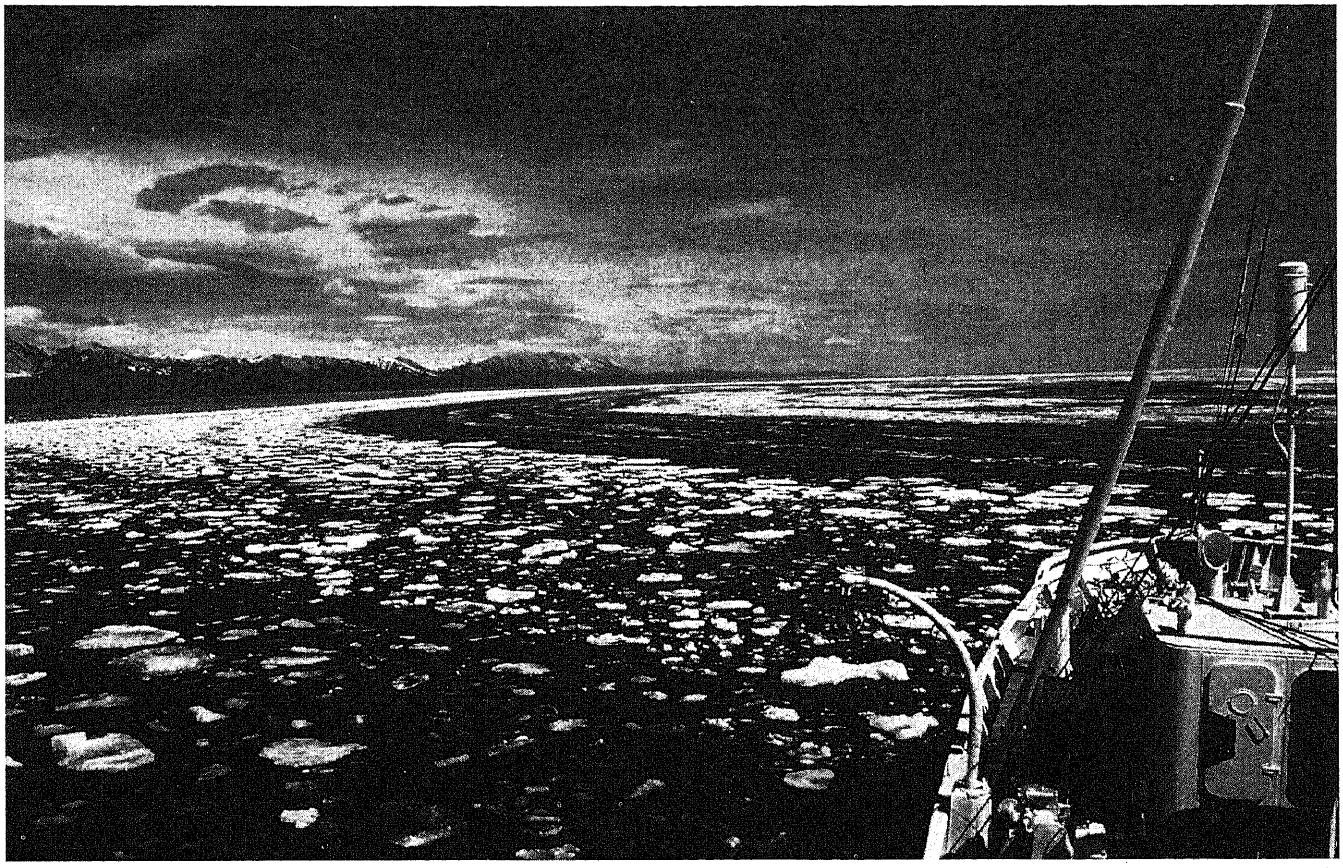
EAWAG

EAWAG NEWS

45 E November 1998

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



Doctoral Research with an Eye to the Future

Graduate students at EAWAG perform the bulk of the scientific work. We are intensively involved in nearly all projects and, therefore, are well represented among the authors to the EAWAG news. Our work covers a wide spectrum of topics – from exploring options for the efficient disposal of toxic chemicals to defining sociological conditions for car-sharing; from analyzing signs of global climate change to monitoring the sedimentation of small lakes.

In doing so, we constantly increase our scientific, technical and social knowledge. On a daily basis, this means late nights puzzling over experiments and coping with inevitable setbacks. It is hard work which aims at a better understanding of humankind's role in and relationship to the environment – nothing less than that.

Our work is both fascinating and urgent. As diverse as the various projects may be, they are all linked by the same future-oriented question: how can we utilize available resources without causing long-term damage to the planet and, at the same time, enhance our quality of life? It is seemingly impossible to find a solution to this quandry, but increasing knowledge of processes in nature and their consequences for technological and social improvements can bring at least a partial solution. We have the privilege to pursue these goals at EAWAG, where an excellent infrastructure is at our disposal. It is comprised of real people, of course, whom we want to thank for their efforts and support – from the technical personnel to the administration, from guest lecturers to the taxpayers.

It should be mentioned, however, that working towards a doctoral degree consists not only of fascinating research; it also has its misfortunes. Apart from being underpaid for several years, one also has to worry about an uncertain future. Graduate students comprise an inexpensive, highly motivated work force which can achieve high productivity; however, exhausting use of this resource has led to dissatisfaction in the graduate student population which, in turn, impairs productivity. Additionally, it has led to a high number of job-hunting graduates. When you, dear reader, just discuss our projects, you create the support for scientific work that will be needed in the future.

With the sight aiming high and forward – Doctoral students at EAWAG.

We have high ambitions for using the experience from our projects at the EAWAG. Each time a graduate student finishes, we not only celebrate the process of achieving another level of maturity, but also eagerly look towards the future.

With kind regards

for the graduate students at EAWAG
Heinrich Eisenmann

EAWAG

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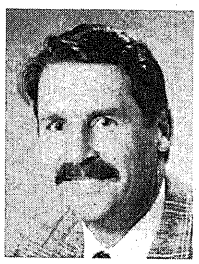
Cover
Lake Baikal is part of a large and very old continental fault zone which was reactivated about 30 million years ago when continental movements linked to the uplift of the Himalayas became more active. Snow-covered mountains (3000 m) surround the lake, and their slopes continue to drop steeply below the water level, to a maximum depth of over 1600 m (see article by Rolf Kipfer).
The lake is situated in the heart of Siberia and regularly freezes over around the end of December; it thaws again some time in May (time when picture was taken). The time of freezing and thawing has been recorded since the early 19th Century. New investigations by UP/EAWAG (David M. Livingstone) indicate that freezing occurs later and later each year. The melting of the ice correlates well with circulation conditions over the North Atlantic (NAO-index) and reflects the meteorological conditions on the northern half of the globe.

Susanne Kytzia and Peter Baccini

Resource Management: Living Space as an Example

Susanne Kytzia



Peter Baccini

In order to translate visions for sustainable development into realistically applicable strategies, we have to better understand how anthropogenic systems function. Economic theories can make an important contribution to interdisciplinary research. To this end, we would like to present an approach that combines descriptions of both physiological and economic processes on the basis of an analysis of the flow of materials.

Human Activities as a Starting Point for the Analysis

The analysis method chosen in this case (substance flow analysis [1, 2]) is based on the hypothesis that human needs can be described in terms of four main activities without regard to cultural level and living standard: (1) to nourish, (2) to clean, (3) to transport and to communicate, and (4) to reside and to work.

The activity area *"to reside"* accounts for a significant portion of resource use in Middle Europe today. It is responsible for one third of the energy use [3] and one third of the annual turnover of goods [4] of a given economy. In densely populated areas of the Swiss Midlands, for example, roughly 40% of the land is reserved for housing [5]. The schematic diagram in Fig. 2 depicts the most important processes and dominant flow paths for goods in the system *to reside*. It may be characterized by the following properties [2]:

- *Residential buildings are significant reservoirs of materials in private households*

In the Swiss Midlands, 100 tons of building material per person are tied up in residential buildings. This is approximately 98% of all the stored materials in private households.

- *The building stock grows and is renewed at a slow rate*

The material reservoir in residential buildings grows at an annual rate of 1%. Another 1% is replaced annually through renovations and demolitions. The theoretical residence time of building materials in the residential building pool is, therefore, approximately 100 years.

- A *significant portion of energy use can be attributed to building operations*

The energy used during operation of a building (heat, lights, etc.) is ten times the amount of energy used during construction.

Which Players Define the Materials Flow System?

Key processes of the materials and energy balance in the area of *housing* are building operation and construction. The economic analysis focuses

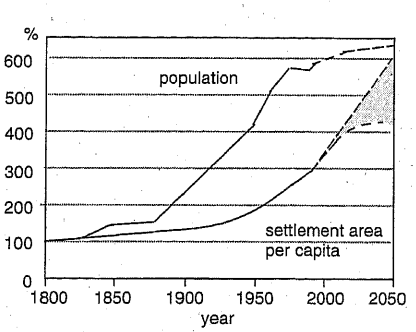


Fig. 1
The average land use per capita increases at a greater rate than the population. The dashed lines represents two extreme scenarios of land use.

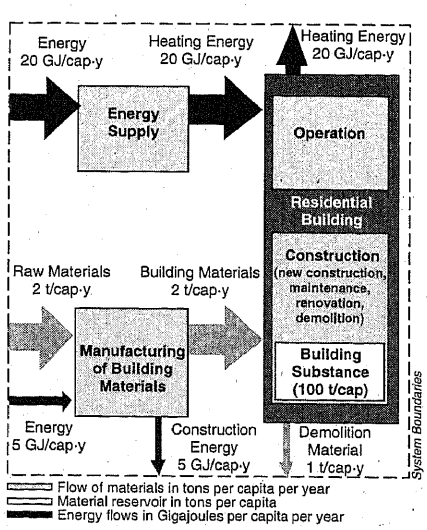


Fig. 2
Analysis of material and energy fluxes within the activity area "living" in the case of the City of Olten (reference year 1990). See detailed description in [8].

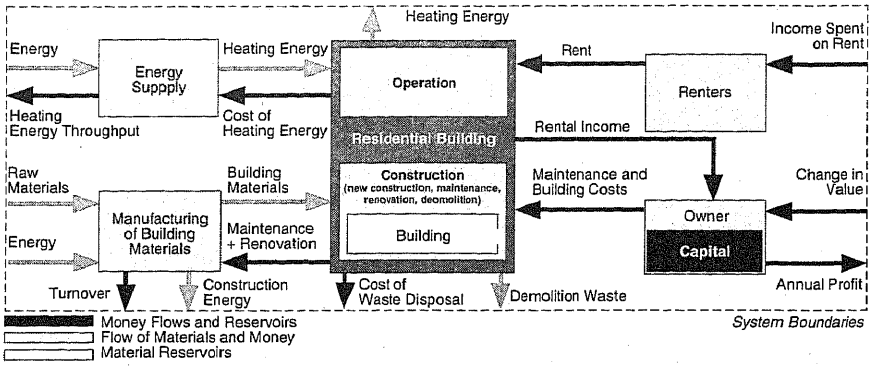


Fig. 3
Extension of the system analysis – introduced are money fluxes related to energy and material costs, namely heating costs, the cost of building maintenance and new construction as well as waste disposal. Money fluxes unrelated to flows of energy or materrial are represented by rental income, changes in value and annual yield on the capital invested.

on the players that control these two processes: the *owners* of residential buildings and the *renters* of the living space [6].

From Material Flow Analysis to "Money Flow Analysis"

In order to describe the behavior of the major players in economic terms, money flows and reservoirs have to be added to the system (see Fig. 3). As a first step, we include money fluxes which are directly related to material and energy fluxes; namely, money transfers between the players in the exchange for materials and energy.

In a second step, reservoirs of materials are assigned an economic value. The current market value is a possible basis for evaluation. It reflects the expected profit from the future use of the materials and depends on its function as well as its expected resale value. The resale value includes the value of the materials themselves as well as the value for the land they occupy.

A third step incorporates those money fluxes which are not directly related to energy or material fluxes. We need to differentiate between changes in value and realization of the value. The value of a residential building, for example, will change over time as a consequence of aging building materials as well as land becoming more valuable (relative to other commodities). The value of a residential building can be realized through the use of the building as living space. Rent compensates for use of the building, while owners also expect a return on their investment through interest payments.

Economic Phenomenology of Residential Buildings

Money fluxes were estimated for the city of Olten based on data from the population and building census conducted in 1990, standard values from the literature, and expert interviews (Fig. 4). Results reveal the following properties of the system:

- *Residential buildings represent a significant portion of capital in the economy*

In the City of Olten, approximately Sfr. 120 000 per person are tied up as capital in residential buildings. One third of that value is the value of the land the building occupies; two thirds is the value of the building itself.

- *The costs of capital exceeds maintenance and construction costs*

Despite the fact that 50% of the rental income is used to recover the capital investment, owners on average realize an annual yield of only about 3%.

- *Energy costs are primarily borne by renters*

The dominant role of *building operation* in the generation of energy costs in the *housing* system is a consequence of the user structure in energy consumption. Building operation accounts for roughly 50% of the annual expenses related to residential buildings which are not related to the capital investment itself.

A few additional assumptions enable us to interpret the described properties of the materials, energy and capital balance with respect to possible management strategies. The following examples shall illustrate this procedure.

Example: Increasing Energy Cost

What effect does an increase in energy prices, introduced as a targeted eco-political measure, have on energy consumption in the area of *housing*? In order to answer this question, we have to make five additional assumptions regarding system behavior [7, 8].

- The increase in energy prices is payed by renters.
- Renters can save up to a maximum of 30% of energy consumption through behavior modification.
- Changes in living space demand will not be felt for an additional two years due to high adaptation costs (search costs, etc.).
- Modernization of residential buildings can reduce energy consumption

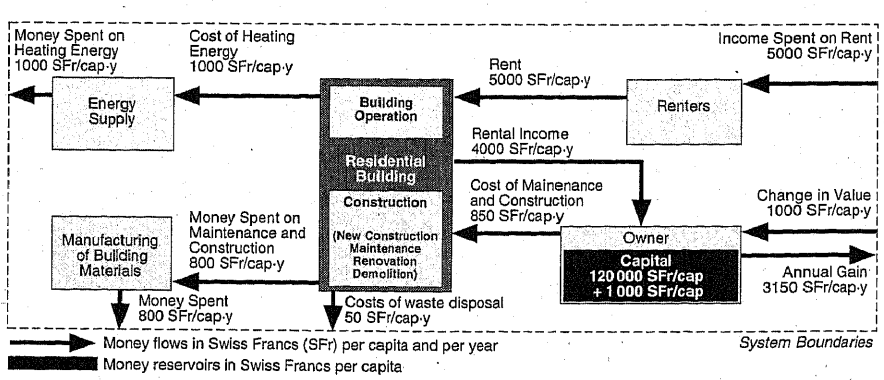


Fig. 4
Money flux in the system "to reside" in the example of the City of Olten (for 1990) assuming no new construction; detailed description in [8].

by 60% (renovation) to 85% (building replacement).

- An increase in empty rental property reduces investment activity in new construction.

Based on the above assumptions and general system properties, we can formulate the following hypotheses on the effects of energy price increases:

> *The steering measure affects primarily renters through increased heating costs.*
> *Options for adaption and changes on the renter's part are limited in the short term.*
> *The effect of the targeted price increase is significantly dampened because of the inertia of the system.*

Demand for more energy-efficient living space increases only over an extended period of time. The low rate of renovation and replacement causes the demand to be met only partially. Renters have to move to smaller apartments, the proportion of unrented space increases. As investment activity decreases, the adaptation process slows down further.

An increase in energy prices should, therefore, be accompanied by measures which can significantly accelerate the adaptation process of the system *"to reside"*. Leverage points are residential building policies and urban planning.

Example: Renovation of Residential Structures

What are the economic impacts of an accelerated rate of renovation of residential buildings on building owners and renters? To answer this question, we compare a hypothetical renovation scenario for the next 50 years with a reference scenario ("continuing on current course", see Table 1). We need to make the following additional assumptions regarding system behavior [7, 8]:

- Building value and energy consumption for heating depend on the rates of renovation, replacement and maintenance of residential buildings.
- Land values increase by 2% annually.
- The population and rental income remain constant.
- All other variables in the materials, energy and money flux system depend linearly on the rates of change in the building stock.

Results from calculations based on the above scenario [8] lead to the following hypothesis:

> *In the long-term, it is economically advantageous for both building owners and renters to follow the scenario "accelerated renovation" instead of initiating new construction.*

The steady growth of building mass sketched in the reference scenario leads to increasing maintenance costs. This affects the cost of building maintenance and capital costs as well as energy costs for heating. "Zero growth", in the case of the renovation scenario, stops this cost development (Fig. 5) and frees up additional resources for the renovation of existing buildings.

Building Category	Reference (in% of the material pool of the previous year)	Renovation (in% of the material pool of the previous year)
New Construction	1.0	–
Renovation	0.3	0.3
Replacement	0.5	1.4
Maintenance	1.0	1.0

Tab. 1
Assumptions in the annual building renewal rates for the two scenarios "continuing at current rates" and "renovation".

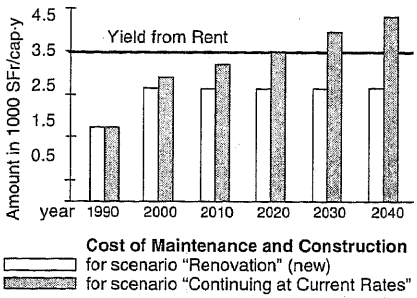


Fig. 5
Effects of the two scenarios "continuing at current rates" and "renovation" on rental income and maintenance and construction costs [6, 8].

Development of an Economic-Ecological Model

The example *living space* demonstrates that the integration of economic data into a material and energy flow system can expose new insights on the functioning of anthropogenic systems. In contrast to approaches typically used by economists who analyze individual markets, the approach presented here proposes to analyze the complete system and considers the major players and interactions between them. In addition to information on material fluxes, this approach yields information on effect parameters which are not directly related to material or energy fluxes (such as the cost of capital investments). This approach uses a standard "language" (system description in terms of material flow analysis) to describe anthropogenic systems and can be used for qualitative as well as quantitative analyses.

The development of this approach still is in its infancy. In the next phase, economic descriptions of activities such as to clean, to transport and to communicate, and to nourish, and to work will be developed. Information on the economic aspects of the regional materials balance provides the basis for improved enonomic-ecological models.

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Rolf Kipfer, Roland Hohmann, Frank Peeters,
Michael Sturm and Dieter M. Imboden

Lake Baikal:

Basic Research as the Nucleus of Environmental Responsibility?

Why carry out research on Lake Baikal located 7000 km away from Switzerland? The commitment of the Environmental Physics Department of EAWAG and ETH, initiated in 1992, has little to do with exotic places or an urge to travel; responsibility and courage are more appropriate motivations for the work. The responsibility of preserving a unique ecosystem under UNESCO protection and the courage to transfer knowledge, under adverse circumstance, to where it is needed are our priorities.

The Importance of Lake Baikal

Lake Baikal is the *largest* body of freshwater on Earth, although this statement does not adequately reflect its surprising dimensions (Fig. 1). Lake Baikal in Eastern Siberia extends from 51° N/104° E to 56° N/110° E, with a length of 700 km and covers an area of ⅔ of Switzerland. Having a volume of 23 000 km³, Lake Baikal contains over 20% of the available surface freshwater of the Earth, more than all of the North American Great Lakes combined.

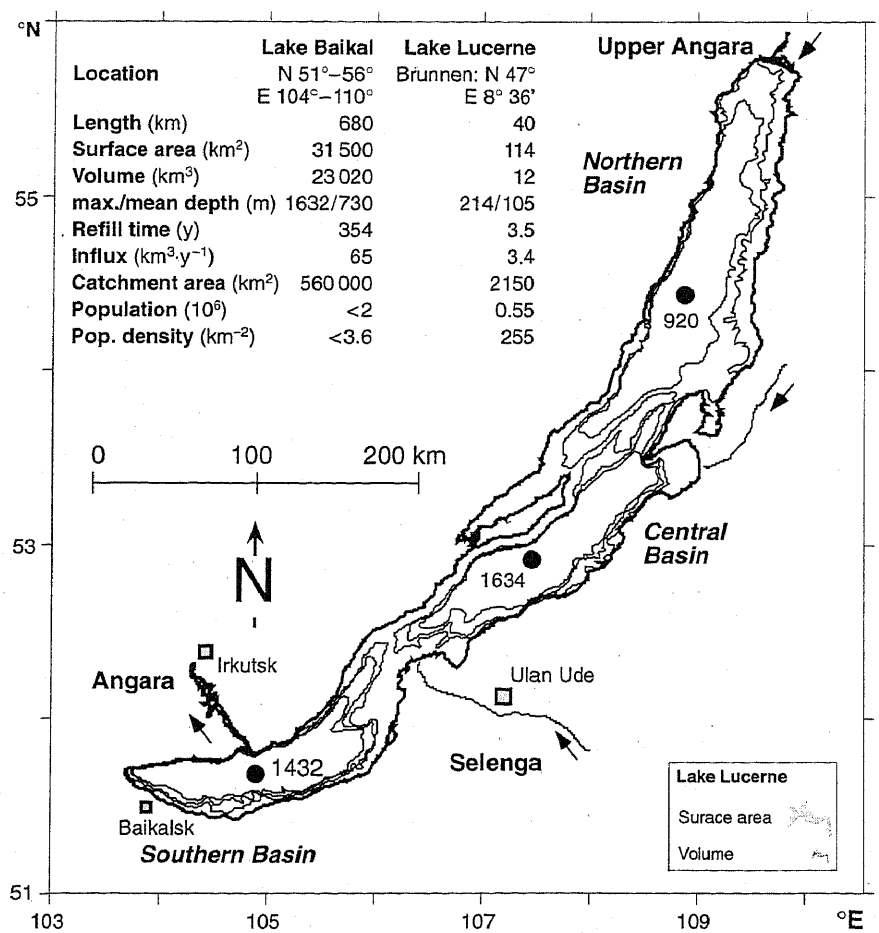


Fig. 1
Over 2500 endemic species live in Lake Baikal, the world's largest limnetic ecosystem. Its surface area is ca. 280 times and its volume 1920 times larger than that of Lake of Lucerne (LL), a typical alpine lake on the Swiss Plateau. These numbers stress the global importance of Lake Baikal representing the largest, liquid freshwater resource on Earth.

Lake Baikal is not only the largest lake on the planet, but with a depth of over 1600 m, it is also the *deepest*. And at an age of over 20 million years, it is by far the *oldest* body of freshwater on Earth. Together with the large East African lakes, Lake Baikal belongs to a special class of tectonically-formed rift lakes, in which the subsidence of the basins are closely linked to movements along large continental fault zones. Topographical rises with large shallow water zones (depth <300 m) subdivide Lake Baikal into northern (920 m), middle (1630 m) and southern basins (1430 m), whose deep water zones are regarded as limnologically and dynamically independent units. Its origin as a rift lake explains its extraordinary age. Lake Baikal contains sediments over 7 km thick, a unique environmental archive having recorded climatic changes in the center core of the Asian continent since the early Miocene.

Called "the pearl of Siberia" in Russian, the lake has developed a unique flora and fauna. To date, the lake hosts over *2500 endemic species*, i.e., only existing there, which makes it the

Earth's *limnetic ecosystem with the most species*. In contrast to media headlines, the lake is still in a near-natural condition, and direct anthropogenic influences are very marginal. Fewer than 2 million people live in the large catchment area of Lake Baikal, and only about one fourth of these live directly on the lake. The population density is within the range of that in desert areas (<3.5 people/km^2); correspondingly, the *water quality is excellent* and the water can be used for drinking without treatment.

Although cellulose factories near Baikalsk discharge untreated wastewater into the southern basin and locally pollute Lake Baikal, this "point source" pollution only minimally impacts a lake of this enormous size. Signs of diffuse changes in the lake are observed: among others, nutrient levels seem to increase. As these slow subtle changes involve the lake as a whole, they may possibly be of environmental importance. Because of its worldwide importance as a unique limnetic ecosystem, Lake Baikal was added to UNESCO's list of *"world heritage sites"* in December 1996 and has thereby been deemed worthy of protection by the international community.

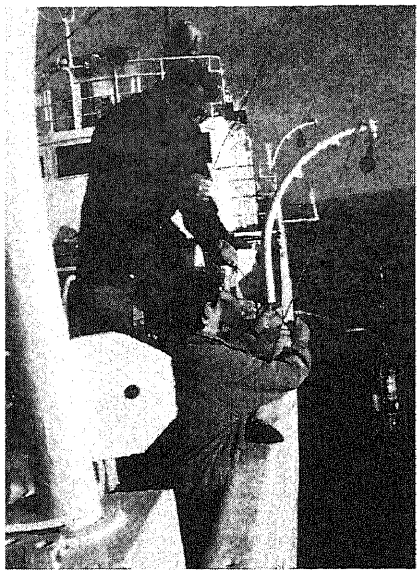
Switzerland and BICER (Baikal International Center of Ecological Research)

The research initiative *BICER* is attempting to live up to this responsibility on an international level and is demanding measures to *Lake Baikal* on a broad basis. Dr. Michail Grachev, head of the Limnological Institute in Irkutsk and leading BICER director, recognized the signs of change in 1988 and took the initiative to found *BICER as an international research center*. Thanks to the scientific collaboration with foreign partners, the Limnological Institute is able to continue high level research as almost the only research institute on Lake Baikal. In spite of the many social and political changes in Russia, BICER realizes the environmental responsibility resulting from the uniqueness of the lake. Switzerland, represented by the Department of Environmental Physics of EAWAG and ETH, joined BICER in 1992 as the sixth and latest member in order to contribute its hydrophysical and multidisciplinary expertise in describing lakes as integral systems. Russia, Belgium, Great Britain, Japan and the University of South Carolina (USA) are all founding members of BICER.

Swiss Research Focused on Lake Baikal

Swiss research has been concentrating on the exchange and transport of water and substances in Lake Baikal, primarily focusing on the *formation of deep water* and *recent sedimentation*. For the first time, the mixing processes which replace annually over 10% of the deep water by surface water have been described in detail (Fig. 2) [1, 2, 3]. This immense renewal rate explains why the water column of Lake Baikal is almost saturated with oxygen to its greatest depth (Fig. 2), a condition which is far from realized in many Swiss lakes, in spite of all environmental protection efforts.

Like alpine lakes, Lake Baikal is a "cold" lake, in which the temperatures of the deep water are constantly around 4 °C, i.e. the temperature at which freshwater reaches its greatest density at atmospheric pressure (T[ρ_{max}]). In such "cold" water bodies, the density of the water column depends on both the distribution of the temperature and on the amount of ions dissolved in the water. This statement, surprising at first glance for a freshwater system like Lake Baikal (~100 mg dissolved ions per liter), can be explained by the fact that the changes in density ($\Delta\rho$) resulting from the slight variations in temperature (ΔT <0.3 °C) in the deep waters are extremely small as the gradient $\Delta\rho/\Delta T$ disappears at 4 °C. Adding ions to such a body of water changes the density by more than what even relatively large temperature fluctuations would cause. The density structure of the water column is mainly determined by the ion gradient. In Lake Baikal, the calculation of the water's density is additionally complicated by the fact that T(ρ_{max}) is a function of the hydrostatic pressure and decreases strongly with increasing depth [4].



Rolf Kipfer (left) on an expedition on Lake Baikal (winter 1995).

Our investigations suggest that *dissolved ions play a central role in renewing the deep water* of Lake Baikal. The relevant differences in ion concentrations are distributed over a water depth of more than 1000 m and are extraordinarily low (0.5 mg/kg, Fig. 2). In spite of this, they determine the transport of surface water to a depth of 400 m, whereas at greater depths, temperature gradients mainly control the exchange of water (Fig. 2, 3) [4, 5, 6]. The data suggest, however, that the inflowing rivers discharge more ions to the deep water than the lake loses via its outflow. Although these changes are extremely small, the slowly rising ion content could disturb the mixing dynamics and oxygen transport into the deep water which could consequently threaten the entire ecosystem (Table 1).

In spite of its generally excellent condition, signs of subtle changes can be detected in Lake Baikal. A few diatoms adapted to nutrient-rich rivers have been slowly encroaching from the delta regions into the open water.

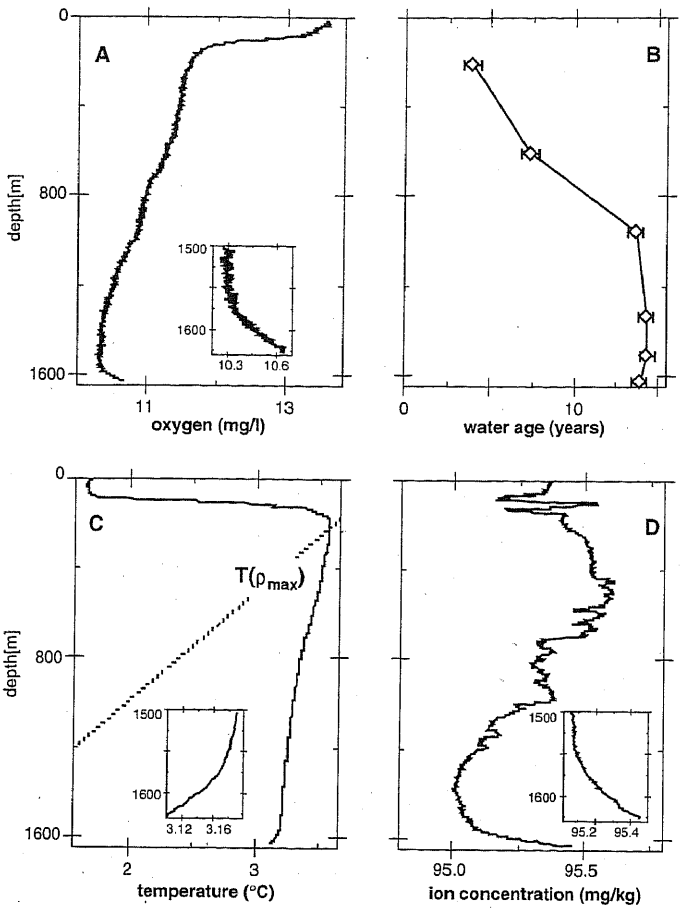


Fig. 2
Deep water exchange

A: Lake Baikal exhibits high oxygen levels throughout its entire water column; throughout the water column oxygen concentrations exceed more than 80% of the equilibrium concentration at the surface (A). Small insert: the oxygen concentration ($[O_2]$) even rises just above the lake bottom, as it does in the oceans but in sharp contrast to Swiss lakes.

B: In the bottom water water age (WA, a measure of the time elapsed since the water was in last contact with the atmosphere) decreases. High $[O_2]$ and low WA at the bottom water indicate that the lower most deep water rapidly replaced by surface water (saturated with O_2, WA ≈ 0) being transported advectively along the sides.

C/D: Every process that renews deep water leaves characteristic traces in the distribution of temperature and ions in the water column. The young and oxygen-rich bottom water of the central basin of Lake Baikal is colder (C) and contains more particles and ions (D) than the water above.

Water with similar properties can be found in an underwater canyon where the Selenga leaves its delta. In spring the water found in the canyon water which respresents a mixture of riverine and lake water is colder and enriched in particles and ions compared to pure water. Therefore it has a distinctly greater density and sinks along the canyon's topography into larger depths where it spreads out to the deepest regions of the central basin.

The invading algae are an indicator of the locally increasing availability of nutrients. Increased nutrient levels and the suspected disequilibrium of salts in Lake Baikal could be interpreted as being an expression of the rising pressure of human civilization around the lake. Thus, the intensified urbanization through the use of the rivers for agriculture could intensify soil erosion in the catchment area and negatively influence the nutrient and salt budgets of Lake Baikal. As the water residence time, i.e., the time it takes the inflowing rivers to replace the water mass of Lake Baikal completely, is approximately 350 years, this type of disturbance is difficult to detect, but it does remain in the system for centuries. This means that changes taking place in the lake are may be regarded as irreversible in regards to the relevant times scales of human societies.

In order to quantify the subtle changes taking place in Lake Baikal and to critically assess their possible impacts, BICER has decided to direct its future research activities towards the over 330 tributaries and catchment area of Lake Baikal to study their influence on internal mixing dynamics. As a first step, *ion and nutrient loads of the three main tributaries* will be determined in detail in order to calculate the corresponding mass balances for Lake Baikal.

A Look at the Future of Research on Lake Baikal

"Purely" scientific projects on Lake Baikal still have a good chance of receiving support from national and international agencies. These funds, however, cannot be used for the infra-

Processes of deep water renewal	effects on temperature	ion content
river inlets	–	+
hydrothermal activity	+	+
thermohaline fronts	+, –	+
exchange between basins	–	0, –
total	**"zero?"**	**+**

Table 1
The processes that have been proven to renew deep water of Lake Baikal as well as their effects on the distribution of temperature and ions are summarized: some processes warm the deep water, others cool it so that the overall effect becomes compensated and, thereforethe average energy content of the lake does not change. This agrees with long term measurements of temperature which suggest that the deep water temperature remains constant over.

In contrast, all known mixing processes seem to add ions to the deep water and hence to increase the mineralization ofthe lakewater. This means that either mixing processes which supply freshwater to the deep water or other "ion sinks" have remained undetected until now. Alternatively, the ion content of the deep water is expected to increase but continuously. If the second interpretation is correct, the presumed mineralization increase could change the long term mixing dynamics of the water columns salinity gradients contribute significantly to deep water formation of Lake.

structure needed to conduct the research, (e.g., transportation, analytical equipment), as the funds are normally targeted for the research itself – and not to maintain Russian infrastructure. During the last 6 years, the infrastructure, which is absolutely vital for research, could be financed with BICER money. As these sources of support will soon run out, the maintenance of the basic infrastructure needed to conduct a high level of research will become more difficult to sustain. This development may already temporarily *hinder all research on Lake Baikal*, if not prevent it altogether.

Thus, means and ways have to be found to *maintain the infrastructure of the Russian institutes on Lake Baikal.* This new "type" of support should orientate itself less towards fundamental research and more towards the structural necessities of Russian research.

Insight and critical knowledge always give rise to responsibility. EAWAG, the ETH and, therefore, also Switzerland have accepted the responsibility of preserving this *"world heritage site"* in its entirety and to conserve its unique flora and fauna for future generations. This is becoming ever more urgent as the anthropogenic pressures on the remaining intact ecosystems will likely increase in future.

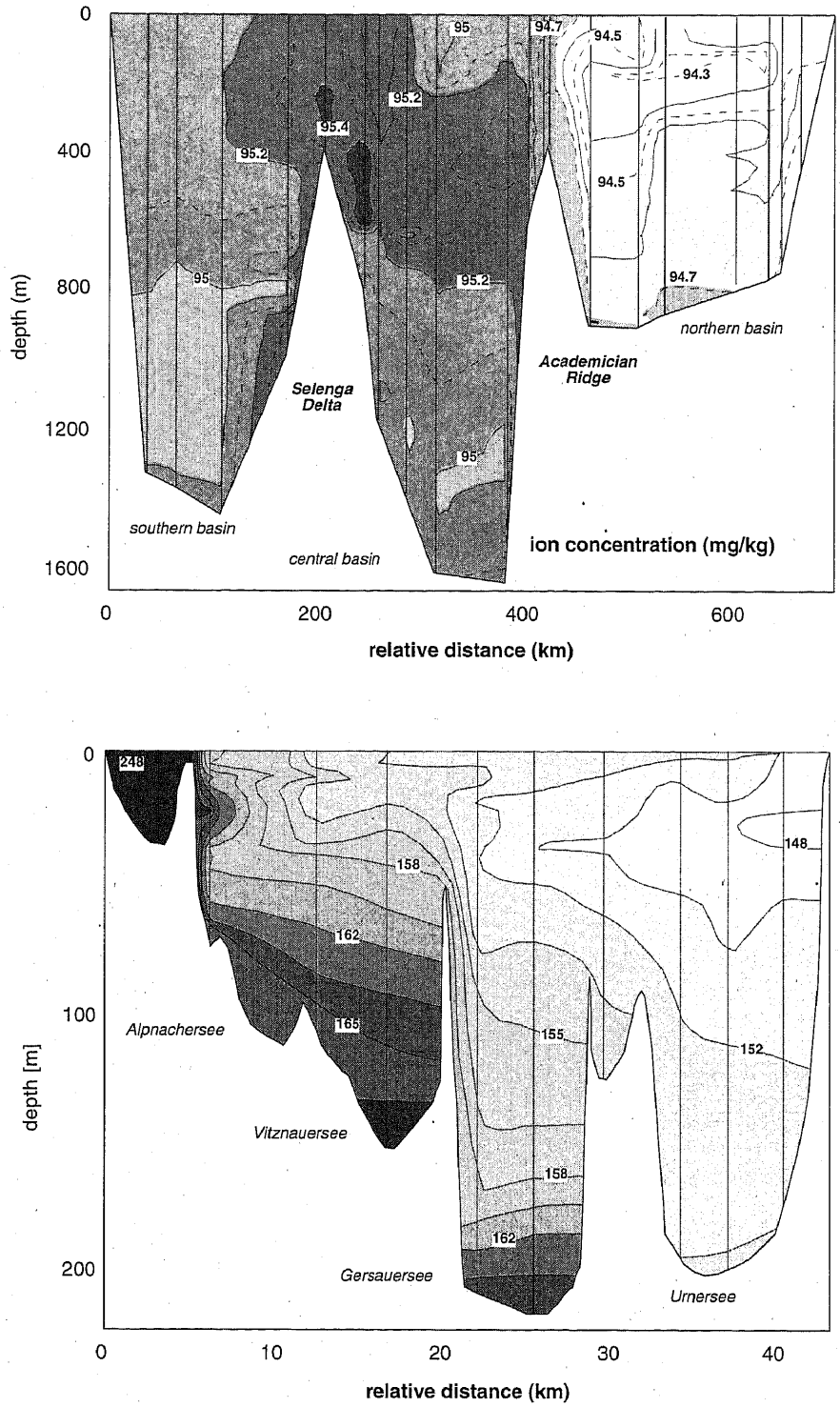


Fig. 3
Both in Lake Baikal (left) and in the Lake of Lucerne (right), the density structure (ρ) is not determined by temperature (T) alone but also by the distribution of ions (S). Both vertical and horizontal ρ-, T- and S-gradients develop. These gradients drive the formation of deep water and lead to the development of a thermo-haline circulation in both systems, similar to that in the oceans.

The different ion concentrations in the various basins of Lake Lucerne are maintained by the differing salt contents of the inflowing rivers (Alpnacher Aa [catchment area containing limestone: strongly mineralized, Alpnachersee] and Reuss [crystalline catchment area: low ion concentrations, Urnersee]). The main tributary of Lake Baikal, Selenga, drains into the central basin and exhibitsa degree of mineralization that is about 50% higher than that of open lake water. In contrast, Upper Angara, the second largest tributary, pours freshwater into the northern basin. Therefore, the water in the central basin is the most strongly mineralized all over Lake Baikal.

The different orders of magnitude of the spatial gradients of salt in both lakes are worth noting: although Lake Baikal is about 10 times deeper and 20 times longer than Lake Lucerne, its differences in ion concentrations are 200 times smaller. The relevant ion gradients are thus typically 3 or 4 orders of magnitude lower in Lake Baikal than in Swiss lakes.

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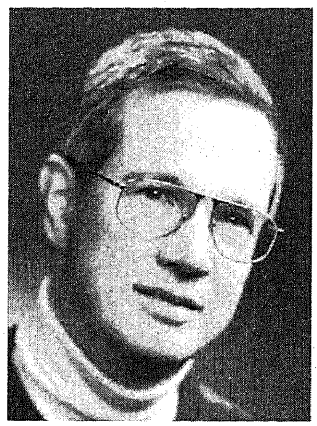
Rudolf Koblet

Past and Present of Swiss Waters



Rudolf Koblet

The familiar look of Switzerland's water system is the result of many years of development, both of the streams and lakes as well as of the anthropogenic component. For thousands of years, humankind has used water and, for just as long, it has tried to protect itself from its power. Of particular interest are changes that have occurred over the last few centuries, since they have most significantly impacted the appearance of today's environment.

When studying old maps or paintings, one notices striking differences from our contemporary landscape. For one, there are vast tracts of land appearing open and empty, settlements are small and tightly packed, with large open fields and wooded areas between them. Secondly, there are virtually no straight sections on any of the rivers or streams; instead, they are meandering through the landscape, split up into smaller streams, form active arms with strong currents and stagnant sections which are cut off from the main stream and temporarily turned into lakes. Today, by contrast, our streams are corrected, straightened, channeled, and settlements have expanded tremendously (Fig. 1).

There are only a small number of cases where meandering and branched sections on our Swiss streams have survived. Examples are the Rotten between the Rhone Glacier and Gletsch, the Hinterrhein near Rhäzüns, and the Vorderrhein in the Ruinaulta Gorge near Flims.

Other stream sections which may appear to be of natural origin are far from it. A prime example is the Maggia between Cevio and Giumaglio, a gravelly desert, many kilometers in length, with frequently branching side-arms, called the "Fiumara". Around 1850, clear-cutting of a forest near Campo and the subsequent drifting of logs in the Rovana, a tributary of the Maggia, reactivated a prehistoric slide area. Since then, the whole village of Campo has intermittently slid downhill. Over the last 100 years, the church has moved horizontally by about 30 m and vertically by about 6 m (Fig. 2).

The bed of the Rovana constantly receives more slide detritus which supplies the material for the next flood! It is possible that the movement of the Campo region is one of the reasons why the bed of the Maggia has turned rather wild below the confluence with the Rovana, although all the other clear-cuts in the upper reaches of the Maggia and the practice of drifting the logs downstream certainly made their contribution.

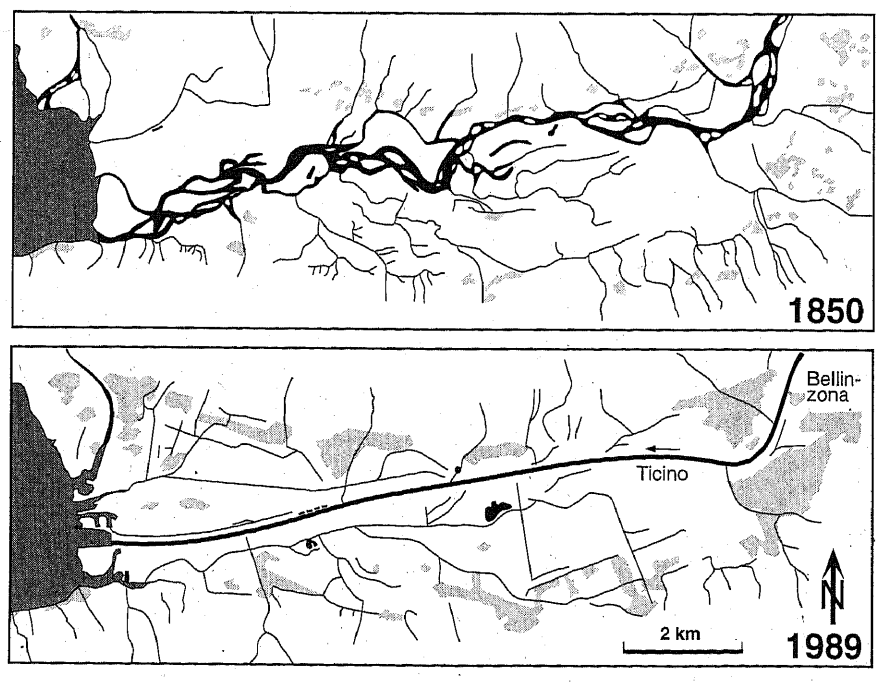


Fig. 1
The Magadino plain and the Ticino in 1850 and in 1989 (Lago Maggiore on the left). Settled areas (shaded) extend further and further into the ameliorated river bed [4, 6].

Why have Meanders been Destroyed?

A natural stream flowing through a plain never follows a straight line, but snakes its way along forming meanders of varying size. These structures are currently in flux and changing their shapes and locations (Fig. 3).

The slope of such a contorted and often braided stream bed is considerably less than that of the theoretical straight line. As long as only the water is flowing, there is no problem; however, as soon as high water carries soil and rock from the mountains into a flat section of the stream bed, this material will deposit where the slope is the smallest. The water is backed up, the plain turns into a swamp, and the river will look for a new path. If the new path happens to go through a settled area, there is a problem, possibly even a catastrophe – all of this is occurring with regularity every few years or decades.

At one time, humans avoided plains and preferred settling along the slopes of a valley, knowing very well that the river is an unpredictable neighbor. Even travel routes rarely followed the valley bottoms. At the end of the Middle Ages, however, the population increased dramatically. Compared to today's population densities, there still was plenty of room at the end of the 14th Century; the population in the area of what now comprises Switzerland was only about ten percent of today's population [2]. Despite that, there was an overpopulation, as more cultivated land was needed to feed the increasing number of people. As a consequence, fields started to encroach on river beds. The insecure but very fertile meadows along rivers were incorporated into the farm land, at first timidly, then gradually more boldly.

In the Emmental, this led to the formation of "Schachensiedlungen" (settlements consisting of temporary shacks) where day-laborers put up primitive cottages. Gradually, these settlements transformed into permanent villages. People were aware of the danger of flooding, but paid little attention to its causes [3]. Only much later were there serious attempts to "correct" streams in order to protect settlements and cultivated land, mostly in the form of straightening and levying.

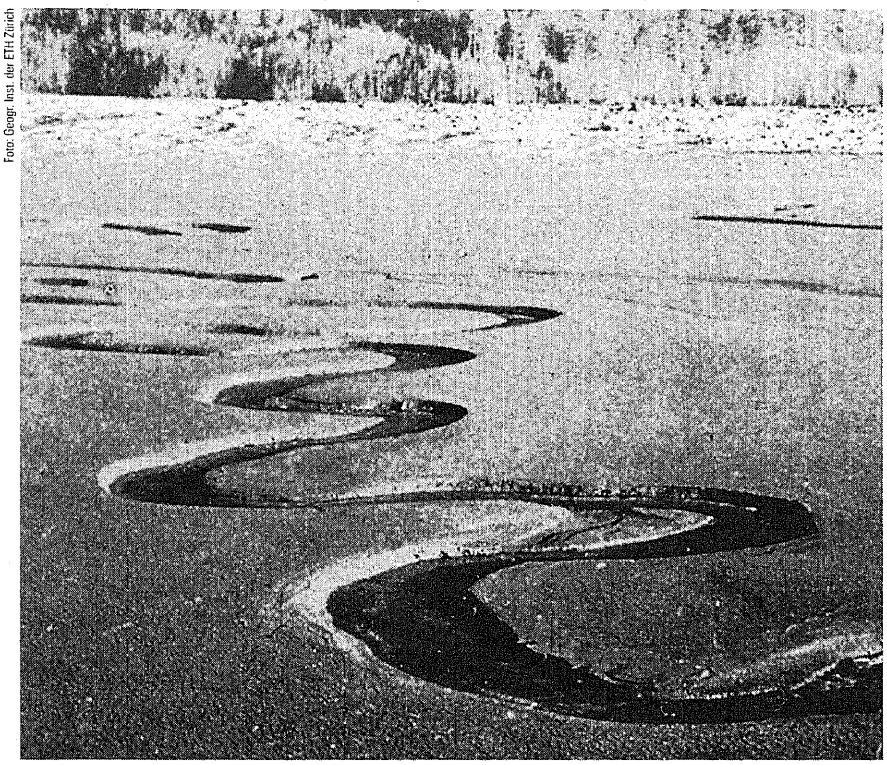


Fig. 3
Meanders in the mud along the shore of Lake Klöntal. A "natural" picture which has become a rare sight.

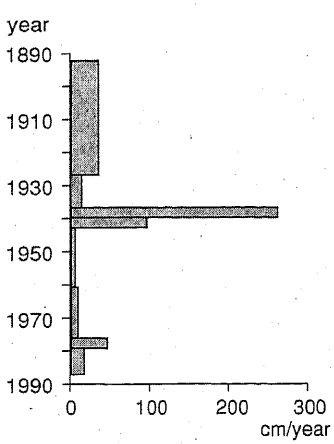


Fig. 2
The downhill slide of the church of Campo Cimalmotto in the slide area between 1892 and 1987. Sloping slide distances per year [3, 9].

Chronicles of Terror

The history of devastation from storm disasters (floods, land slides) in Switzerland is rather frightening. The number of events per century has been rising for over a 1000 years, where the 16th Century saw a peak due to weather conditions [7].

We must remember that records of some floods have been lost from earlier times, and that in earlier days, only massive floods seemed worthy of documentation. As long as river beds were neither settled nor cultivated,

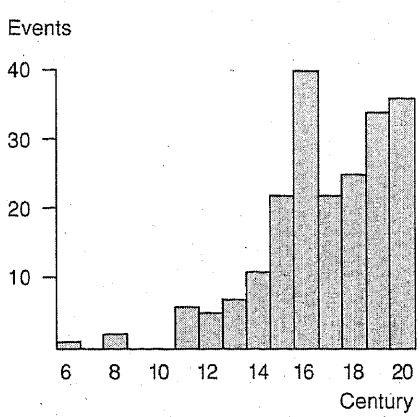


Fig. 4
Severe and catastrophic weather events in Switzerland from the 6th to the 20th centuries (to 1988). Bad weather conditions at the end of the 16th century are clearly reflected [7].

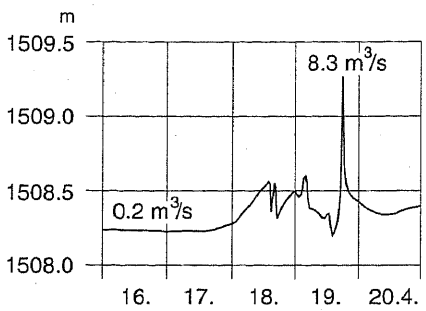


Fig. 5
A diagram illustrating an analogy to the chronicles in the text: the effect of avalanches on the water level of the Ova da Cluozza (Swiss National Park, Zernez) during April of 1962 at an elevation of 1509 m. above sea level. Water breaking through obstacles in a river bed can lead to extreme flood levels.
(Source: unpublished flood stage data of the Swiss National Hydrological and Geological Survey in Berne).

damage from floods was naturally smaller. Even with these problems in historical records, however, there is a documented long-term trend of increasing frequency of severe floods (Fig. 4).

More impressive than numbers are stories from real events, of course. Here are two accounts from the Linth plain, when the Linth was still bypassing Lake Walen:

> *The author still has the sad picture of a swamp desert in front of his eyes. A devastated plain, neither water nor land, full of moldering smells and croaking frogs. Inhabitants appear pale and sickly. Every Spring the villages are full of shivering victims of fevers [1].*

> *In order to grasp the full dimension of this disaster, one has to realize the deplorable situation of the inhabitants. (...) The streets of Wallenstadt and Wesen are passable only by boat during the summer months; the flood has entered the ground floor of most houses and has even reached the second floor here and there; the summer heat produces revolting smells out of the mud the flood left behind, and insects are breeding in large quantities. It is not hard to imagine how this affects the health of the inhabitants! [8]*

Another event that was feared well into the last century was the sudden draining of Lake Märjelen, a lake on the edge of the Aletsch Glacier, normally held back by an ice dam. Between 1813 and 1913, it completely drained eight times, and partially ran off 36 times. The poet Josef Viktor Widman, a chance witness of one of the floods, describes the event as seen from Belalp:

> *We barely were out of sight of the guest house when we suddenly heard a thundering noise from the direction of the glacier; first a loud crack, followed by a sustained roar. Surprised, I glanced across the glacier. (...) At the far side of the glacier, a dirty yellowish stream was rushing along between the glacier and the mountain, with frightening speed and forming cascades here and there, depending on the terrain. Anybody caught in the path of the water at the moment the water broke through the ice wall would have been lost; like a giant snake, the stream would have approached and swept the poor soul away. [10]*

Until the last century, living in the mountains was living with fear. Over centuries, Lake Mattmark, dammed by the Allalin Glacier above Saas-Almagell, burst every ten years on average, while Lake Märjelen broke out almost every other year during the 19th Century [3, 5]. The fear was permanent, and people were accustomed to it since protection was impossible. This is different today. Nature has been pushed back considerably and is no longer at the center of our thinking and feeling as it was in earlier centuries. The struggle with nature, the fear and the respect, have largely been relegated to the background. Letting nature run its course has been replaced by the ability to achieve a relatively high level of protection. Perhaps it is exactly this distance from nature, a false sense of security, which causes our extreme fear when nature produces unexpected events and changes in our environment.

This distancing from nature is, on the other hand, the starting point for a backlash. The radical forms of stream management of the past have caused a lot of uneasy feelings, and there is a general trend to give streams and rivers back some of their space and to let them have their own character. EAWAG is heavily involved in this form of stream renewal.

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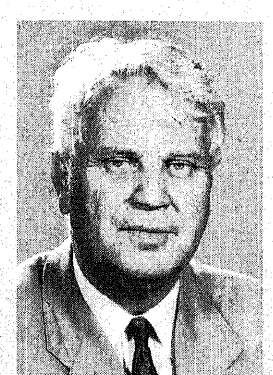
Prestigious Prize for Prof. Stumm



The International Geochemical Society for "lifetime achievement" has awarded Werner Stumm, professor emeritus ETH Zürich and former EAWAG director (1970–1992), its highest award, the Goldschmidt Medal, in the area of geochemical sciences.

Giulio P. Genoni

The Energy Dose Makes the Poison

*Giulio Genoni**

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Chemistry nowadays benefits many human activities. But with some 100 000 substances produced on an industrial scale and 100–200 more added annually, risks of human and environmental toxicity exist. The risks depend on the toxicity of the individual chemical and on the quantities used. "The dose makes the poison", said Paracelsus. His statement was meant in a general way, so we may ask a general question: Why does the dose make the poison?

This question is not easy to answer, since toxicity is not only a matter of dosage but also dependent on the properties of each chemical. Moreover, any particular chemical may have both positive and negative effects.

Rare is Expensive

Ethanol, for example, is acutely toxic to laboratory rats beginning at doses of about 3000 mg/kg; pesticides, cyanide, and some potent snake venoms are lethal at doses a million times lower. Consider that the toxic effects of such widely differing substances as ethanol or snake venom have one thing in common: they occur when the dosage – even the very occurrence of the substance – is *unusual* in the environment or in the body of the organism. Surely ethanol is a common and even natural substance, but it never occurs in nature at such high concentrations as are produced by humans through distillation. Plant toxins and animal venoms are natural substances too, but they are very rare except in the specialized plant or animal organs that synthesize them. Pesticides are novel, but not natural substances, recently synthesized by the chemical industry.

Such rare and sometimes complex substances can exert their desired action because they have been concentrated or synthesized from simple and common substances. The point is this: concentration and synthesis cost energy!

There is more energy needed than that needed for the chemical reaction to proceed thermodynamically; energy is also required to ensure the proper functioning of the chemical reaction (extraction, regulation, storage, and maintenance of all the parts involved); in short, the *"grey energy"* hidden in the product.

Any biological or chemical process can be described as a series of energy transfer reactions (Fig. 1), e.g., the food chain grass–hares–birds of prey or a chemical synthesis or concentration (substrate–product). The major part of the energy flowing through the system is, in fact, dissipated as heat (in organisms, this is the heat of respiration). The energy remaining decreases, and the "relative energy cost" of the useful work done at each step increases from left to right. Grass and common chemicals have a *low* relative energy cost. Birds of prey and complex chemicals have a *high* relative cost, and they are rare because they require a concentration of materials and energy from the lower levels.

In a food chain, differences between successive trophic levels in relative energy requirements often approach an order of magnitude because, at any level, respiration accounts for the larger part of the energy expenditure [1]. For example, in Silver Springs, Florida, 1000 times more energy is required per Joule of predator production than per Joule of plant production [2].

Howard T. Odum, one of the founders of systems science, pointed out that the simple ratio of energy remaining by energy input is a measure of the relative energy cost of different parts of a system. He called this ratio *transformity* [1]. This notion is some-

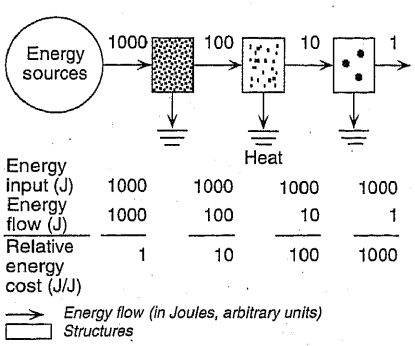


Fig. 1
Hierarchies in thermodynamic systems: The initial energy required for sustaining the process is dissipated for the most part along the chain as heat. The relative energy cost of the useful work increases from left to right. Higher levels have a higher relative cost, and they are fewer (dots symbolize spatial dispersion).

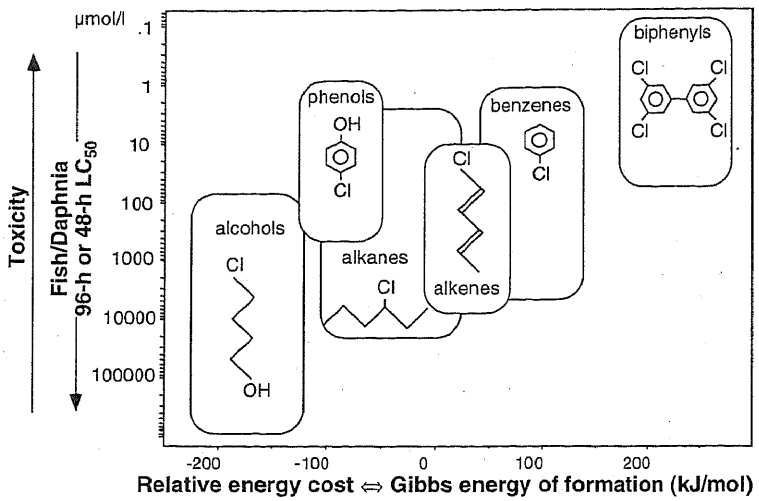


Fig. 2
Correlation between the relative energy cost (measured as the Gibbs energy of formation) and the acute toxicity to fish (sheepshead minnow) and water fleas, for 70 organic chemicals representing six chemical classes, with 0, 1 or more chlorine substituent groups (an example is shown for each class). The acute toxicity is inversely related to the lethal concentration for 50% of the animals (LC_{50}) within 48 h (for water fleas) or 96 h (for fish).

times used in ecological economics to measure the real energy value of different processes. Odum also remarked that things that have different energy costs also have different functions. Simple chemicals, though they have a low influence per unit mass, occur in large quantities and play an important role or roles – as building blocks for cellular components and as general metabolic intermediates (e.g., nutrients, amino acids). Complex and/or rare chemicals have a high influence per unit mass and are also more specialized in their function: essential elements, enzymes, hormones, etc. [3].

For a biological system, common substances are easy to metabolize, whereas unusual ones require more energy-intensive and specialized processing mechanisms. Being difficult to metabolize, it is also the unusual chemicals that bioaccumulate in food chains (i.e., to become more concentrated) [3].

Chemicals are Janus-faced

To say whether a chemical is useful or toxic is very much a question of perspective. Ethanol has both positive effects (it can enhance the personal or social well being), and negative ones (it can cause fatigue or release violence). High doses or highly effective substances are also Janus-faced, and even more strikingly so. When humans use antimicrobial agents or a snake injects its venom, there is a benefit for the species – that is, being toxic to another species!

Evidence from (Eco)toxicology

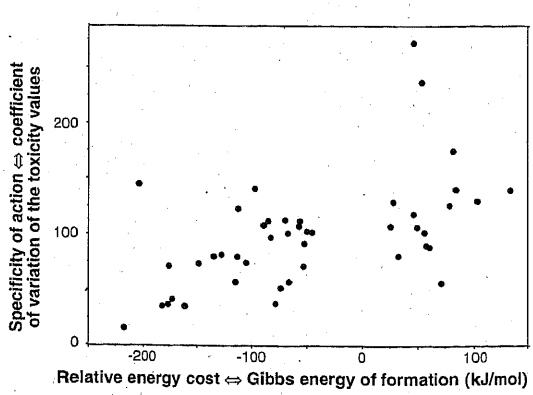
There is much circumstantial evidence that correlates rarity with complexity, and hence the energy required for forming or concentrating a substance, with its tendency to bioaccumulate, its effectiveness and its specificity of action. Like nature, the chemical industry invests energy in concentrating and producing substances that are unusual, chemically complex, effective and specific in their modes of action (as in pharmacology and agriculture). More direct evidence lies in the correlation of molecular volume, which often contributes to molecular complexity with bioaccumulation, toxicity and specificity of action, e.g., for hydrocarbons in fish [4,5].

We can look for even more direct evidence by actually measuring the relative energy cost of different chemicals and comparing them to their toxicity, specificity and tendency to bioaccumulate. It is easy to find data in the (eco)toxicological literature on the toxicity and bioaccumulation of many chemicals; however, it is difficult to estimate their relative energy costs, because we usually do not know all the various energy fluxes.

For chemical compounds, we can use the Gibbs energy of formation as a rough estimate of the relative energy cost, which is known for many substances. This quantity increases during structuring reactions that raise the level of chemical interconnections among atoms [6]. It likely underestimates transformity because it accounts neither for the energy needed to transport a substance to the site of interaction nor for the activation energy involved in each transformation step.

For elements, the relative energy cost may be estimated as the relative amount of energy that biological systems use to maintain an internal concentration different from the concentration in their physico-chemical environment. This is the Gibbs energy of formation inherent in the concentration differential [7]. This, too, may

Fig. 3
Correlation between the relative energy cost (measured as the Gibbs energy of formation) and the specificity of acute toxicity toward 21 aquatic species (estimated by the coefficient of variation) for 45 organic chemicals representing six chemical classes, with 0, 1 or more chlorine substituent groups (an example is shown for each class in Fig. 2).



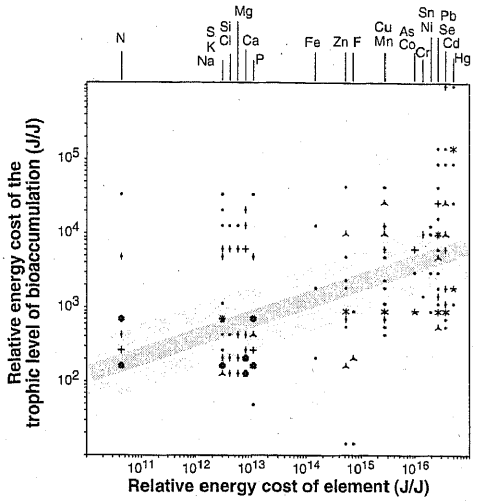


Fig. 4
Correlation between the relative energy cost (measured as the Gibbs energy of formation in the concentration differential between biota and physical environment) and the bioaccumulation (estimated by the relative energy cost of the trophic level of highest accumulation) for 23 elements. Overlapping points are shown as stars.

underestimate transformity. For example, for nitrogen, it does not take into account the fact that in organisms this element is mostly in the form of sugars and proteins, whereas in the chemical environment it is mostly in the form of N_2.

By using these approaches, we observed that for a set of organic compounds broadly used in industry, the relative energy cost indeed correlates with toxicity (Fig. 2) [7] and with specificity of action (Fig. 3) [7]. Moreover, for a variety of elements, it correlates well with their tendency to bioaccumulate in food chains (Fig. 4) [7]. The resulting "hierarchies" of compounds and elements also reflect empirically known patterns. Among elements, for example, alkali and alkaline earth metals occur in the low range and heavy metals in the high range of relative energy cost and bioaccumulation.

A Broad Palette of Substances

In all of these examples, we find that energy cost values span several orders of magnitude. This helps explain why toxicity itself can vary over so many orders of magnitude. The diversity of the chemical environment, with its palette of "energy-cheap" and "energy-costly" substances, thus matches the diversity of processing mechanisms in biological systems. This, by the way, also helps explain why there are such broad differences in sensitivity among organisms. Organisms occupying the lower trophic levels in ecosystems may not deal effectively with unusual substances. At a higher trophic level, however, the occurrence of such substances will be less of a strain on its more sophisticated metabolic machinery. Generally, if an organism has itself a high relative energy cost, it can deal with higher energy inputs. The larger and more mature biological systems, in fact, are often observed to be more resistant (per unit mass) than small systems or young life stages.

Conclusions and Implications for Environmental Management

Rare substances or doses, which represent a high concentration of chemical energy, have a high impact, for better or worse: The energy dose makes the poison... and the remedy. Furthermore, higher-level parts of a biological process or mature systems are more resistant to perturbation: he energy dose confers the resistance.

Some of the general implications of this idea are not new: common substances are less toxic and specific, and bioaccumulate to a lower extent; pristine ecosystems can deal more effectively with toxicants than damaged ecosystems; and intermediate developmental stages are more resistant than early or senescent stages.

From this, it can be recommended that the chemical energy released by human activities should match what biological systems can process. The present-day production of chemicals, many new and complex, many used in massive quantities, does challenge the biosphere, especially since the biosphere's biological diversity is rapidly being reduced (Fig. 5).

Is the energy cost approach applicable to environmental management? Certainly it can be used in the life-cycle analysis of products. But its relevance is even broader and includes ecological economics and ecological engineering. For example, Pritchard [8] evaluated competing alternatives for the recovery of lead in automobile batteries.

At present such applications are hindered by the methodological difficulties in measuring energy and material flows in economic and biological systems. A major task in environmental management is the refinement of these methods and the construction of a corresponding database.

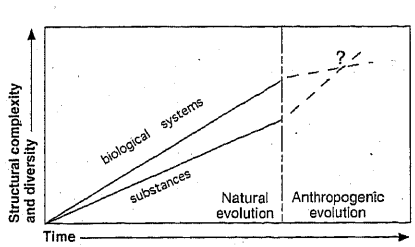


Fig. 5
Present-day human activities reduce biological complexity and diversity while increasing chemical complexity and diversity. This may threaten the processing capability of biological systems.

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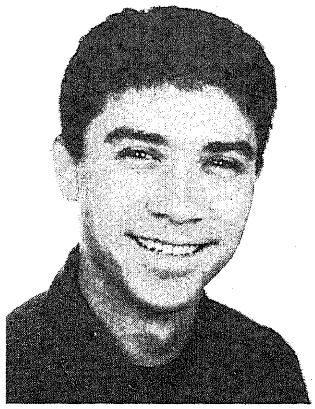
Max Maurer

Plastic Particles Instead of Concrete

An Alternative to Building New Tanks in Sewage Treatment Plants



Max Maurer

A number of Swiss domestic sewage treatment plants are in the process of being improved and expanded. A new treatment process from Norway seems to promise increased purification performance without requiring new tank space. In collaboration with the association of sewage treatment plants in the region of Baden-Wettingen and the Swiss Federal Department of the Environment (BUWAL), EAWAG's Engineering Science Department has been testing the suitability of this technique for the elimination of nitrogen. This is a preliminary report.

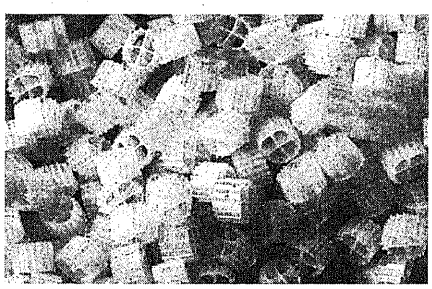


Fig. 1
A commercial carrier material for the fluidized bed (Kaldnes) process. The "little wheels" have a diameter of 1 cm, are made of polyethylene and float on water.

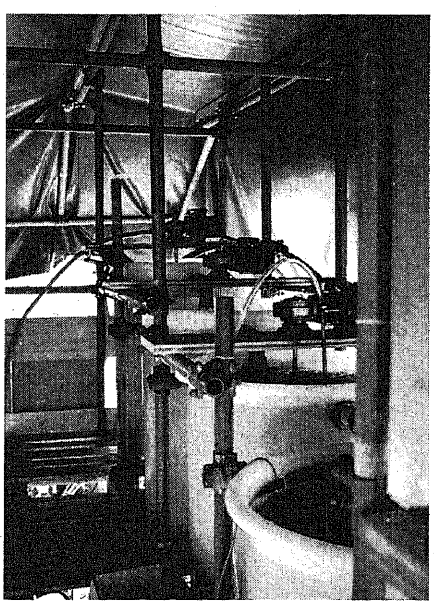


Fig. 2
A view of the influent of the semi-technical scale pilot plant. In the foreground are the two stirred non-aerated tanks, behind them a stirred aerated tank; the other tanks are aerated only.

Modernization of Sewage Treatment Plants

Over the past 30 years, 92% of Swiss households have been connected to one of the 1000 public domestic sewage treatment plants. The first generation of sewage treatment plants was built in order to remove solids and satisfactorily meet the oxygen demand of the wastewater. During the past few years, it has become clear that additional compounds indirectly influencing natural waters also need to be eliminated from wastewaters. These more rigorous demands on sewage treatment plants are being met by the construction of appropriate extensions to existing plants within the framework of previously scheduled improvements.

Sewage Treatment Systems

A current example is the domestic sewage treatment plant "Laufäcker" in Turgi which treats the wastewater of the region Baden-Wettingen (approx. 80 000 inhabitant units). Two systems are under consideration:

- *The conventional activated sludge process:*
This method uses the tendency of microorganisms to form flocculate colonies. Such "sludge" flocks are intensively mixed with wastewater, separated from it after a certain reaction time and used again for the next treatment cycle.
- *The fluidized bed process, novel for Swiss conditions:*
In this so-called biofilm technique, the microorganisms responsible for purification grow on a surface. The wastewater flows over the "living coating" of this surface, so that the pollutants enter the film and can be degraded by the microscopic organisms.

Typical for the fluidized bed process is the use of small carrier particles, usually a few millimeters in diameter (see example in Fig. 1). These particles serve as a growth surface for the biofilm; for this purpose they remain in suspension in normal tanks and are kept in continuous motion.

Fluidized Bed versus Activated Sludge

In order to attain the purification goals set for the sewage treatment plant ARA Laufäcker (nitrogen and phosphorus removal being in operation year round), additional tanks had to be

Denitrification in the fluidized bed *is a joint project of the board of the association of sewage treatment plants of the region of Baden-Wettingen (AVRBW), the Swiss federal Department of Environment (BUWAL) and EAWAG's Engineering Science department.*

We would very much like to thank the personnel of the sewage treatment plant ARA Laufäcker and the engineering firm Hollinger AG for their collaboration.

constructed for the activated sludge system. As a result of the considerable experience gained from this system, the expected purification performance and operating conditions are well-known.

The fluidized bed process could be operated with the present tank volume, although the specific problems of operation and its efficiency are still unknown.

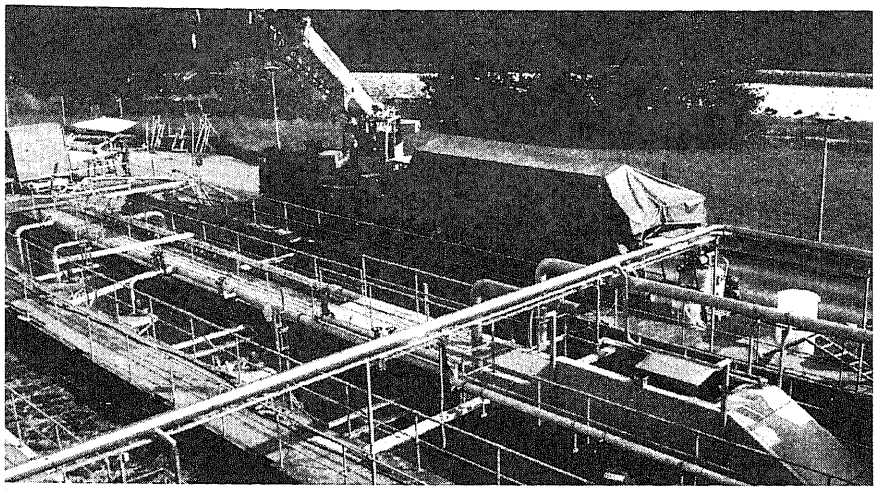


Fig. 3
Both experimental systems of the sewage treatment plant ARA Laufäcker (Turgi, AG). Underneath the cover seen in the background lies the semi-technical scale pilot plant.

Collaboration between EAWAG and the Sewage Treatment Plants

Because of the previously mentioned uncertainties, the board of the association of sewage treatment plants of the region of Baden-Wettingen (AVRBW) has decided to temporarily operate one of the lanes of its existing plant using the new process. A 820 m^3-sized tank will be fitted with separations, stirrers and coarse bubble aeration (Fig. 3). This presents an extraordinary opportunity for EAWAG's Engineering Science Department to investigate this interesting process under conditions in Switzerland. For this reason the project "Denitrification in the fluidized bed" was initiated in collaboration with the AVRBW and the BUWAL (see small insert) in the spring of 1997.

Semi-technical Scale Pilot Plant

In addition to running one lane, a semi-technical scale pilot plant was also installed (Fig. 2). It consists of six tanks with a total volume of 1650 l. The daily amount of about 5000 l of wastewater flows in from the primary clarifier of the sewage treatment plant. Analogous to the partial operation of one lane, the first two tanks are equipped for denitrification (microbial conversion of nitrate into atmospheric molecular nitrogen) and are not aerated. Oxygen is added to the others using air.

This easily manageable and flexible pilot plant allows us to use and investigate different types of carrier materials. Comparisons with the commercial carriers used in the operation of the one lane will show whether and how the different properties of the materials affect purification performance. In a first phase, small foam rubber cubes take over the role of the carrier material.

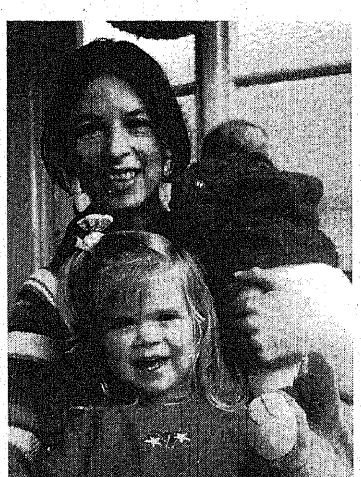
Preliminary Results

At the present time, it is not possible to draw any firm conclusions on purification performance from the one-lane technical scale system. Preliminary results from the summertime operation of the semi-technical scale pilot plant, however, suggest that the purification performance was comparable to that achieved by the activated sludge system. Investigations on maximum degradation performance suggest that the system even possesses significant reserves. Detailed studies on this are being carried out at present.

Further stages of the project include determining the purification performance during operation in winter and a comparison of various carrier materials. Based on the results, recommendations for the construction size of fluidized bed systems will be issued. The publication of these results can be expected by winter 98/99.

1997 Otto Jaag Prize for Water Protection

The 1997 Otto Jaag Prize for Water Protection for has been awarded to Dr. Barbara Baumann, a former doctoral student in the Microbiology Department at EAWAG. Dr. Baumann's dissertation was entitled *"The Dynamics of Denitrification in Paracoccus denitrificans"*.



Dr. Baumann successfully combined classical microbial culturing techniques with new methodologies in molecular genetics to evaluate the very rapid response of bacterial cells to changing environmental conditions. In particular, she studied the abilities of denitrifying bacteria who transform nitrate to nitrogen gas in the absence of atmospheric oxygen. The bacteria are able to very quickly detect the absence of oxygen and immediately turn on enzyme systems that use nitrate instead of oxygen. One of the major findings of her work was that nitrite reductase is induced much later than either nitrate or nitrous oxide reductases. which leads to a temporary imbalance and short-term accumulation of nitrite which is toxic to the cells. For efficient denitrification, however, nitrite concentrations must be as low as possible.

Rolf Hesselmann[1], Dittmar Hahn[2],
Jan Roelof van der Meer[1] and Alexander J.B. Zehnder[1]*

Enhanced Biological Phosphate Removal from Sewage

The Search for the Organism

from l. to r.: Alexander J.B. Zehnder, Jan Roelof van der Meer, Dittmar Hahn, Rolf Hesselmann

* *in collaboration with Dietmar Stax, Ricarda von Rummell and Sol M. Resnick*
[1] *EAWAG*
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For the first time, a specific bacterium has been detected with which enhanced biological phosphate removal has been achieved in sewage treatment plants. Our findings classify the bacterium with known and related bacteria. This was obtained by culturing the organisms in laboratory reactors for several years and by applying the methods of modern molecular biology.

Enhanced biological phosphate removal (Bio-P) is a promising alternative to the chemical removal of phosphate in sewage treatment plants [1]. Since little or no chemical precipitants are needed for the biological removal process, the resulting amounts of sewage sludge, the cost of precipitants and the contamination of the sludge with heavy metals (from contaminated precipitants) all decrease. For this reason, the Bio-P process is the most sustainable phosphate removal technique in many cases [2] and it is being used increasingly in neighboring countries, although the underlying microbiological processes are as yet not fully understood. For example, until now the key organisms (Bio-P bacteria) have never been identified [3]. These gaps in our knowledge hinder the optimization of the process. Our work described here contributes significantly to an improved understanding of the Bio-P process.

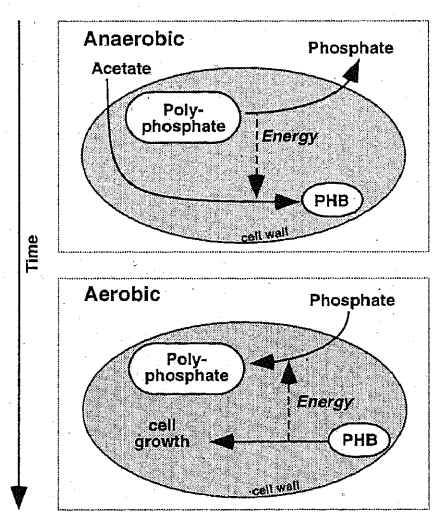

Fig. 1
Simplified representation of the metabolism of a Bio-P bacterium.

Physiological Model

The principle behind the Bio-P process is based on the accumulation of polyphosphate stores in bacteria. The cells fix more phosphate than they need for growth. This accumulation of polyphosphate is stimulated by alternating aerobic and anaerobic conditions. Technically this is accomplished by the integration of a non-aerated tank in the activated sludge system of sewage treatment plants.

The simplest model for the Bio-P process uses acetate as a model substrate [4]: acetate is stored in the form of polyhydroxybutyrate (PHB) under anaerobic conditions (Fig. 1). The necessary energy is gained from the degradation of intracellular polyphosphate, whereby the concentration of phosphate in the water increases initially. Under aerobic conditions, the accumulated PHB is utilized for growth and replenishment of the polyphosphate store. A temporary energy surplus from the respiration of PHB occurs in the cells and more polyphosphate is produced than was previously decomposed, resulting in an overall net removal of phosphate. Both polyphosphate and PHB are stored as osmotically inert granules in the bacteria.

Which Bacteria are Involved?

To date, it has not been possible to isolate a single bacterium responsible for the physiological process described in the above model. Since classical microbiological methods for identifying bacteria depend on obtaining pure cultures, the definitive identification of Bio-P bacteria was not possible until now. In the second section below, we describe a molecular method whereby such limitations were overcome. In order to simplify the method in prac-

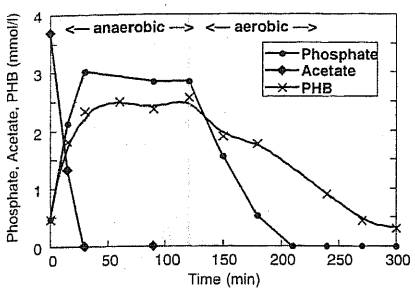

Fig. 2
Concentration of the compounds in the enrichment culture. Acetate is almost completely assimilated by the cells and stored in the form of PHB after 35 min in the anaerobic phase. The simultaneous increase in phosphate concentration indicates the degradation of polyphosphate. In the aerobic phase, phosphate is completely assimilated, and the PHB store is consumed.

tice, a bacterial culture containing as large a fraction of Bio-P bacteria as possible was needed first.

Enrichment in the Laboratory Reactor

A laboratory reactor was run for three years under optimal conditions to enrich for Bio-P bacteria. For this purpose, activated sludge was grown under alternating anaerobic and aerobic conditions using acetate as the sole organic substrate. Acetate was added at the beginning of the anaerobic phase and was completely assimilated before the aerobic phase ensued. Since acetate can be utilized by very few organisms under strictly anaerobic conditions, these conditions resulted in a selective advantage for the Bio-P bacteria. As expected, the enrichment culture attained a high level of Bio-P activity (Fig. 2) which made it easier to apply the molecular techniques.

Ribosomal RNA *(rRNA) is a structural component of the ribosomes (the sites of protein synthesis in the cell). Messenger RNA (mRNA) and transfer RNA (tRNA), two other types of RNA molecules, are also involved in protein synthesis. The building plans (genes) for rRNA are also part of the DNA of the cell's nucleus; i.e., they belong to the genetic makeup of the organism. A cell contains over 500 identical ribosomes distributed over the entire cell plasma. The 100-fold presence of the target sequences distinctly increases the sensitivity of the method compared to the basic DNA sequence being the sole target of the probes.*

Ribosomal RNA and Phylogenetic Classification

In recent years, methods in molecular biology have been developed with which a single type of bacterium can be detected and characterized without depending on pure cultures. Such methods are based on the identification of specific sequences of ribosomal RNA (rRNA) [5]. Typically common sections of these sequences allow bacteria to be compared with other related bacteria. Since the late 1970s, a family tree of bacteria based on their rRNA has been gradually constructed. This "phylogenetic classification" is one of the most important methods for classifying microorganisms today *(phylon,* Greek: phylum, tribe; *genesis,* Greek.: origin, emergence).

Using the rRNA sequences, rRNA probes can be produced that will detect specific bacteria in mixed populations. Short nucleotide sequences are synthesized which bind to characteristic sites on the rRNA. As the probes are additionally coupled to a fluorescent stain, the specific binding in the target cells can be detected using an epifluorescence microscope: the bacteria in question glow when stimulated with UV light (Fig. 3).

The rRNA probes can be designed for different levels of specificity. The percentage of large groups which are present can first be determined for an unknown population (broad degree of relation). The interesting groups can then be divided into subgroups, families, genera and, finally species, using probes of increasing specificity.

Composition of the Population in the Enrichment Culture

The enrichment culture was first investigated using gene probes, each of which can detect single major groups belonging to the kingdom of bacteria. The results suggested that over 80% of the organisms in the culture belonged

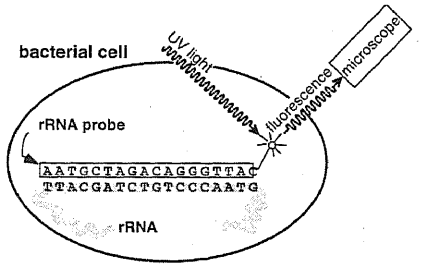

Fig. 3
An 18 nucleotide-long rRNA probe linked to a fluorescent stain has bound to a complementary base sequence of the rRNA of a bacterium. After activation with UV light, the stain radiates fluorescent light which can be seen in the microscope. Since over 500 ribosomes are uniformly distributed throughout the cell, the entire cell body glows.

to the beta-*Proteobacteria* (Fig. 4). Using more specific rRNA probes, their affiliation was further delimited to the second subgroup of the beta-*Proteobacteria.* Following this process, a new gene probe was developed which was specific for the genus *Rhodocyclus.* Even using this considerably specific probe, approximately 80% of all the organisms still reacted. We assume that long-term cultivation in the laboratory reactor resulted in a significant enrichment of a single group of bacteria belonging to the genus *Rhodocyclus* or organisms very closely related to it.

Distinguishing from the Genus *Rhodocyclus*

The members of the genus *Rhodocyclus* are capable of anoxygenic phototrophic growth. Apart from determining its phylogenetic affiliation, this

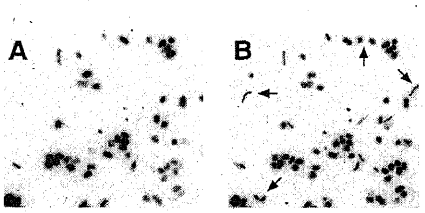

Fig. 4
Sample from the enrichment culture (inverted epifluorescence images).
A: Sample stained using an rRNA probe for beta-Proteobacteria (BETA probe).
B: Identical frame as in A after nonspecific staining of all cells (DAPI fluorescent stain). The arrows indicate cells which have not been identified with the BETA probe (compare to A).

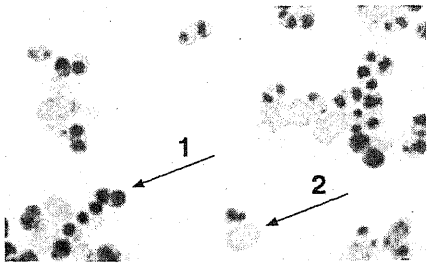

Fig. 5
Sample from the end of the aerobic phase after staining polyphosphate granules (bright field image after Neisser staining).
1: Cell with 2 polyphosphate granules
2: Cell without granules.

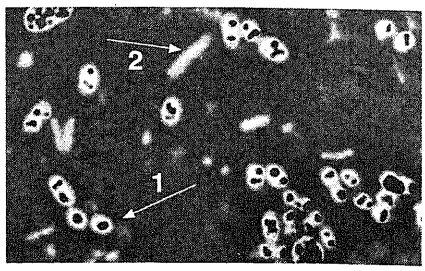

Fig. 6
Sample from the end of the anaerobic phase after staining of PHB granules (inverted epifluorescence images after Nile blue staining). In order to make the cell outlines visible, an inverted phase contrast image was superimposed.
1: Cell with one PHB granule (dark body within the light cell outline)
2: Cell without granule.

physiological characteristic is important for classifying a species of bacteria to the genus *Rhodocyclus* [6]. Corresponding control experiments using the enrichment culture showed, however, that the dominant species of bacteria of the Bio-P culture are not able to grow phototrophically. Our Bio-P bacterium, therefore, seems to be closely related to the genus *Rhodocyclus*, but clearly differs in its basic physiology. The available information suggests that our Bio-P bacterium belongs to an as yet unknown genus (our provisional label being "pseudo-*Rhodocyclus*") which requires more precise characterization.

For now, we have something akin to a "fingerprint" of our bacterium with which we can detect it among other bacteria at the "scene of the crime". But we cannot yet distinguish it from its "siblings" and we do not yet possess a complete profile of the "culprit".

At present we are working on the identification of the complete rRNA sequence of the dominant bacterium which will permit a more accurate classification and the development of more specific gene probes.

Detection of Polyphosphate and PHB

The dominant bacterium's high degree of enrichment permitted an indirect confirmation that it acts like a Bio-P bacterium. For this purpose, stains were used which either specifically bind to polyphosphate granules or to PHB granules [7]. In samples taken at the end of the aerobic phase, 80% of all cells harbored distinct polyphosphate granules (Fig. 5).

An analogous picture resulted from samples taken at the end of the anaerobic phase using the PHB stain: over 80% of the cells contained distinct PHB granules (Fig. 6). As the rRNA probe and the granule stains could not be applied simultaneously to the same microscopic specimen, it was not possible to *directly* assign either polyphosphate storage or PHB storage to the "pseudo-*Rhodocyclus*" bacteria; however, based on the high percentages of stained bacteria in each subset, a large intersecting set can be indirectly inferred. In addition, the largest part of this intersecting set had a uniform cell morphology. The fact that the two opposing processes of formation (accumulation) and degradation of polyphosphate and PHB take place in the same cell was clearly corroborated here for the first time. The dominant bacterium in our enrichment culture is thus unquestionably a "genuine" Bio-P bacterium, essentially corresponding to all assumed characteristics of the model.

Potential Applications of the rRNA Gene Probe

The development of the gene probe has made the search for these bacteria in diverse Bio-P treatment plants feasible. Such investigations will show how well phosphate removal correlates with the number of such bacteria. Our results do not suggest that our dominant bacterium is the only or the most important Bio-P bacterium; this question will be addressed in future investigations.

The probe can also be used for screening isolates from mixed Bio-P cultures. We have already tested various pure cultures isolated from our reactor with the *Rhodocyclus* probe. The results indicate that none of the isolates is identical to the dominant Bio-P bacterium, confirming the acknowledged difficulties of obtaining a pure culture of the Bio-P bacterium.

Bio-P bacteria are not an isolated case; many naturally-occurring bacteria cannot yet be cultured in the laboratory. This is one of the reasons why only a small number of the total species of bacteria are known up to now. This work is not only a contribution to understanding enhanced biological phosphate removal – it is also an example of how molecular methods expand the possibilities for investigating complex biological systems in general.

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Sybille Borner and Heinz Stalder

Crocodiles in the Lake of Lucerne

Sybille Borner[1]

Heinz Stalder[2]

[1] *Sybille Borner is dipl. biologist and worked on the "Sumpfkrebs-Projekt" ("Procambarus clarkii crayfish project") in 1997 at EAWAG*
[2] *Biologist, WWF Switzerland, Zürich*

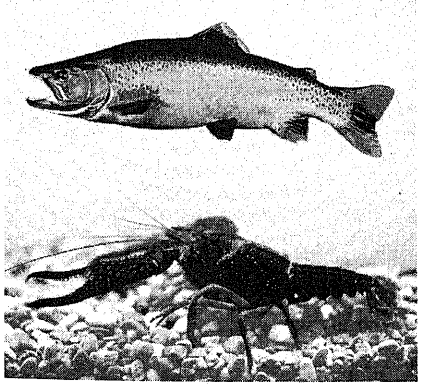
Humans have been manipulating the natural diversity of animal and plant communities for many thousands of years, both purposely and by chance. Today we can find species in every region of the Earth which do not belong to the original composition. The consequences are controversial: while ecologists warn us of a disturbance in the biological equilibrium and veterinarians and agronomists recognize the danger of new diseases, others are pleased with the so-called "valuable additions" to the local flora and fauna.

Among the introduced species EAWAG primarily focuses its attention on are fish. In 1996/97 an additional species moved onto the stage: it is the red swamp crawfish (or crayfish, *Procambarus clarkii,* see Fig. 1). Much has been discussed, often quite vehemently, about this crayfish over the past several months. In this article, we attempt to discuss the problem within a larger context.

Foreign versus Local

The topic "foreign species" cannot be approached without defining the words "foreign" and "native". It soon becomes obvious that the borders are fluid and, in part, artificial. Generally, those animals and plants regarded as foreign (neophyta and neozoa) settled in the country after 1500 AD [1]. This rather arbitrary year can be explained by the crossing of the Atlantic Ocean by Columbus, and it defines the beginning of the Modern Age. Increasing trade, migration, wars and voyages of discovery favored the exchange and spread of species that had only occurred locally until that time. But already in earlier times did the large-scale reshaping of the original natural landscape into a rural landscape contribute to a change in the composition of species. Civilization has created new habitats, and the alien species profit from momentary advantages – invading meadows, fields and ruderal areas. For example, plants such as vervain, cornflower, common poppy, sweet chestnut, the walnut tree and the skylark and common swallow immigrated before 1500 – and are thus classified as native. The arable weeds were introduced as "stowaways" together with various cereals from the Near East. Farming reached Central Europe over 6500 years ago via Greece and the Balkans, but probably also by way of Southwest Europe and the Rhone Valley. Arable weeds also invaded remote areas very quickly, as the seeds of these plants stick to the fur, hooves and claws of animals. Thanks to insufficient cleansing of grain seed and the lack of effective weed control, these species were able to maintain themselves over large areas until a few decades ago. Today it is assumed that 16% of all species of plants in Central Europe had been introduced by humans, either directly or indirectly. Some of them, especially the arable weeds and fauna, are currently being deliberately promoted in organic farming and used in pest control or for improving soil fertility.

Fig. 2 shows the enormous influence of agriculture and, on a smaller scale, forestry in the Middle Ages on the number of species (species of plants in the environs of Zürich) [1, altered]. Together with intensified agriculture and the abandonment of special crops (e.g., flax), many of these introduced species disappeared again, especially those associated with specific farming techniques. Distribution range can, however, also be extended naturally when changed conditions in neighboring habitats offer advantages. The collared dove, for example, has been



Photos: Armin Peter and Thomas Stucki

Fig. 1
The rainbow trout and the Red swamp crawfish, Procambarus clarkii, have been pests to the indigenous fauna since their introduction.

continuously advancing into the western European continent from Asia Minor. In Switzerland alone, the tally of new species of locally breeding birds which have become native since 1940 totals 32. It is clear that in many cases classifying animals and plants as foreign or native is primarily a question of viewpoint and time frame.

Especially under Pressure: Insular Flora and Fauna

Species living on islands are especially threatened by foreign ones. Through spatial isolation from the continent, the fauna and flora have undergone different directions of development and thus are often defenseless against introduced diseases and predators [2]. The colonization of New Zealand with cats, dogs and rats – brought in by the Europeans in the 19th Century – was a disaster for many flightless birds. Goats and pigs, released on the Galapagos Islands for their meat, are still grazing the land bare of plants and destroying this extraordinary habitat – in addition to numerous other threatening factors. Experience has shown that, even with massive efforts, it is not possible to get rid of introduced species.

Current Examples of Introduced Plant Species

Humans have influenced species diversity in two ways: on the one hand, organisms have reached places which they would never have done so on their own; on the other hand, many new habitats have come into existence (fens, calcareous grasslands, orchards, etc.). A large number of useful plants belong to formerly foreign species: potatos, tomatoes, corn, beans, carrots, leeks, tobacco, etc. Looking into any garden, we can see that, apart from the edible plants, a large number of ornamental plants have been and still are being imported. Many of these plants depend on care and could not spread beyond the gardens and fields of Switzerland. For example, they may lack protective mechanisms against the winter cold or

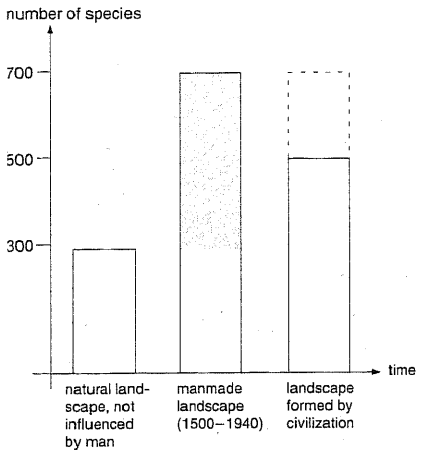


Fig. 2
As a result of forestry and agricultural practices over the last 500 years, several species have immigrated to Europe (dark section of bar). Intensified land use during the past decades has, however, considerably reduced the number of species again (dashes).

are controlled by competing species. They may grow too slowly or cannot find enough water and nutrients. Some species, however, are competitively strong and spread out correspondingly. The Canadian goldenrod *(Solidago canadensis)*, growing up to 2 m high with yellow flowers, colonizes sides of railroad embankments, ruderal areas and marshes and has become a problem for nature conservation. Indian Balsam *(Impatiens glandulifera)*, with pink flowers and an intense odor, is spreading along lakes and rivers throughout the Swiss Plateau. In the case of Canadian goldenrod, an enormous attempt has been made to thin out the local populations with the help of cleverly planned mowing cycles or special treatment (burning off, covering, weeding out) – so far without success.

Current Examples of Foreign Animal Species

Worldwide, approximately 160 fish species have been released into the wild and distributed on a large scale. In Switzerland, the rainbow trout is on the top of the list of prominent strangers among the fish fauna in our waters and has become the most widely distributed species. It was imported as a table fish and has been successfully moving into new habitats since the 19th Century thanks to its natural migratory habits and competitive strength. The Red swamp crawfish *Procambarus clarkii* is another representative of an introduced animal species. It comes from North America and was released into the wild for the same reasons as many fish have been. Because of its rapid growth and undemanding nature, it is being grown in aquaculture. In most Western European countries it is, however, already multiplying outside the rearing tanks. The Red swamp crawfish has also gained a foothold in Switzerland in the Cantons of Aargau and Zürich. The media's interest in this species of crayfish may give the impression that this is the only alien species in Switzerland; this is not the case. Two additional crayfish from Northern America and one species from Eastern Europe are also in competition with our three indigenous species. The greatest threat in this case does not come from direct competition for habitat and food, but from a fungal disease transmitted by the American species to which they themselves are not susceptible. The native crayfish die within a short time from this so-called "crayfish plague".

Tourism Opens All Gates and Doors

Apart from the worldwide trade in living material, tourism also presents new opportunities for spreading organisms. The large number of tourists and the small size of plant parts needed for dispersal (seeds, cuttings) render border controls ineffective. For this reason, more emphasis has to be put on information and the responsibility of travelers. A major threat is the introduction of disease. For this reason, it is prohibited to import plants of the rose family (Rosaceae). Fire blight, which only infects Rosaceae, is a feared fungal disease and can easily be introduced by the parts of an infected plant. It attacks many ornamental plants and orchard species (e.g., apple and pear trees). Animal and plant species from other countries do not belong in the luggage.

A Look into the Future

The immigration rate of plants will likely decrease in the future as those plants which have a high distribution potential have already spread widely over the Earth [4]. The change in climate will, however, play a role in shifting the competitive relationships between various species which will locally cause new species to appear and existing populations to disappear [4]. The manipulated composition of species existing today can be regarded as a huge experiment in evolutionary biology; in the course of a few centuries, we have shaken up the natural distribution of species so much that it is nearly impossible to predict the long-term consequences of these interventions [5].

Dealing with Foreign Species

We cannot simply turn back the wheel of colonization by foreign plants and animals, but we do have to try to secure the success of existing species for the future. Of primary importance is the preservation of near-natural habitats, although great efforts still must be undertaken in this direction.

Introduced species are an additional stress factor in already heavily pressured ecosystems. It is not possible to make any predictions as to the spread and effects of exotic species in a new environment [6, 7]. For this reason, the most precautionary principle should apply; that is, the exportation and release of foreign species of plants and animals into the wild should be generally prohibited. The same principle applies to genetically modified organisms which should be treated as foreign species in this sense, the release of which is a risk which cannot be calculated in advance. Trade in species which transmit diseases or which can reproduce and spread uncontrollably must be strictly monitored. By applying appropriate measures, those species already introduced should be kept under control.

Among travellers and the public in general, an understanding of the restrictions and regulations must be improved by informing them of the threats involved.

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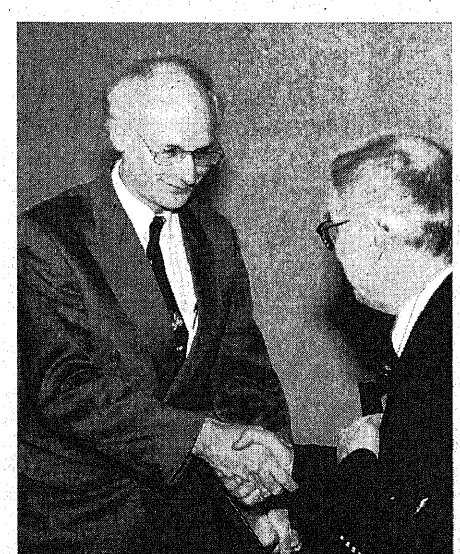
1998 Greinacher Prize



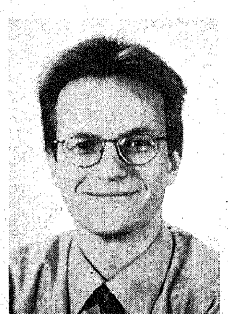
The prize from the Professor Heinrich Greinacher Foundation for 1998 has been awarded in equal parts to Jürg Beer, leader of the group Radioactive and Chemical Tracers in EAWAG's Department of Environmental Physics and docent at ETH Zürich, and to Peter Jenni (CERN). The prize is in the amount of sFr. 30 000.

The two honored scientists both studied at the University of Bern and embarked on outstanding carreers abroad. Jürg Beer received the award for "his innovative efforts to develop new applications in the field of accelerator mass spectrometry, as well as for outstanding contributions to studies in solar variability and its effects on the Earth's climate".

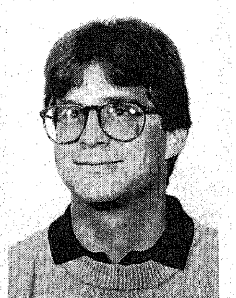
Heinrich Greinacher was a Professor of Physics and Director of the Physical Institute at the University of Bern between 1924 and 1952.

From EAWAG to EPFL

Hauke Harms and Christof Holliger have been appointed to the faculty in the Department of Civil Engineering at the EPFL in Lausanne.



Hauke Harms, member of the Department of Microbiology for the last five years, will be Assistant Professor of Soil Microbiology in the "Laboratoire de Pédologie" where he will work on microbial activity in terrestrial systems.



Christof Holliger, member of the Department of Biogeochemistry for the last six years, will be Assistant Professor of Environmental Biotechnology in the "Laboratoire Génie Biologique" where he will devote his studies to the degradation of pollutants and the development of industrial wastewater treatment processes.

"Strategy Environment" of the Board of the FIT Domain

The Domain of the Swiss Federal Institutes of Technology (FIT) comprises the two Federal Institutes for Technology in Zürich and Lausanne and the research institutions PSI, WSL, EMPA and EAWAG. In its document entitled "Strategy Environment", the Board of the FIT Domain affirms its commitment to globally sustainable development which involves a reorientation in teaching, research, and service.

In order to give the notion of sustainability a real face, the term "2000-watts society" has been coined. In reality, this translates to the long-term goal of a global per capita energy consumption of no more than 2000 watts. Thanks to consistent increases in energy efficiency and cost-efficient implementation of these innovations, this vision could be a reality in Switzerland within 20 to 30 years without any significant reduction in essential services.

With 2000 watts per capita used for all of the world's population, the atmospheric CO_2 concentration could be limited to 560 ppm (560 CO_2 molecules per million air molecules), which would keep the predicted warming of the planet within reasonable limits. In the case of Switzerland, where the current energy consumption is on the order of 6500 watts per person, this would require significant increases in efficiency, optimization of energy use and a simultaneous reduction in energy use by about two-thirds.

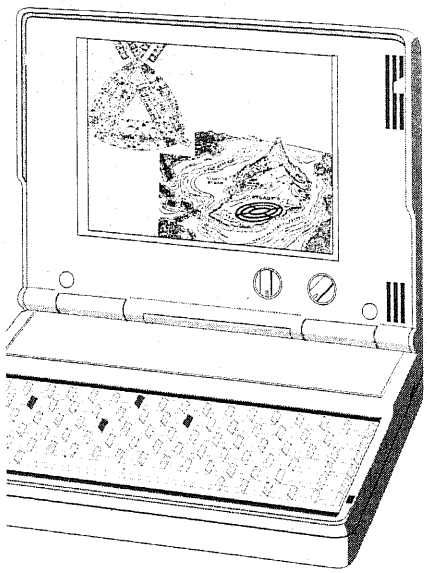
The FIT Board would like to achieve these goals for a sustainable future in close collaboration with industry, not the least of which would include strengthening the Swiss work place.

Shortcomings Identified?

In 1995, the FIT Board requested an analysis of the "Environmental Sciences within the ETH-Domain". Teaching and research received high marks for scientific and technical competence in environmental problems, but was criticized for a lack of consideration of economic and social aspects. As a result, the FIT Board launched the project "Strategy Environment", which is supposed to bring together national and international partners in making major contributions towards the development of a sustainable society. Internally, the goals are improvements in teaching, research and service as well as environmentally relevant cooperation with industry and the financial world.

Effects on Curricula

If society is supposed to move towards an environmentally sensitive and sustainable life style, the process of rethinking must also occur in the academic world. Initially, this will reflect itself in far greater flexibility in course programs that students will be able to setup. With a unified credit system, students will need fewer credits from required courses and instead be able to add credits towards the diploma by selecting from a variety of courses and course packages in other departments or schools (e.g., environmental sciences, business administration, social sciences).



Curtains open for the virtual urban planning of Nova Atlantis (top: Eco-apartment building [Fingerhuth, "Die Gestalt der Postmodernen Stadt", "the shape of the post-modern city"], bottom: Paul Schliemann's Atlantis [Richner]).

Dialogue between Science and Economy

The FIT Board would like to create an economic forum to coordinate the development of sustainable technologies and lead them to competitive products. It is envisioned that a select group of "economic forum" professors will lead this effort – individuals not only distinguished by their technical expertise but also by their entrepreneurial flair and sense for problems with regard to sustainability.

A Culture of Innovative Risk-taking

The FIT Board has used the Internet to establish a virtual urban region it calls "Nova Atlantis" (http://www.novatlantis.ch). The FIT Board has presented its ideas on environmental efforts to the international community and hopes to spark global discussion and participation.

Noch ein Drittel Strom pro Kopf

Zürich: Die ETH geht mit der Vision einer 2000-Watt-Gesellschaft in die Energie-Offensive

2000-Watt-Bürger als Ziel des ETH-Bereichs

Nachhaltigkeit – Thema von Lehre, Forschung und Diensten

ETH-Forschung lanciert eine Umweltoffensive

2000 Watt sind genug

Die ETH will sich für eine nachhaltige Anwendung der Energie einsetzen.

Von Beat Gerber

Press conference in January 1998 makes headlines.

Environmental Education in a Dialogue between Science and Practice

Five Years of PEAK*

Scientific results can be transferred most efficiently through continuing education. Five years ago, EAWAG established PEAK, a course series focusing on the practical applications of scientific findings for professionels from private industry, administration and government. Experts from all EAWAG departments and partner institutions present new results and insights. PEAK courses typically are short (a few days), interdisciplinary and are offered only once.

Courses between 1993 and 1997

When environmental topics began to be incorporated into regular curricula about 10 years ago, there were very limited options for practicing environmental professionals to obtain supplemental education. For the most part, they had to acquire information at meetings and by self-study. At the request of cantonal environmental personnel, EAWAG developed a concept for continuing education: PEAK.

The first PEAK course was held September 13–17, 1993 at the Research Center for Limnology in Kastanienbaum (LU) under the title *"The Influence of Stream and Lake Morphology and Type on Aquatic Organisms"*. Since then, 32 courses have been held as part of PEAK, with a total of 156 course days. The themes have been covered in an interdisciplinary way and reflect the wide spectrum of research at EAWAG, with emphasis on wastewater treatment, drinking water treatment, environmental analytical chemistry, the fate of substances in natural systems, studies of streams and rivers, sustainable management of natural resources and the disposal of wastewater and human waste in developing countries.

Year	Courses	Course Days	Days/ Course	Participants
1993	3	10	3.3	105
1994	5	14	2.8	143
1995	8	53	6.6	215
1996	9	47	5.2	180
1997	7	32	4.6	143
Total	32	156	4.9	786

Overview of PEAK courses held to date. In 1995, students of the post-graduate course "Urban Hydrology and Water Protection" (NDS at ETH Zürich) participated in the PEAK program for the first time.

In 1994/95, the post-graduate course "Urban Hydrology and Water Protection" was redesigned, and PEAK became an integral part of the course. As a consequence, the demand for PEAK courses increased, which has led to more frequent and more lengthy courses (see Table). In 1995, there were 53 course days per year, with an average course duration of 6.6 days. This was too great a demand for many of the lecturers. Experts from private industry voiced concerns about courses lasting longer than 2–3 days. Today, the average offering is around 30 course days per year.

It is typical for PEAK courses to cover a wide range of topics. So far, there has been almost no repetition, and each course draws a different audience. To date, most participants have taken only one course. Over the first five years, 65 individuals, roughly 160 companies and approximately 90 public offices and laboratories have been among the clientele.

Reactions of Course Participants

Naturally, course leaders and lecturers sense rather quickly how a particular course is being received, although these impressions can be singular, subjective, and shifted towards more positive memories as time goes on. In order to have a more objective evaluation, participants are asked to complete a rather extensive questionnaire. This allows us to evaluate the course through the eyes of the participants as well as to collect ideas for changes and additional topics. Here are a few representative examples of comments:

"The scientific contribution by EAWAG in the area of practical applications is extremely valuable to governmental entities and should be expanded."

"Talks were presented too much in a hurry (in order to stay within a tight schedule)."

"The field trip into the Alps was most impressive."

"Measure utopias against reality, but keep discussing utopias as well."

"The portion dealing with 'Theoretical Background' was more extensive than expected."

"For some participants, the courses dealt with too wide a spectrum of topics and problems."

"The relaxed atmosphere and motivation of the course organizers were most appreciated."

"A need for education which EAWAG should address exists in areas such as water management and agriculture, the cycling of chemical substances in factories and businesses, and economic evaluations."

For the most part, evaluations were rather positive and gave valuable tips for improvements. This, in turn, has increased the motivation of the lecturers and helped create the pleasant atmosphere which is obviously appreciated. We would like to highlight one point that became clear from the questionnaires, though: it is very valuable to carefully word the course

* German acronym for **P**raxisorientierte **EA**WAG-**K**urse.

advertisement in order to target the correct interest group and not to raise false expectations.

What is the Future of PEAK?

Both the need for continuing education and the offering of programs are increasing. Modern information technology opens entirely new possibilities for information exchange and dialogue. EAWAG wants to utilize these new tools and develop PEAK accordingly. Major areas of change include an increased partnership with other universities and technical institutions, with people working in the field, and more active engagement of course participants by using modern instructional methods and the tools of information technology. In addition to courses focused on individual topics, PEAK will offer an integrated course covering all the primary topics related to natural waters and water management. This course will not only draw on the strong expertise within EAWAG, but also involve external partnerships.

Herbert Güttinger
Director PEAK

PEAK Program 1999

March, 16–19 — **Taxonomy and Ecology of Aquatic Organisms, Part 2: Hydracarina** (A9/99)

A good systematic knowledge of aquatic communities is a prerequisite to the study of the biological diversity of streams, wetlands, lakes and ground waters. The Department of Hydrobiology and Limnology at EAWAG has, therefore, initiated a series of courses with the goal of teaching the taxonomy of aquatic fauna. Six selected groups of organisms will be presented in a three-year cycle. The course is intended for undergraduate, graduate students, and personnel of EAWAG and ETH, private firms dealing with ecological questions, and cantonal agencies and environmental organizations.

Part 2 Hydracarina introduces common morphological characteristics of aquatic mites (mainly Hydrachnidiae, true freshwater mites) as well as the most important European species found in standing waters, springs and streams. Participants will identify mites using collections of European Hydrachnidia species.

Reinhard Gerecke (Tübingen), Klement Tockner

June, 23–25 — **Sanitation in Developing Countries: Waste Management** (V19/99)

Problems of waste removal in urban areas. Experiences, lessons learned and possible solutions from practical experience.

Roland Schertenleib, Christian Zurbrügg

August, 24–26 — **"Natural" Tracers in the Environment: Fundamentals and Practical Applications**

Introduction to the theory and methodology of using radioactive and chemical tracers in environmental studies (transport processes, age determinations, etc.).

Werner Aeschbach, Jürg Beer, Rolf Kipfer

Aug., 30 – Sept., 1 — **Material Fluxes in Streams** (V9/99, repetition of V9/96)

(Sept., 6–8) Data collection (sampling and sample analysis), data processing and interpretation on the basis of primary chemical, physical and biological processes.

René Gächter, Jürg Zobrist

Sept., 14 — **InfoDay 1999** on the topic of **Ground Water**

Theresa Büsser et al.

September, 15–17 — **Taxonomy and Ecology of Aquatic Organisms, Part 3: Chironomidae** (A10/99)

Introduction to the taxonomy, biology, anatomy and morphology of Chironomidae; overview of literature and techniques for collection and conservation. Identification of species from the most important families.

Berthold Janecek (University of Wien), Klement Tockner

September, 27–28 — **System Identification and Modelling with AQUASIM** (B7/99, Repetition of course B7/98)

Introduction to the use of AQUASIM, a flexible computer program for the analysis of data and for the simulation of natural and technical aquatic systems. The course will be given in English.

Gerrit Goudsmit, Peter Reichert, Oskar Wanner

September, 29–30 — **Modelling of Lakes and Reservoirs with AQUASIM** (V20/99)

Usage of AQUASIM for the simulation of stratification, turbulence, substance transport, reaction and conversion processes in lakes and reservoirs. The course will be given in English.

Gerrit Goudsmit, Peter Reichert, Oskar Wanner, Alfred Wüest

October, 20–22 — **Fish in Swiss Lakes and Rivers** (B9/99)

The fish fauna of our rivers and lakes. Species, life histories, and habitats.

Rudolf Müller, Armin Peter

Address: PEAK, EAWAG, CH-8600 Dübendorf.
Fax: 0041-1-823 53 75; e-mail: heidi.gruber@eawag.ch
The current program can also be found at http://www.eawag.ch/Courses/peak.html

A Productive Institution Needs Qualified Employees

Continuing education is an important part of one's professional development. When one performs the same activities for years and is not open to changes and advances in the field or in society, (s)he will eventually not be able to adequately function in the workplace.

For employees of a scientific institution, this is even more true since the knowledge base in all of the different fields is continuously growing. In addition, it may become necessary to apply new work strategies as, for example, when traditional disciplines fall by the wayside or are merged with related disciplines. Another recent trend is an increasing orientation towards the practical application of research which ensures that research can be put to beneficial use.

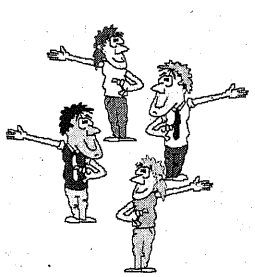
Personality Development Gaining Importance

In addition to technical training, increasing attention is given to "personality development": an institution is represented to the public by its employees and, therefore, has to ensure that they can fulfill this role satisfactorily. The institution must also provide a work environment which is conducive to creativity and unencumbered by personal quarrels or organizational problems.

EAWAG's Self-Image

EAWAG is well on its way in all of these respects, and its employees have the right (actually, the responsibility) to devote 5% of their time to continuing education. This directive has been binding since 1996 and has its origins both in directives from the Federal Government and in guidelines which EAWAG set for itself in 1994. The goal is to educate employees to the point where they are technically competent and able to work both independently and in teams. Leadership qualities and responsible thinking are strengthened on all levels. This is achieved through four continuing education focus areas:

- specific technical training,
- general training (e.g., didactics/teaching skills),
- personality training,
- leadership training.



Current Situation

A 1997 survey of EAWAG employees revealed that there was a large gap between continuing education interests and the actual use of course offerings. Three times more people were looking for a certain offering than the number who had participated in a course of their interest. It is the primary task for the near future to close this gap.

Primary areas of interest according to EAWAG personnel include in-depth training in their own fields, the communication of technical expertise to other personnel or lay people, project and work planning, and the acquisition of extra qualifications such as languages and information technology. The perceived need to develop stronger interdisciplinary ties was more ambivalent. While a majority of employees expressed interest in participating in projects cross-cutting disciplines, only a few considered it necessary to acquire technical knowledge in an unfamiliar field.

Various forums are trying to meet the wishes of EAWAG employees. For example, language courses have been part of EAWAG's course offerings for some time, and are now stabilized at a high level. Courses dealing with communication and project management are in the planning stages. Since 1993, EAWAG has had its own leadership training program. When EAWAG is not able to meet the education needs with its own resources, it is able to take advantage of close ties with ETH and other federal agencies to access their diverse offerings in continuing education.

Continuing Education for EAWAG's Graduate Students

Education of graduate students is becoming ever more important. Until 1992, participation in post-diploma coursework was required along with the actual dissertation work. Since then, requirements for the formal education of graduate students have been left up to individual departments and institutes and are, therefore, highly variable. In order to guarantee equal access to educational opportunities and to ensure a minimal level of education for all graduate students, an ETH-wide framework is being developed which will prescribe minimum requirements for graduate students. Graduate students themselves have submitted proposals. Continuing education is explicitly being reintroduced as a required part of doctoral studies. In addition to certain compulsory components, most proposals allow considerable room for voluntary educational activities. EAWAG has welcomed these proposals and is trying to offer its own courses and/or to facilitate participation in other courses of interest to its graduate students.

Future Needs

Overall, many positive changes are in progress. Despite the variety of educational opportunities, discussions persist in some departments

To the Retirement of Heidi Bolliger

When she came, over 30 years ago
her brown hair still quite aglow

to start and draw on EAWAG's staff,
titles, texts, numbers and graphs,

were still drawn with pen and with ink
with stencils and fingertips all pink.

At her desk the ruler she'd wield,
over a drawing board as large as a soccer field.

Madly she was drawing for the engineer,
and sewage lines and pipes were soon to appear.

Basins, containers, levies and tubs
for trickling filters and real live bugs,

viewed from above and below and behind,
from morning 'til late, she didn't mind.

Later she gained a new group of fans,
a good portion of the chemistry clan.

She saw how all these pH plots
can be traced back to the chemist's lot.

She created for the good of the American crowd
the now infamous-famous Stumm cloud,

a mysterious pile of aquatic-chemical data
generously wrapped in beautiful strata.

Lines and curves, thick and thin,
were dashed and hatched with the expert's spin.

So she created with the simplest of means
drawings that stunningly gleamed,

for scientist of all types and demeanors,
bearded or spectacled or neither.

Soon her art was known 'round the globe
and sent here and there to be probed.

At many a meeting researchers proudly present
what Heidi had produced to her content,

and all the world saw it with ease,
it had to be a Bolliger piece!

Drawn with that steady hand,
a masterpiece from Heidiland.

Suddenly a new age was here,
temporarily instilling some fear.

The peaceful world of graphic design
was intruded by PC's and CAD unkind.

An end to the ink and the mess
with pieces of paper as large as a dress.

The change from paper to screen,
she mastered with flexibility unseen.

Designer, Canvas, Photoshop,
they all were mastered in a hop.

Out with the drawing board as big as a house,
in with a funny new tool, called the mouse.

With the mouse firm in her hand,
she creates lines to cover the land,

all in a day's work without fright
and in color to everyone's delight.

Click and drag, copy and paste,
that's how figures are born in a haste.

Scanned from film, put on paper for print,
looking so good, books just can squint.

She satisfies her customer's growing demands
with circles and squares straight from her hand.

She often labored far into the night,
listening too easily to a desperate plight,

and then quietly cursed in a slow dribble
while trying to decipher an illegible scribble.

Often the scientists were rather confused
as to what to draw and which color to use,

and left the what and the where
simply up to Heidi's own flair.

Sometimes happy, sometimes in stress,
but mostly proud of her success,

she was glad to be surrounded so much
by all the scientist and researcher bunch,

and to produce at a fabulous rate
all the drawings that just couldn't wait.

Large is the number of authors about,
writing EAWAG publications day in and day out,

and keeping up the steady stream
of graphics to go onto the screen.

Thanks to our obsession with writing
we now can congratulate on retiring,

because the productions from Heidi Bolliger's hand
are known as the "Jewels from Switzerland",

shown in journals and books all about,
the most published figures, no doubt.

Heidi, you will leave us so soon,
throwing the whole bunch in a sad gloom.

We thank you for every line and every dash
out of your most valuable artist's stash.

We rise to a standing ovation:
"All the best to your retiration"!

Markus Boller
Original german version in EAWAG news 45D

Translation: Norbert Swoboda-Colberg
(in an attempt to imitate the master)

as to whether or not "valuable work time is lost to educational efforts". It can sometimes be difficult to justify participation in a given course; it may sometimes be easier to forgo participation rather than endure protracted departmental debates. This is where the leadership at EAWAG should step in and promote continuing education as an enrichment and stimulation for employees rather than a burden. The Personnel Representatives (PV) at EAWAG support such activities and function as intermediaries between personnel and continuing education personnel. They can be called upon to voice concrete suggestions for courses as well as problems regarding intradepartmental attitudes towards continuing education.

Sylvia Harms
Member, Personnel Representatives

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

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