the introduction of an ecolabel for detergents. In Germany, the "Blue Angel" was first awarded for a detergent in 1993 [3]. The criteria for receiving the Blue Angel are listed in Table 2. Similar requirements are contained in a proposal, currently under discussion in Brussels, for an ecolabel in the European Union. The criteria are comparatively strict. By deliberately exceeding the legal requirements, the EU is aiming to create a stimulus for more environmentally acceptable products. Fulfilling the requirement for anaerobic biodegradability, in particular, is proving a major problem for today's principal surfactant, LAS.

Cationic Surfactants in Fabric Softeners

By way of illustration, this section describes the results of investigations cur-

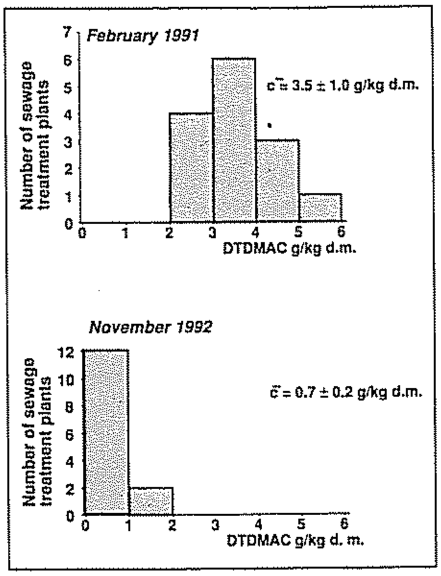

Fig. 6
Frequency distribution of DTDMAC concentrations in digested sludge from fourteen different mechanical-biological sewage treatment plants in the canton of Zurich. Samples were taken before (February 1991) and after (November 1992) the phasing out of DTDMAC.

rently being conducted in the Chemistry Department of EAWAG. The target products are fabric softeners, which are used to make textiles feel as soft as possible. The use of these products in Switzerland has been increasing slightly in recent years (annual consumption approx. 12,000 tonnes or 1.8 kg per head). Until 1991, the principal active ingredient in fabric softeners was the cationic surfactant DTDMAC. Its use was discontinued in 1991 and so it no longer forms an ingredient in fabric softeners. Fig. 5 shows the chemical formulae for DTDMAC and two of the currently used substitutes, which are both quaternary diesters with hydrolyzable ester compounds. The objective of the EAWAG studies was to determine the DTDMAC content in digested sludge samples in order to monitor the effects of the voluntary phasing out of this substance. We can exploit the fact that DTDMAC accumulates in digested sludge, due to its high affinity for surfaces and its anaerobic persistence, to check for any changes in the quantities used.

The first part of the project, the development of a specific method for the quantitative analysis of DTDMAC in sludge samples, required the use of special extraction, separation and detection techniques. Details of the methods used are described elsewhere [4]. Fig. 6 summarizes the results from 14 sewage treatment plants in the canton of Zurich. Following a high average of 3.5 g/kg of dry sludge measured in February 1991, DTDMAC levels had dropped to 0.7 g/kg by November 1992. Current studies indicate even lower levels for 1993. This analytically confirmed 80% drop in DTDMAC concentrations in digested sludge is due to the replacement of this active substance and is a clear illustration of the effects of the producers' voluntary ban. The next phase will probably involve investigation of the replacement substances, in which event the analytical method may need to be further adapted. To sum up, in conducting its analytical investigations in the environment, EAWAG has a vital control function.

[1] Giger, W., Schaffner C., Kari, F.G., Ponusz, H., Reichert, P., and Wanner O. (1991). Auftreten und Verhalten von NTA and EDTA in schweizerischen Flüssen. *Mitteilungen der EAWAG* 32D, 27–31.
Présence et comportement du NTA et de l'EDTA dans les rivières suisses. *Nouvelles de l'EAWAG* 32F, 27–31.

[2] Giger W. (1989). Organische Verunreinigungen im Klärschlamm: Herkunft und Verhalten in der Umwelt. *Mitteilungen der EAWAG* 28D, 8–11.
Polluants organiques dans les boues d'épuration: origine et comportement dans l'environnement. *Nouvelles de l'EAWAG* 28F, 8–11.

[3] Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit (BMU) und Jury Umweltzeichen, Grundlage für Umweltzeichenvergabe. Press release, Bonn, 10.3.1993.

[4] Fernández, P., Alder, A.C. and Giger, W. (1994). Determination of cationic surfactants in sewage sludges by supercritical extraction and HPLC. Publication in preparation.

Roland Schertenleib

Environmental Protection in Developing Countries: A Question of Survival

The Environmental Problems of Developing Countries Differ from Those of the So-Called Developed North

In the industrialized North, mostly regional and global environmental problems prevail. They are neither very acute nor do they pose immediate health problems that are directly perceived by the average citizen. The entire environmental issue is, however, perceived quite differently by the population of the so-called developing countries (DCs). The majority of the 4 billion people in the Third World are still directly confronted with acute and serious problems in their immediate surroundings.

One such acute environmental problems is the fact that *over a billion people have no access to qualitatively and quantitatively sufficient drinking water.* The water sources are either heavily polluted or they are situated so far away that only a few liters of water per day are available to the households. (In order to maintain a sufficient personal hygiene a minimum of 20–40 liters per person per day are necessary).

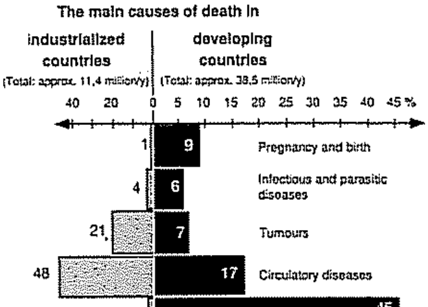

Fig. 1
The main causes of death in developing and in industrialized countries [3]

As regards to disposal of human excreta, the situation is even more precarious as *over 1.7 billion people have practically no access to hygienic human waste disposal systems* [1].

Additional serious environmental problems are caused by the fact that in the cities of the Third World usually only a fraction of all the municipal solid waste produced is collected. This leads to numerous small waste dumps within the cities. Major focal points are open sewage drains and crossings over creeks. In addition, even the collected waste is dumped on such sites where its disposal requires the least amount of efforts and expense. Disposal sites which are more or less controlled and environmentally compatible are practically non-existent [2].

These directly perceived environmental problems are not just of an aesthetic nature; *they constitute a serious and real health hazard* for the population, particularly for the poorest who are hit the hardest. In developing countries, infectious and parasitic diseases are by far the main causes of death as shown in Fig. 1. Most of these infectious diseases are directly or indirectly associated with an insufficient water supply, excreta and waste disposal. *In developing countries, over 8 million people, most of them children, die every year as a result of polluted drinking water and inadequate hygiene.* Table 1 shows the number of cases of illness and deaths from a selection of infectious diseases that are directly or indirectly associated with inadequate drinking water supplies and insufficient excreta disposal. WHO estimates that about 80% of all diseases occurring globally are associated with an insufficient water supply and inadequate excreta disposal.

Under these circumstances it is hardly surprising that bare survival is the main priority for most people in DCs, and that the concerns of the industrialized North for ecological and/or global environmental problems are met with little understanding.

Diseases	Cases of illness (in millions/yr.)	Deaths (in 1000/yr.)
General cases of diarrhoea	3–5'000	4–5'000
Typhoid fever	1	25
Ascariasis (Roundworm)	800–1000	20
Trichuriasis (Whipworm)	500	a few
Ancylostomiasis (Hookworm)	7–9000	50–60
Trachoma	6–9	
Bilharziosis	200	200
Dracontiasis (Guinea worm)	>10	
Elephantiasis	90	
Malaria	800	1200
Onchocerciasis (River blindness)	18	20–50

Source: WHO Geneva, 1992. Our Planet, Our Earth. Report of the WHO Commission on Health and Environment

Table 1
Examples of infectious diseases associated with both insufficient water supply and inadequate excreta disposal [3]

Environmental Issues Gaining Importance in Developing Countries

Objectively seen, environmental problems are gaining importance, even in DCs, but especially in the rapidly industrializing countries of Asia and Latin America. The water quality of various rivers is continually decreasing in DCs. (Fig. 2). This is a direct result of the fact that in Latin America, for instance, less than 5% of the wastewaters are treated before they are released into a receiving water.

Deterioration of surface water quality not only results in environmentally damaging effects, but has substantial economic impacts as well. The constantly increasing pollution of surface waters, especially by industrial wastes, is one of the main reasons why the specific costs of future water supplies in many cities of the Third World will be 2–3 times greater than the present costs (Fig. 3). The city of Shanghai is an example of this trend; every few years it has to draw its water supply from several kilometers further upriver in order to treat the river water at an acceptable cost. In other cities such as Dakar, Jakarta, Lima, and Bangkok, overuse of ground water results in the infiltration of seawater with a consequential increase in the salt content of the ground water; heavily polluted surface water then must be increasingly treated for use as drinking water [5].

Wastewater treatment plants should be given the same priority as drinking water production plants in cities of the Third World. For economic reasons, however, this is nearly impossible, especially since in those DCs experiencing a high rate of industrial development, a wide array of

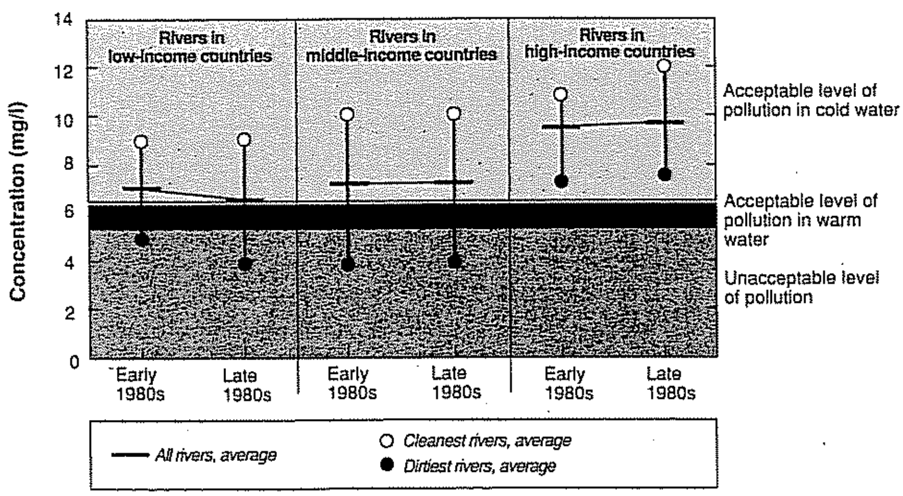

Fig. 2
Dissolved oxygen in rivers: levels and trends across country income groups [4]

water protection problems crop up almost simultaneously. In contrast, in today's industrialized countries these problems occur at staggered intervals, enabling each one to be dealt with separately (Fig. 4).

Causes of Global Environmental Issues Mainly in the Industrialized North

Both the acute environmental problems of direct health consequences as well as those of a more general environmental nature can be most clearly illustrated by citing examples of large metropolitan agglomerations in DCs. This is undoubtedly one of the negative consequences of population growth and, above all, of the extremely rapid urbanization. By the year 2025, almost half of the world's population (i.e., about 4 billion people) will be living in metropolitan agglomerations in DCs. Seventeen of these agglomerations will have populations of over 10 million individuals, and in Asia alone, more than 52 cities will total over 4 million inhabitants each [6; 7].

It should be emphasized that in spite of the rapid increase in world population and the dramatic urbanization of the Third World, the causes of global environmental problems today and in the near future are largely to be found in the industrialized North. The question is not how many people live in a certain area, but how they live. When energy and resource consumption of industrialized countries is compared with that of developing countries, it becomes apparent that from an ecological point of view (consumption of raw material and energy), the annual increase in birth rate of about 0.5% in the industrialized North is about two to three times more serious than the increase in population of about 1.7% in the developing countries (Fig. 5) [8].

Conclusions

While the acute environmental problems of the developing countries are largely a consequence of poverty and lack of economic development, the environmental issues in the North are primarily linked to an economic "over-development" or "mis-development".

In the South, the poorest suffer most from the deteriorating environmental conditions. Moreover, due to economic reasons, environmental protection measures are given low priority in DCs. Immediate survival continues to be the main problem which is directly associated with the rapid increase in population. Seen in an historical context, a decrease in population has always been a consequence of economic development and not vice versa. The standard of living, therefore, has a direct influence on population growth.

In contrast with the South, the industrialized North is characterized by its heavy wastage of resources. Seen in a global context, it may be concluded that the consumption of resources in industrialized countries actually jeopardizes the ecological capacity of the earth and, consequently, also that of the DCs. In contrast to most developing countries, the industrial nations have already used up their "environmental credit", as they have consumed much more than the average share of environmental resources in proportion to their population and surface area.

Curbing the consumption of resources in industrialized countries is just as imperative as slowing population growth in the poorer countries of the South.

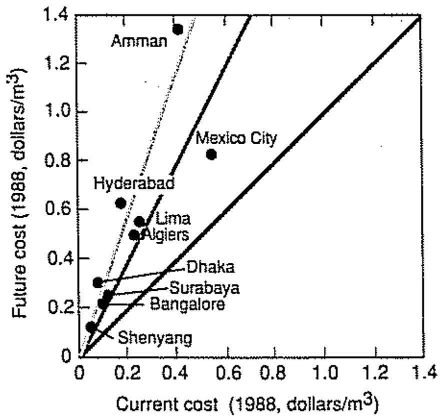

Fig. 3
Supplying water to urban areas: current cost and projected future cost [4]

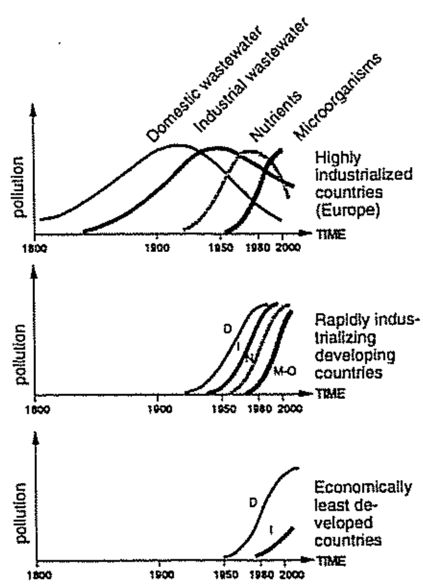

Fig. 4
Evolution of water pollution problems in countries according to development pace and status [5]

EAWAG's Contribution

As federal research institute, the EAWAG is primarily concerned with environmental problems of the North and particularly with those of Switzerland. At the same time, a small research group within the EAWAG ("Water and Sanitation in Developing Countries") is also working on specific problems of water supply, wastewater management and waste disposal in DCs. Its activities focus on determining the most appropriate and sustainable measures and technologies for various economic, sociocultural and physical conditions.

In the past decades, in spite of international efforts in the water sector, it was not possible to significantly increase the supply of clean water in economically less developed regions. Consequently, at the beginning of the 1990s, new strategies and priorities were formulated for development cooperation programs in which the EAWAG also participated. Based on the motto "some for all rather than more for some", priority is currently given to the continuous availability of sufficient clean water for all. Community water and sanitation measures are being planned for the remotest possible areas. The most impor-

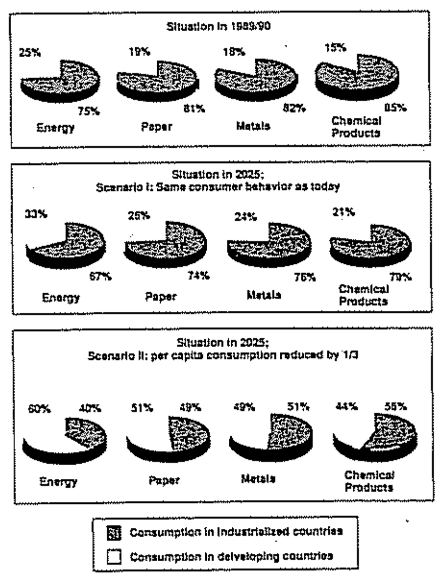

Fig. 5
Comparative resource consumption in industrialized and in developing countries

tant guidelines for the realization of these goals are [9]:

- Protection of health and the environment through the integrated management of water resources and solid and liquid waste.
- Institutional reforms to promote an integral strategy, including changes in procedures, habits and behavior, as well as women's participation at all levels of this sector.
- Operation of installations by local community groups and promotion of measures to strengthen local institutions in the planning and implementation of sustainable water and sanitation programs.
- Improved use and management of existing installations and plants through application of certain management principles and through consequent application of appropriate technologies.
- Administration of the resources water and soil at the lowest possible institutional level.
- Treatment of water (with all of its difference uses) as an economic commodity.

[1] WHO: "The International Drinking Water Supply and Sanitation Decade; End of Decade Review", Geneva, 1992

[2] Schertenleib, R. and Meyer, W.: "Municipal Solid Waste Management in Developing Countries: Problems and Issues; Need for Future Research", *IRCWD News No. 26*, 1992

[3] WHO: "Our Planet, our Health", Geneva, 1992

[4] The World Bank: World Development Report 1992. Oxford University Press, 1992

[5] Schertenleib, R.: "Flüsse als Objekte vielfältiger Nutzung in Entwicklungsländern", EAWAG News 32D, 1991

[6] UNCHS/Habitat: "Urbanization and Sustainable Development in the Third World: An Unrecognized Issue", Nairobi, 1989

[7] UN/ESCAP: "State of the Environment in Asia and the Pacific 1990", Bangkok, 1992

[8] Sachs, Ignacy: "Transition Strategies for the 21st Century", *Nature and Resources*, Vol. 28, No. 1, 1992

[9] DEH Fachdienst Wasser: Sektorpolitik Wasserversorgung und Siedlungshygiene. Bern, 1993

Ueli Bundi

Nitrogen Balance in Switzerland

Guidelines for Environmental Management

Nitrogen is an issue that calls for networking strategies involving a variety of natural processes and human activities. The largest sources of nitrogen-related environmental problems are agriculture and combustion (including motor traffic). Urgent action needs to be taken in agriculture since it affects numerous other areas of the environment, the economy, social matters and politics. A general reorientation of agriculture is needed.

Problems and Challenges

Nitrogen plays a key role in the environment. Occurring in various forms, it is both an essential nutrient and a pollutant. Its turnover and concentrations in the environment are greatly increased by human activity which lead to a number of problems (described in detail in [1] and [3]) in the water, soil and air.

The causes and manifestations of most nitrogen-related problems are closely intertwined. That is why both *local and regional approaches* are needed, though these should be developed in a national and, where necessary, international framework according to a set of jointly formulated principles. Switzerland, however, must not address nitrogen problems only at home. As a signatory to various international conventions, it must substantially reduce its *exportation of nitrogen* via the Rhine in an effort to protect the North Sea.

The various problems stemming from nitrogen have common causes in *agriculture, mobility and water use.* They are closely interlinked through complex natural and anthropogenic processes. Remedial measures are essential in all of these areas. In order to optimize the impact and prevent counterproductive effects, the steps taken in agriculture, combustion processes, motor traffic and wastewater treatment must be *carefully harmonized.* A number of other environmental issues affected by nitrogen management must also be taken into account.

Nitrogen Balance in Switzerland, 1990

Fig. 1 depicts the nitrogen balance in Switzerland [1]. It shows the main flows connecting the *anthroposphere* (population, households, trade and industry, transport and settlement), *atmosphere*, *pedosphere* (agriculture and alpine pastures, forest, unproductive land, farm animals) and *hydrosphere* (surface water and ground water). The figure does not distinguish between the different chemical forms of nitrogen.

The major *sources* of nitrogen pollution in the environment are *fertilizer and foodstuff imports* to Switzerland (a total of 95'000 metric tons of nitrogen annually), *agricultural soil management methods, motorized traffic* and *domestic water use.* All of these sources results in large nitrogen emissions to the soil, water and air. In this way, complex natural processes are set in motion which dramatically increase the nitrogen flux between the various environmental compartments.

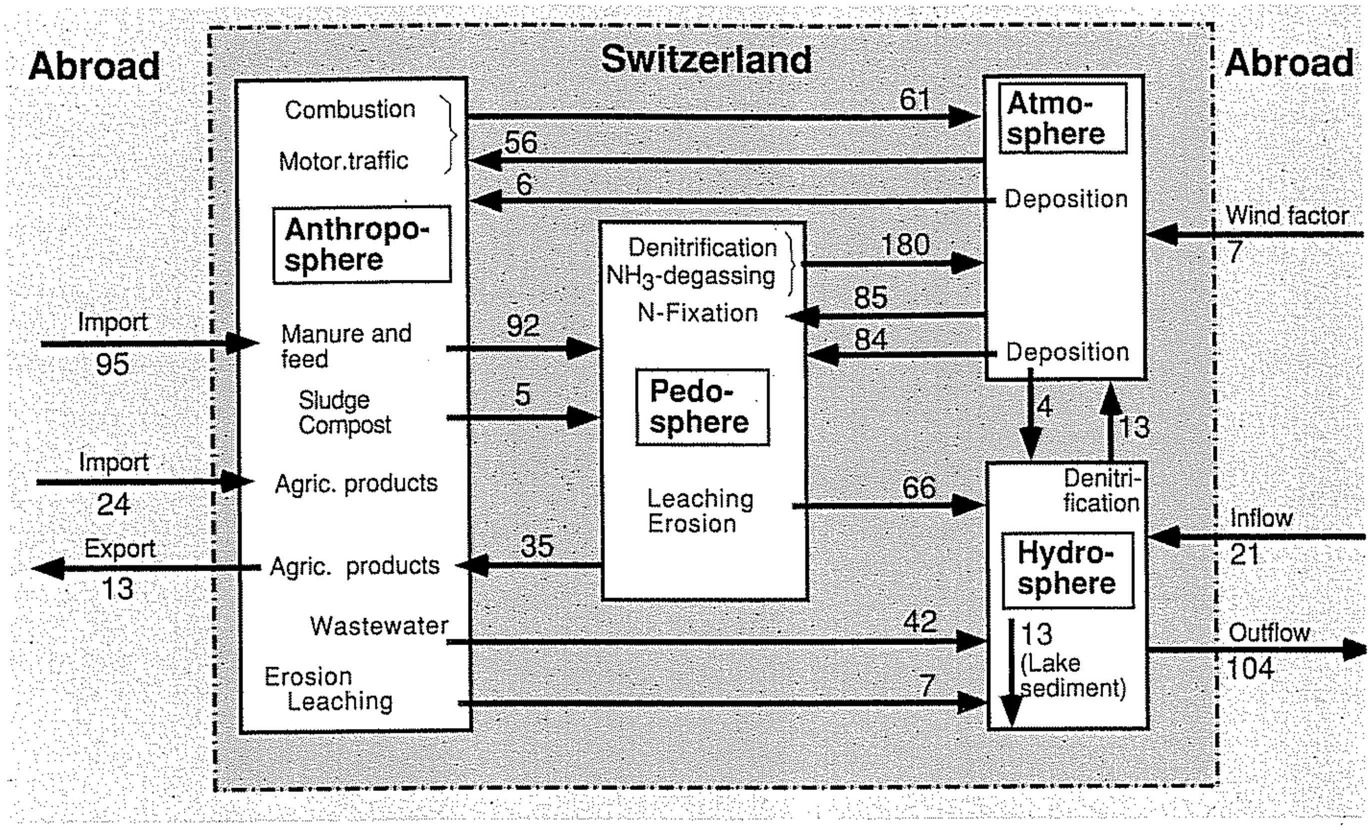

Fig. 1
Nitrogen balance in Switzerland, 1990. Data in 1000 t nitrogen per annum of the major sources of nitrogen. There are minor differences between the different spheres due to uncertainty about the data.

Mineral fertilizer imports, for instance, permit *higher agricultural productivity*, by producing more feed, thereby allowing an increase in animal density. The drawbacks include increased production of manure, higher ammonia emissions to the atmosphere and increased leaching of nitrates from the soil to the ground water. Fertilizer imports, which are responsible for productivity gains in agriculture, generally result in environmental pollution with considerable follow-up costs.

In the Swiss catchment area, *119'000 metric tons of nitrogen* end up in the water. Of this total:

- 38% originates from agriculture
- 35% comes from wastewater
- 8% results from combustion processes (motor vehicles, industry, heating)
- 2% comes from various minor sources
- 17% originates from natural sources

Today, nitrogen input into water bodies in Switzerland is about *six times* the input under normal conditions, though the quantities vary greatly from one region to another. Every year, 104'000 metric tons of nitrogen are exported from Switzerland in the water, 81'000 metric tons of which are transported via the Rhine River.

A look at the *atmosphere* shows that Switzerland is confronted with ever increasing nitrogen levels. Annual nitrogen emissions in the air now stand at 254'000 metric tons. Of this amount, 135'000 metric tons are in the form of harmful compounds. Combustion processes contribute 56'000 metric tons of NO_X-N, while agriculture adds 47'000 metric tons of NH_3-N and 20'000 metric tons of N_2O-N to the air. The remaining 12'000 metric tons of NH_3-N and N_2O-N come from other emission sources and natural processes.

The Costs and Benefits of Remedial Action

The means chosen to reduce the harmful output of nitrogen must be selected carefully. The strategy should take into account both the effects of the various nitrogen compounds and the interactions between water, soil and air. A study carried out by the Federal Water Protection Commission [1] investigated a number of different measures:

A wide range of plans exists for *reduction of nitrogen oxide emissions*. These include the measures mentioned in the *Federal Council's Clean Air Concept* [2] of 1986, subsequent additions and additional legislative action of the Cantons. Many of these measures have already been, or will soon be, implemented. Economic incentives, along the lines discussed by politicians for some time now, could bring about major advances in reducing fuel consumption.

In the area of *wastewater treatment*, various technologies already exist for removing nitrogen from wastewater. Basically, they involve various options for biological denitrification (following nitrification). They include retrofitting of all wastewater treatment plants serving more than 10'000 inhabitant units with partial or complete denitrification systems.

To reduce nitrogen emissions from *agriculture*, solutions may lie in agricultural technology and to less intensive production; e.g., improved stable techniques and fertilizer use, appropriate crop rotation methods, avoidance of fallow, a reduction in the number of animals, integrated or biological production methods, setting aside of agricultural acreage and the creation of ecological acreage as a compensatory measure (cf. Fig. 3).

Turning to *nitrogen emissions in the hydrosphere*, Fig. 2 illustrates the reduction

Causes	Reduction potential[1]		Cost/benefit ratio	Duration[2] of time to onset of effect
	in kt N/yr	in % of total pollution	in Fr./kg of avoided nitrogen	in years
Combustion/ Traffic[3]	6	5%	80 – 4'000	5 – 15
Wastewatertreatment	25	21%	15 – 25	5 – 15
Agriculture[3]	30	25%	5 – 100[4]	10 – 20

Fig. 2
Swiss potential for reduction of nitrogen emissions into the hydrosphere.

[1] Emissions in the Swiss hydrosphere from the national catchment area amount to 119'000 metric tons nitrogen per annum.

[2] Including the time needed to implement the measures and soil reaction time. These figures are based on the assumption that the necessary instruments are already in place or can be put in place within 1–3 years.

[3] Measures in the areas of agriculture and combustion/motor traffic reduce nitrate leaching into ground water and have numerous other environmental benefits.

[4] These costs imply that under the current product price conditions these measures have no impact on income.

potential for the various causes and the cost/benefit ratios.

Wastewater Treatment as Opposed to Agrarian Measures

The data in Fig. 2 require a certain degree of interpretation and evaluation. In particular, the totality of the environmental effects – and not just the reduction of nitrogen levels in the hydrosphere – have to be taken into consideration. This is best illustrated by means of a comparison.

By introducing additional treatment steps in *wastewater treatment plants* at an annual cost of some *350 million Swiss francs* (operating and capital costs), the amount of nitrogen entering flowing waters and lakes could be reduced by 20'000 metric tons a year. The benefit of a measure of this kind, however, is limited, since emissions into the ground water, which suffers most from nitrogen pollution, are only slightly reduced. Moreover, there is insufficient evidence to demonstrate that nitrogen levels in the North Sea are a serious enough problem to warrant the large investment needed to rapidly improve nitrogen removal efficiency in wastewater treatment plants.

By spending some *600 million Swiss francs* on *agriculture*, nitrogen emissions into water bodies could also be reduced by about 20'000 metric tons per annum. Ground water would benefit most, while this approach would greatly reduce nitrate levels as well. At the same time, harmful ammonia nitrogen emissions into the air stemming from agriculture would be reduced by about 15'000 metric tons per annum (an analogous reduction in nitrogen oxides from combustion processes would cost the economy more than one billion francs a year). Furthermore, these measures have a beneficial effect on both surface waters and the soil.

Changes in the utilization of soil by agriculture are essential in order to halt the ever worsening nitrate pollution of ground water. A good deal of progress can be made through the consistent implementation of existing legislation (e.g., water protection, environmental protection and agriculture acts). The best example is the *balanced use of fertilizer*, an important advance, provided it is properly implemented and monitored.

A Reorientation in Agriculture

A omparison in the previous section shows that *urgent steps are necessary* in agriculture in order to solve the problem of nitrogen pollution. This issue has an impact on other areas of the environment as well as on the economy, society and political life. This brings us to the fiercely debated questions of the ecological and economic reorientation of agriculture. Fig. 3 summarizes some important elements of this reorientation stemming from an analysis of nitrogen pollution.

If all of the measures mentioned were implemented, they would cost up to one and a half billion francs a year (assuming that farmers suffered no loss of income). The costs would be largely offset by the numerous environmental benefits and related savings (e.g., less environmental damage and large agricultural surpluses). The additional expenditures and loss of

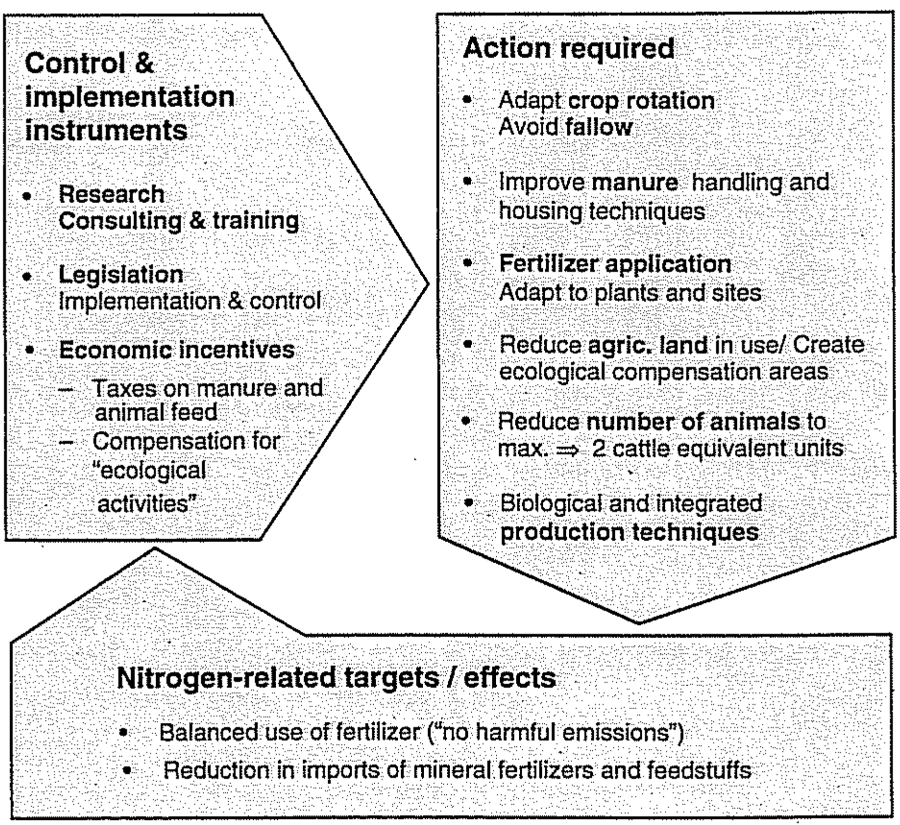

Fig. 3
Reorientation measures in agriculture designed to deal with the nitrogen pollution problem.

income could be compensated in part by *direct payments*, as currently discussed in political circles. From the economic and ecological vantage point, however, these must be *strictly linked to activities undertaken by farmers to protect the environment*. At the same time, measures to protect the water, soil and air would have to be streamlined in order to insure both acceptable and efficient environmental protection in agriculture.

Overall Strategy

A targeted overall strategy aims to optimize the use of resources in solving nitrogen-related environmental problems, while taking into account other environmental issues. Within 5–10 years, the necessary measures will have to be taken to cut anthropogenic nitrogen emissions into groundwater (nitrates) and the atmosphere (nitrogen oxides and ammonia) in half. The following approaches should be developed:

1. An ecological approach to agriculture

- economic incentives which should provide some cushion against economic and social hardship
- coordination of the various environmental problems on each farm

2. Development and implementation of the clean air concept

- economic incentives to reduce the consumption of fuels

3. Ecological, technical and economic improvements to wastewater treatment plants

- within the next 20 years
- economic incentives (wastewater taxes)

The action that needs to be taken in agriculture was explained in the previous section. Contrary to the prevailing international opinion on the question of *wastewater treatment plants*, large investments should not be made over a short period to eliminate the problem of nitrogen pollution. The ecological, technical and economic development of wastewater purification takes time and should be adapted to the normal regeneration cycle of the plant. However, the *reduction in nitrogen oxide emissions*, which is one of the aims of the Federal Council's clean air concept, remains undisputed. This would not only improve air quality but represents a considerable benefit for protection of water, soil and natural systems.

By exploring all of the possible solutions available under present social conditions, nitrogen emissions could be lowered by as much as two thirds in certain areas (air/NO_X, groundwater). Emissions into surface waters could be cut in half by the year 2010. The costs would come to more than two billion Swiss francs per annum (without the costs for NO_X-reduction). Further reductions would necessitate a fundamental review of water use, traffic and consumer behavior, settlement policy and economic development.

The final point is that Switzerland can make a major contribution to *protecting the North Sea* if it manages to bring its nitrogen emissions under control.

[1] Eidg. Gewässerschutzkommission, Bundi U. und D. Leu et al., Der Stickstoffhaushalt in der Schweiz – Konsequenzen für Gewässerschutz und Umweltentwicklung, Schriftenreihe Umweltschutz, BUWAL Bern, November 1993.

[2] Clear Air Concept of the Federal Council, Bern, 10 September 1986.

[3] EAWAG News 30, Stickstoff in Wasser und Luft – Implikationen für den Gewässerschutz, Dübendorf, December 1990.

Ueli Bundi

From Environmental Protection to Environmental Management

The Consequences for EAWAG

Environmental management involves a system-based approach in which the objectives are determined by sustainability criteria. It can encompass the integrated protection of ecosystems, the environmentally acceptable design of technologies or the organization of whole sectors of economic activity. EAWAG focuses its efforts on the requirements of environmental management and is committed to a gradual reduction in the use of natural resources and the curbing of environmental pollution.

Environmental Management is Nothing New, but...

The title of this article – the same as that used for the 1993 EAWAG Information day – is *rhetorical*, and is simply intended to highlight the need for new ways of thinking and acting. In actual fact, environmental protection will always form an essential goal of environmental management and, conversely, traditional environmental protection increasingly incorporates elements of environmental management.

The *lake restoration strategies* developed in the 1970s serve as a useful illustration. These strategies were based on models for recording internal lake processes and from which were derived acceptable target levels of phosphorus in individual lakes. Where phosphorus levels were too high, measures were then proposed on the basis of the various sources of phosphorus. As a result, wastewater treatment plants in many places were subsequently designed to eliminate as much phosphorus as possible, the ban on phosphorus-containing detergents was passed in Switzerland in 1986 and steps were also taken to reduce the agricultural phosphate input into the lakes. This form of "environmental management" does, however, have its *limitations*: wastewater treatment requires considerable technical, material and financial resources such as only affluent societies can afford; the vital agricultural measures could only be implemented to a very modest extent, and other important requirements for lake ecology, such as the maintenance of undisturbed shallow water and shore zones, were completely ignored. So although the lake restoration strategies may have been exemplary at the time, they were only able to deal with the situation in a compartmentalized, piecemeal manner, with little attention given to the technical, economic and behavioral roots of the problem. This was primarily due to the fact that society failed to understand and address the underlying conflicts of interest in the demands placed upon natural resources.

Pragmatic Definition of Environmental Management

According to current thinking, "environmental management" involves a *system-based approach* covering various aspects, some of which are briefly described below. Measures for protecting individual or interrelated environmental resources are *ecologically and economically optimized*. In other words, measures with the most favorable cost/environmental benefit ratio are implemented, while costly and relatively irrelevant improvements are ignored. This allows us to achieve the greatest environmental benefit for a given amount of resources. Faced with the limitations of technical, curative measures, *preventive, cause-based measures* assume a central role. But these may hardly be introduced in an "isolated" manner, since they generally involve a tangled web of widely differing consequences. Ultimately, and inevitably, this means that *whole sectors of industrial and economic activity have to be managed in an environmentally-sensitive manner*. Whether this is feasible depends crucially upon economic, social and cultural demands. Significant progress in this area is almost inconceivable without the *inclusion of interrelated social factors*.

In this new, integrated approach, the pathway of action is determined by *sustainability criteria*. By this we mean for example, reducing the use of natural resources, "closing" the life cycles of materials, preserving ecological networks while, at the same time, avoiding adverse social and economic reactions. This view no longer focuses on a one-sided approach to the conservation of Nature. Humankind is part of Nature and cannot help but leave its imprint on Nature. We, therefore, have to resign ourselves to the fact that the concept of Nature 'untouched by man' is now unachievable, except in national parks. The new watchword is *environmental management*. These general considerations are outlined in greater detail in the article "Nitrogen Balance in Switzerland – Guidelines on Environmental Management" which offers specific illustrations.

Consequences for EAWAG

For EAWAG, the challenge of environmental management involves research, education and consultation (see the article by Alexander J. B. Zehnder "Environmental Development: The Way Forward"). *Over the coming years, EAWAG will commit itself to a gradual reduction in the use of natural resources and the curbing of environmental pollution. To this end, EAWAG will support developments designed to ensure the preservation of a high quality of life in the long term.*

EAWAG's objectives are:

- to make nationally and internationally effective contributions toward the development of scientifically-based *environmental protection and development concepts* at local, regional and global levels.
- to complement innovative, scientific and technical approaches by increasingly taking into account *social aspects*, in seeking solutions to environmental problems.

These aims are reflected in the establishment of the EAWAG Human Ecology group in 1993 (see EAWAG news 35), the specific activities of the specialist departments and, in particular, in the research focus of EAWAG.

The *research focus for 1993–1997* is entitled *"Sustainable Resource Management – Water Bodies and Anthropogenic Sediments"*. The goal is to develop regional management plans for hydrographic networks, ground water, landfills and contaminated soils and sediments. Technical expertise will play a crucial role in this venture, particularly in the area of contaminated site remediation. By combining the interrelated findings from the various specialist areas, EAWAG ultimately hopes to identify basic principles that can be utilized in integrated sustainable regional development plans. Achieving these objectives will require close cooperation with external partners, including science, government and the private business sector. This research focus is described in detail in EAWAG News 35.

Other projects investigating the scientific principles, methods, technologies and concepts of environmental management are currently in progress or in the pipeline. One particular project aims to develop *resource-friendly technologies for supply and disposal connected with new housing development and regional structures*. This will design and test possible options for ecologically and economically stable, long-term supply and disposal systems.

Specific aims are:

- to prepare housing and regional development concepts in which the sustainable use of resources is an integrated component (timescale: 30–50 years)
- to develop integrated systems of water management for housing developments, taking into account supply and disposal and the requirements of natural water bodies
- to design a resource-efficient management system for solid material in housing developments

In making these, and other, contributions to *environmental management*, EAWAG is pursuing two different, though closely interrelated, objectives. On the one hand, it seeks to resolve *regional problems* of resource management and environmental degradation; on the other, it hopes to make a wider contribution towards the *management of global environmental problems* in Switzerland at regional and national levels.

Inside EAWAG

Grottker and Schilling: Professors in Germany and Norway

In the summer of 1993, two members of the Urban Hydrology group in the Environmental Engineering Division left EAWAG to take up new challenges in Germany and Norway.

On 1 August 1993, Dr. Matthias Grottker was appointed professor at Lübeck Engineering School, Germany. Grottker joined EAWAG in the summer of 1990 and was primarily involved in various projects forming part of the "Integrated Urban Drainage" study in Fehraltorf, where he assumed responsibility for, and also largely monitored himself, the whole measuring system. As part of this overall study, he also worked on the sewage storage project and was temporarily involved in the investigation of rainwater seepage. Together with Wolfgang Schilling, he organized a number of international workshops in 1992 and 1993 for young scientists. In addition, he was one of the lecturers in the EAWAG "Urban Hydrology" training courses and also taught hydraulics for civil engineers at the Engineering School in Zürich.

Dr. Wolfgang Schilling took up his new post as Professor in the Department of Hydraulic and Environmental Engineering in the Norwegian Technical University in Trondheim on 1 October 1993. Schilling joined EAWAG in the fall of 1988 and was involved in a number of wide-ranging tasks in the Urban Hydrology group. He played a leading role in setting up and directing the group and was also involved in the organization and management of the "Integrated Urban Drainage" research project. As part of this study, he also worked on his own pet project: sewage outfall control. In his capacity as lecturer at the Federal Institute of Technology in Zurich, he was responsible for arranging various educational events and successfully motivating budding civil and environmental engineers to respond to the needs of modern urban drainage.

Although these two highly qualified experts and admired colleagues have formally left our group, we look forward to remaining in close contact on both a professional and personal level. We wish them every success and much satisfaction in their new positions.

Matthias Grottker
Fachbereich Bauwesen
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Stephensonstrasse 3
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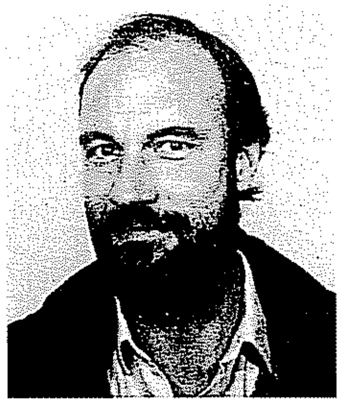


Wolfgang Schilling
Institutt for Vassbygging
NTH (Norges Tekniske Hogskole)
S.P. Andersens vei 5
N-7034 Trondheim

Double Honor for Jürg Hoigné

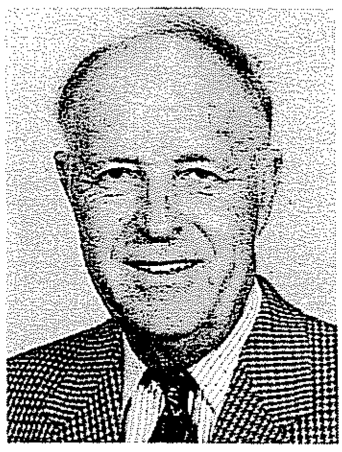
Honorary member of the International Ozone Association

On the occasion of the 11th World Ozone Congress in August 1993 in the United States, Professor Jürg Hoigné was appointed an honorary member of the International Ozone Association in recognition of his outstanding contributions to the furtherance of the association's aims.

Harvey M. Rosen Memorial Award

Jürg Hoigné and Susan Masten were jointly awarded the Harvey M. Rosen Memorial Award for their paper entitled "Comparison of Ozone and Hydroxyl Radical-Induced Oxidation of Chlorinated Hydrocarbons (Solvents) in Water". The award is given in recognition of the best paper, in the opinion of the editors, to appear in the *Journal of Ozone Science and Engineering* during 1991–1992.

Dr. Masten is currently an Assistant Professor in the Department of Civil and Environmental Engineering at Michigan State University. She completed this particular section of her dissertation at EAWAG when she was studying as a Harvard University doctoral candidate under the supervision of Hoigné.



Events

Bernhard Truffer, Gregor Dürrenberger and Silvia Rothen

Will the "Car of the Future" be Developed in Switzerland?

A Report on the EAWAG Supercar Workshop

Are there any ecological alternatives to today's car and, if so, how can they be realized? These questions formed the focus of an international workshop held on 20–21 September1994 and organized by the EAWAG Human Ecology Group. The most significant conclusions were that cars with a fuel consumption of one liter per 100 km were technically feasible, and that the level of expertise in Switzerland is almost unmatched.

Climate, Mobility and an Innovative Environment

The atmospheric changes caused by emissions from human-made products have increased dramatically over the past few decades and may have serious consequences for the world's climate. Motorized passenger traffic is one of the primary sources of greenhouse gases and air pollutants. One of the most interesting approaches to resolve this problem has been the development of electric vehicles. A pioneering group made up of light-engineering companies, ecologically interested engineers and motivated students has gained considerable know-how in recent years in the design of lightweight vehicles and produced a whole range of forward-looking vehicle concepts. Switzerland is in the vanguard in prototype development. And on the demand side, roughly one third of all electric vehicles in use worldwide run on Swiss roads.

The Workshop

As part of a research project (see box), the EAWAG Human Ecology Group is currently investigating the problems and potential benefits of lightweight vehicles based on the state-of-the-art. A two-day workshop was organized. The stimulus for this event was provided by contact with the American energy expert Amory Lovins, who has been concerned with the development of energy and pollution efficient vehicles – otherwise known as supercars.

The workshop focused on three questions:

- Which technical concepts promise the greatest potential for savings with respect to energy consumption and emission of pollutants (including CO_2), and what is the current state-of-the-art in the Swiss pioneering group?
- What problems are involved in building these vehicles on an industrial scale?
- How might a future market for energy and pollution efficient vehicles develop, and what strategies should be given priority?

For Switzerland, these three problem areas can be summed up in one question: Is there a viable industrial option for energy-efficient vehicles? Some 50 experts from Switzerland and other countries were invited to discuss these issues. The principal participants were developers of lightweight vehicles from Switzerland, the United States, France and Scandinavia. Representatives from Swiss industry, financial institutions and government departments were also invited to deliberate upon the relevance of the industrial option. Other participants included scientists, representatives of environmental organizations and the media.

The first day of the workshop was devoted to technical and production-related aspects, with contributions coming primarily from developers, the American guests and the financial institutions. Market considerations and promotion strategies constituted the main topics for discussion on day two. Various Swiss lightweight vehicles were presented between the main sessions.

The findings from the workshop were broadcast to a wider public by various routes. Swiss television produced a short report, and articles on the workshop appeared in various newspapers. On the evening of the second day, Amory Lovins, energy expert and research director at the Rocky Mountain Institute, Snowmass, Colorado, USA, and Paul MacCready, lightweight vehicle engineer and consultant to General Motors, USA, gave a public lecture at the Federal Institute of Technology.

Main conclusions

What were the responses to the three central questions?

Lightweight construction

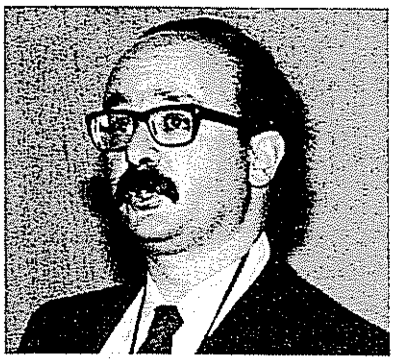
The workshop participants were of one mind in concluding that energy and pollution efficient vehicles can only be successful in practice if lightweight construction and design principles are consistently applied. A relatively liberal attitude was apparent on the subject of the ideal form of propulsion. Efficient vehicles can employ either electric motors only or internal combustion engines only; the precise design of the engine should take into account the specific use of the vehicle. Hybrid concepts involving the intelligent combination of electric and internal combustion engines appear to offer the most promise in the medium term. Generally-speaking, vehicles that run on less than 1 liter per 100 km were considered to be perfectly feasible in the longer term. The current

Paul MacCready, lightweight vehicle engineer and consultant to General Motors, USA

level of know-how in the Swiss pioneer group can be considered amongst the best in the world, and the Swiss even occasionally play a leading role.

Who will build the vehicles?

Efforts to implement the technical concepts on an industrial scale are still in their infancy. A capital investment of several hundred million Swiss francs was considered by all participants to be a realistic requirement before mass production can begin. The bank representatives stressed that it was fairly difficult in Switzerland to raise such sums on the capital market and that Swiss developers would, therefore, probably not be able to go it alone. Ideal partners for industrial production would be firms in the automotive industry, although the consistent use of lightweight construction would represent a fundamental change in their traditional practices. Workshop participants generally doubted the automotive industry was ready for such a change. A collaborative venture involving the pioneer group and Swiss industry could offer an interesting alternative option. The relevant industrial know-



Amory Lovins, energy expert and research director at the Rocky Mountain Institute, Snowmass, Colorado, USA

how is certainly available in Switzerland.

Initial large-scale trial

The outlook for the industrial production of energy-efficient vehicles hinges on the market prospects. However, the market is determined by numerous conditions that are difficult to predict. The "lightweight electric cars" program promoted by the Swiss Department of Energy appears particularly promising; through a regionally focused campaign, the percentage of lightweight cars in a medium-sized Swiss town is scheduled to reach a significant proportion – about 10% – of overall vehicles. This large-scale trial will provide important information on market dynamics.

To sum up: serious potential definitely exists in Switzerland for the production and marketing of pollution and energy efficient vehicles. This conclusion is based not only on the high level of technical knowledge possessed by the pioneer group, but also on the existence of potential industrial partners and the presence of an initial market that will prove significant for the early phases of market development.

The perceived risks of global warming have led to increased international research efforts. In Switzerland, some 20 research projects, funded through the Swiss National Fund's environmental program, are currently tackling the climate problem. These projects range from atmospheric physics, via ecosystem modeling to questions of social science, and form part of the CLEAR program (CLimate and Environment in Alpine Regions). As part of a separate social science project, the EAWAG Human Ecology group is investigating social innovation processes that can contribute toward a reduction in the anthropogenic production of climate gases.

Current Relevance of this Subject

The next step is to put these ideas into practice. A few days after the workshop, U. S. President Bill Clinton announced that the 'big three' U. S. car manufacturers would, with government support, be pushing ahead with the development of a three-liter car over the next ten years. According to the workshop findings, it is perfectly feasible to produce vehicles with a much lower fuel consumption, and Switzerland can make a key contribution in this respect.

The production of a supercar itself is not enough. Lovins expects oil prices to drop still further. Faced with the problem of excessive mobility, he has just one answer: "negakilometers" and "negacars", i. e., cut back on traffic through policies that reflect the true costs involved and through various fiscal instruments.

EAWAG's Role

What role can research, and EAWAG in particular, play in these activities? Naturally, one of our tasks is to serve as a platform for publicizing and discussing environmentally relevant developments. In fulfilling this role, EAWAG must concentrate on preparing theoretical concepts and empirical data that are not available, or only to a limited extent, to the other players involved. The Human Ecology group continues to operate on two levels: investigating the relevance of the industrial options in greater depth and assessing and defining the future market. Accordingly, we will be investigating the dynamics of this emerging market. The workshop has shown that a high level of interest exists in this area.

Publications

Can be ordered seperately from the EAWAG library (use last page)

EAWAG Publications

Corrigenda

1702 **Müller, R.**: Trophic State and its Implications for Natural Reproduction of Salmonid Fish. Hydrobiologia *243/244*, 261–268 (1992).

1723 **Lukac, Maja, Aegerter, Rita**: Influence of trace Metals on Growth and Toxin Production of *Microcystis Aeruginosa*. Toxicon, *31*, 293–305 (1993).

New Publications

1745 **Kohler, H.-P.E., Schmid, A., van der Maarel, M.**: Metabolism of 2,2'-Dihydroxybiphenyl by *Pseudomonas* sp. Strain HBP1: Production and Consumption of 2,2',3-Trihydroxybiphenyl. J. Bacteriol. *175*, 1621–1628 (1993).

1746 **Kerr, J.A.**: Strengths of Chemical Bonds. In: «Handbook of Chemistry and Physics. 74th Edition». David R. Lide, (Ed.) CRC Press, Boca Raton 1993.

1747 **Zuo, Y., Hoigné, J.**: Evidence for Photochemical Formation of H_2O_2 and Oxidation of SO_2 in Authentic Fog Water. Science *260*, 71–73 (1993).

1748 **Auling, G., Busse, H.-J., Egli, T., El-Banna, T., Stackebrandt, E.**: Description of the Gram-Negative, Obligately Aerobic, Nitrilotriacetate (NTA)-Utilizing Bacteria as *Chelatobacter heintzii*, gen.nov., sp.nov., and *Chelatococcus asaccharovorans*, gen.nov., sp.nov. System. Appl. Microbiol. *16*, 104–112 (1993).

1749 **Wilberg, Elvira, El-Banna, T., Auling, G., Egli, T.**: Serological Studies on Nitrilotriacetic Acid (NTA)-Utilizing Bacteria: Distribution of *Chelatobacter heintzii* and *Chelatococcus asaccharovorans* in Sewage Treatment Plants and Aquatic Ecosystems. System. Appl. Microbiol. *16*, 147–152 (1993).

1750 **Kohler, H.-P.E., van der Maarel, M.J.E.C., Kohler-Staub, Doris**: Selection of *Pseudomonas* sp. Strain HBP1 Prp for Metabolism of 2-Propylphenol and Elucidation of the Degradative Pathway. Appl. Environ. Microbiol. *59*, 860–866 (1993).

1751 **Gujer, W., Kappeler, J.**: Modelling the Competition of Filamentous and Flocforming Bacteria in Activated Sludge Plants. In: «Prevention and Control of Bulking Activated Sludge». D. Jenkins, R. Ramadori, L. Cingolani. (Eds.), Perugia 1993; 55–68.

1752 **von Gunten, U., von Gunten, H.R., Hoigné, J.**: The Bromate Issue: Is Potassium-40 Really an Alternative Explanation for the Carcinogenicity of Potassium Bromate? Ozone News *21*, 20–21 (1993).

1753 **Pollingher, Utsa, Ambühl, H., Bürgi, H.-R.**: A New Method for Processing Clay-rich Unconsolidated Sediments for Paleoecological Investigations. J. Paleolimnology *7*, 95–101 (1992).

1754 **Pollingher, Utsa. Bürgi, H.-R., Ambühl, H.**: The Cysts of *Ceratium hirundinella*: Their Dynamics and Role within a Eutrophic (Lake Sempach, Switzerland). Aquatic Sciences *55*, 10–18 (1993).

1755 **Breedveld, M.W., Canter Cremers, H. C. J. C., Batlec, M., Posthumus, M. A., Zevenhuizen, L. P. T. M., Wijffelman, C. A., Zehnder, A. J. B.**: Polysaccharide synthesis in Relation to Nodulation Behavior of *Rhizobium leguminosarum*. J. Bacteriology *175*, 750–757 (1993).

1756 **van der Meer, J. R., Bosma, T. N. P., de Bruin, W. P., Harms, H., Holliger, C., Rijnaarts, H. H. M., Tros, Marijke E., Schraa, G., Zehnder, A. J. B.**: Versatility of Soil Column Experiments to Study Biodegradation of Halogenated Compounds Under Environmental Conditiones. Biodegradation *3*, 265–284 (1993).

1757 **Zehnder, A. J. B.**: How Long Will the Soil Feed Us?. In: «Integrated Soil and Sediment Research: a Basis for Proper Protection». H.J.P. Eijsackers, T. Hamers (Eds.) Kluwer Academic Publ., Dordrecht 1993; 755–756.

1758 **Zehnder, A. J. B.**: River Rhine: From Sewer to the Spring of Life. In: «Ciba Foundation Symposium 175». Wiley, New York 1993; 42–58.

1759 **Uetz, T., Egli, T.**: Characterization of an Inducible, Membrane-bound Iminodiacetate Dehydrogenase from *Chelatobacter heintzii* ATCC 29600. Biodegradation *3*, 423–434 (1993).

1760 **Ahel M., Giger. W.**: Aqueous Solubility of Alkylphenols and Alkylphenol Polyethoxylates. Chemosphere *26*, 1461–1470 (1993).

1761 **Ahel, M., Giger, W.**: Partitioning of Alkylphenols and Alkylphenol Polyethoxylates Between Water and Organic Solvents. Chemosphere *26*, 1471–1478 (1993).

1762 **Wehrli, B.**: Chemie am Seegrund. Vierteljahresschr. Naturforsch. Ges. Zürich *138*, 69–79 (1993).

1763 **Bundi, U.**: Grundsätze der Gewässerentwicklung – neue Ansätze im Gewässerschutzgesetz. VGL Umwelt-Information *2/93*, 3–9 (1993).

1764 **von Piechowski, M., Nauser, T., Hoigné, J., Bühler, R. E.**: O_2^- Decay Catalyzed by Cu^{2+} and Cu^+ Ions in Aqueous Solutions: A Pulse Radiolysis Study for Atmospheric Chemistry. Ber. Bunsenges. Phys. Chem. *97*, 762–771 (1993).

1765 **Bonting, C. F. C., Kortstee, G. J. J., Boecketein, A., Zehnder, A. J. B.**: The Elemental Composition Dynamic of Large Polyphosphate Granules in *Acinobacter* Strain 210A.. Arch. Microbiol. *159*, 428–434 (1993).

1766 **Bosshart, U., Ebneter, J., Freitag, A., Hungerbühler, E., Kutil, H., Mörgeli, B., Oschwald, R., Siegrist, H.R.**: Stickstoffentfernung aus dem Schlammwasser von Kläranlagen. Schriftenreihe Umwelt *195*, (1993).

1767 **Uehlinger, U., Meyer, Elisabeth**: Die Wirkung eines geschiebeführenden Hochwassers auf die benthische Biozönose in einem voralpinen Fluss. In: «DGL Deutsche Gesellschaft für Limnologie e.V. Jahrestagung 1992 in Konstanz» 1992; 407–411.

1768 **van der Maarel, M. J. E. C., Kohler, H.-P. E.**: Degradation of 2-*sec*-butylphenol: 3-*sec*-butylcatechol, 2-hydroxy-6-oxo-7-methylnona-2,4-dienoxic acid, and 2-methylbutyric acid as intermediates. Biodegradation *4*, 81–89 (1993).

1769 **Stumm W.**: Aquatic Colloids as Chemical Reactants: Surface Structure and Reactivity. Colloids & Surfaces A: Physicochem. Engineering Aspects *73*, 1–18 (1993).

1770 **Akeret B.**: Zur Biologie von *Chaoborus flavicans*, *Leptodora kintii* und *Bythotrephes longimanus* unter dem Einfluss interner Restaurierungsmassnahmen in drei Schweizer Seen. Diss. ETHZ Nr. 10137, 1993.

1771 **Ammann, M.**: Das durch Wasserkraftnutzung veränderte Abflussregime eines alpinen Fliessgewässers und dessen Auswirkungen auf das Makrobenthos. Diss. ETHZ Nr. 10106, 1993.

1772 **Höhener, P., Gächter, R.**: Prediction of Dissolved Inorganic Nitrogen (DIN) Concentrations in Deep, Seasonally Stratified Lakes Based on Rates of DIN Input and N Removal Processes. Aquatic Sciences *55*, 112–131 (1993).

1773 **Eberhard, J., Müller, Claudia, Stocker, D. W., Kerr, J. A.**: The Photo-Oxidation of Diethyl Ether in Smog Chamber Experiments Simulating Tropospheric Conditions: Product Studies and Proposed Mechanism. Int. J. Chem. Kinetics *25*, 639–649 (1993).

1774 **Deng, Yiwei, Stumm, W.**: Kinetics of Redox Cycling of Iron Coupled with Fulvic Acid. Aquatic Sciences *55*, 103–111 (1993).

1775 **Boller, M.**: Filter Mechanisms in Roughing Filters. J. Water SRT – Aqua *42*, 174–185 (1993).

1776 **Wieland, E., Santschi, P.H., Höhener, P., Sturm, M.**: Scavenging of Chernobyl ^{137}Cs and Natural ^{210}Pb in Lake Sempach, Switzerland. Geochim. Cosmochim. Acta *57*, 2959–2979 (1993).

1777 **Pahl-Wostl, Claudia**: Food Webs and Ecological Networks Across Temporal and Spatial Scales. Oikos *66*, 415–432 (1993).

1778 **Jaeger, C., Dürrenberger, G., Kastenholz, H., Truffer, B.**: Determinants of Environmental Action with Regard to Climatic Change. Climatic Change *23*, 193–211 (1993).

1779 **Livingstone, D. M., Imboden, D. M.**: The Non-Linear Influence of Wind-Speed Variability on Gas Transfer in Lakes. Tellus *45B*, 275–295 (1993).

1780 **Pahl-Wostl, Claudia**: The Influence of a Hierarchy in Time Scales on the Dynamics of, and the Coexistence within, Ensembles of Predator-Prey Pair. Theor. Population Biology *43*, 184–216 (1993).

1781 **Jaeger, C.**: Sustainable Regional Development: A Path for the Greenhouse Marathon. In: «Advances in Human Ecology». Vol.2. Jai Press Inc., 1993; 163–190.

1782 **Uehlinger, U.**: Primary Production and Respiration in the Outlet of an Eutrophic Lake (River Glatt, Switzerland). Arch. Hydrobiol. *128*, 39–55 (1993).

1783 **Faber, F., Egli, T., Harder, W.**: Transient Repression of the Synthesis of OmpF and Aspartate Transcarbamoylase in *Escherichia coli* K12 as a Response to Pollutant Stress. FEMS Microbiol. Lett. *111*, 189–196 (1993).

1784 **Huggenberger, P.**: Kleinwasserkraftwerke für die Umwelt. Tages-Anzeiger 22.9. 1993, S. 84.

1785 **Bundi, U.**: Umweltprobleme mit Stickstoff. Neue Zürcher Zeitung Nr. 231, 5.10. 1993, S. 23.

1786 **Peeters, F., Wüest, A., Imboden D.M.**: Comparison of the Results of Tracer Experiments in Lakes with Predictions Base on Horizontal Mixing Models. Verh. Internat. Verein. Limnol. *25*, 69–74 (1993).

1787 **Livingstone, D. M.**: Temporal Structure in the Deep-Water Temperature of Four Swiss Lakes: A Short-Term Climatic Change Indicator? Verh. Internat. Verein. Limnol. *25*, 75–81 (1993).

1788 **Bürgi, H. R., Elser, J. J., Richards, R. C., Goldman, C. R.**: Zooplankton Patchiness in Lake Tahoe and Castel Lake USA. Verh. Internat. Verein. Limnol. *25*, 378–382 (1993).

1789 **Akeret, B.**: Lunar Periodicity of the Emergence of *Chaoborus flavicans*. Verh. Internat. Verein. Limnol. *25*, 625–626 (1993).

1790 **Hajdas-Skowronek, Irena**: Extension of the Radiocarbon Calibration Curve by AMS Dating of Laminated Sediments of Lake Soppensee and Lake Holzmaar. Diss. ETHZ Nr. 10157, 1993.

1791 **Kappeler, J., Gujer, W.**: Influence of Operating Problems in Wastewater Treatment Plants on the Interactions Between Sewers, Treatment Plant and Receiving Water. Water Sci. Technol. *27*, 199–203 (1993).

1792 **Boller, M. A., Eugster, J.**: Upflow Anaerobic Filtration of a Sugar Containing Wastewater. Water Sci. Technol. *28*, 125–134 (1993).

1793 **Holliger, C., Pierik, A. J., Reijerse, E. J., Hagen, W. R.**: A Spectroelectrochemical Study of Factor F_{430} Nickel(II/I) from Methanogenic Bacteria in Aqueous Solution. J. Am. Chem. Soc. *115*, 5651–5656 (1993).

1794 **Holliger, C., Schraa, G., Stams, A. J. M., Zehnder, A. J. B.**: A Highly Purified Enrichment Culture Couples the Reductive Dechlorination of Tetrachloroethene to Growth. Appl. Environ. Microbiol. *59*, 2991–2997 (1993).

1795 **van Cappellen, P., Charlet, L., Stumm, W., Wersin, P.**: A Surface Complexation Model of the Carbonate Mineral-Aqueous Solution Interface. Geochim. Cosmochim. Acta *57*, 3505–3518 (1993).

1796 **Huggenberger, P., Meier, E.**: Anwendung des Georadars in der Hydrogeologie. Wasser Energie Luft *85*, 119–123 (1993).

1797 **Hoigné, J., Bader, H.**: Kinetics of Reactions of Chlorine Dioxide (OClO) in Water – I: Rate Constants for Inorganic and Organic Compounds. Water Res. *28*, 45–55 (1993).

1798 **Tratnyek, P. G., Hoigné, J.**: Kinetics of Reactions of Clorine Dioxide (OClO) in Water – II. Quantitative Structure-Activity Relationships for Phenolic Compounds. Water Res. *28*, 57–66 (1993).

1799 **Mason, C. A., Egli, T.**: Dynamics of Microbial Growth in the Decelerating and Stationary Phase of Batch Culture. In: «Starvation in Bacteria». Staffan Kjelleberg, (Ed.) Plenum Press, New York 1993; 81–102.

1800 **David, M.**: Estimation of the Yields of Tropospheric Degradation Products of Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs). EAWAG, Dübendorf, 1993. 31 pp.

1801 **van Veen, H. W., Abee, T., Kortstee, G. J. J., Konings, W. N., Zehnder, A. J. B.**: Mechanism and Energetics of the Secondary Phosphate Transport System of *Acinetobacter johnsonii* 210A. J. Biol. Chem. *268*, 19377–19383 (1993).

1802 **Breedveld, M. W., Zevenhuizen, L. P. T. M., Cremers, H. C. J. C., Zehnder, A. J. B.**: Influence of Growth Conditions on Production of Capsular and Extracellular Polysaccha-

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rides by Thizobium leguminosarum. Antonie van Leeuwenhoek *64*, 1–8 (1993).

1803 **Bonting, C. F. C., Kortstee, G. J. J., Zehnder, A. J. B.**: Properties of Polyphosphatase of *Acinetobacter johnsonii* 210A. Antonie van Leeuwenhoek *64*, 75–81 (1993).

1804 **Rijnaarts, H.H.M., Norde W, Bouwer., E.J., Lyklema., J., Zehnder, A.J.B.**: Bacterial Adhesion under Static and Dynamic Conditions. Appl. Environ. Microbiol. *59*, 3255–3265 (1993).

1805 **Lotter, A. F., Birks, H. J. B.**: The Impact of the Laacher See Tephra on Terrestrial and Aquatic Ecosystems in the Black Forest, Southern Germany. J. Quaternary Sci. *8*, 263–276 (1993).

1806 **von Gunten, U., Zobrist, J.**: Biogeochemical Changes in Groundwater-Infiltration Systems: Column Studies. Geochim. Cosmochim. Acta *57*, 3895–3906 (1993).

1807 **Sedlak, D. L., Hoigné, J.**: The Role of Copper and Oxalate in the Redox Cycling of Iron in Atmospheric Waters. Atmospheric Environment *27A*, 2173–2185 (1993).

1808 **Kuhn, Annette, Sigg, Laura**: Arsenic Cycling in Eutrophic Lake Greifen, Switzerland: Influence of Seasonal Redox Processes. Limnol. Oceanogr. *38*, 1052–1059 (1993).

1809 **Hart, K. M., McDow, St. R., Giger, W., Steiner, D., Burtscher, H.**: The Correlation Between In-Situ, Real-Time Aerosol Photoemission Intensity and Particulate Polycyclic Aromatic Hydrocarbon Concentration in Combustion Aerosols. Water Air & Soil Poll. *68*, 75–90 (1993).

1810 **Hart, K.M., Tremp, J., Molnar, Eva, Giger, W.**: The Occurrence and the Fate of Organic Pollutants in the Atmosphere. Water Air & Soil Poll. *68*, 91–112 (1993).

1811 **Tremp, J., Mattrel, P., Fingler, S., Giger, W.**: Phenols and Nitrophenols as Tropospheric Pollutants : Emissions from Automobile Exhausts and Phase Transfer in the Atmosphere. Water Air & Soil Poll. *68*, 113–123 (1993).

1812 **Raab, D., Stumm, W.**: Effect of Acid Deposition on the Displacement of Al(III) in Soils. Water Air & Soil Poll. *68*, 199–212 (1993).

1813 **Ochs, M., Brunner, I., Stumm, W., Cosovič, Bozena**: Effects of Root Exudates and Humic Substances on Weathering Kinetics. Water Air & Soil Poll. *68*, 213–229 (1993).

1814 **Zobrist, J., Wersin, P., Jaques, C., Sigg, Laura, Stumm, W.**: Dry Deposition Measurements Using Water as a Receptor : A Chemical Approach. Water Air & Soil Poll. *71*, 111–130 (1993).

1815 **Dönni, W.**: Verteilungsdynamik der Fische in einer Staustufe des Hochrheins mit besonderer Berücksichtigung der Ökologie des Aals (*Anguilla anguilla* L.). Diss. ETHZ Nr. 10287, Zürich 1993.

1816 **Zeh, M.**: Reproduktion und Bewegungen einiger ausgewählter Fischarten in einer Staustufe des Hochrheins. Diss. Nr. 10288, Zürich 1993.

1817 **Siegenthaler, C., Huggenberger, P.**: Pleistocene Rhine Graval: Deposits of a Braided River System with Dominant Pool Preservation. In: «Braided Rivers», J.L. Best, C.S. Bristow (Eds.). Geol. Soc. Special Publ. 75, London 1993, pp. 147–162.

1818 **Huggenberger, P.**: Radar Facies: Recognition of Facies Patterns and Heterogeneities Within Pleistocene Rhine Gravels, NE Switzerland. In: «Braided Rivers», J.L. Best, C.S. Bristow, C.S. (Eds.). Geol. Soc., Special Publ. 75, London 1993, pp. 163–176.

1819 **Deng, Y., Stumm, W.**: Reactivity of Aquatic Iron(III) Oxyhydroxides – Implications for Redox Cycling of Iron in Natural Waters. Appl. Geochemistry *9*, 23–26 (1994).

1820 **Boller, M.**: Die Grundprinzipien der Filtration. Italienisch-Französisch-Schweizerische Fachtagung Turin, 9.–11.9.1993. Centro Congressi Unione Industriale, Torino 1993, S. 19–44.

1821 **Cirpka, O., Reichert, P., Wanner, O., Müller, S.R., Schwarzenbach, R.P.**: Gas Exchange at River Cascades: Field Experiments and Model Calculations. Environ. Sci. & Technol. *27*, 2086–2097 (1993).

1822 **Jenal-Wanner, U., Egli, T.**: Anaerobic Degradation of Nitrilotriacetate (NTA) in a Denitrifying Bacterium: Purification and Characterization of the NTA Dehydrogenase-Nitrite Reductase Enzyme Complex. Appl. Environ. Microbiol. *59*, 3350–3359 (1993).

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