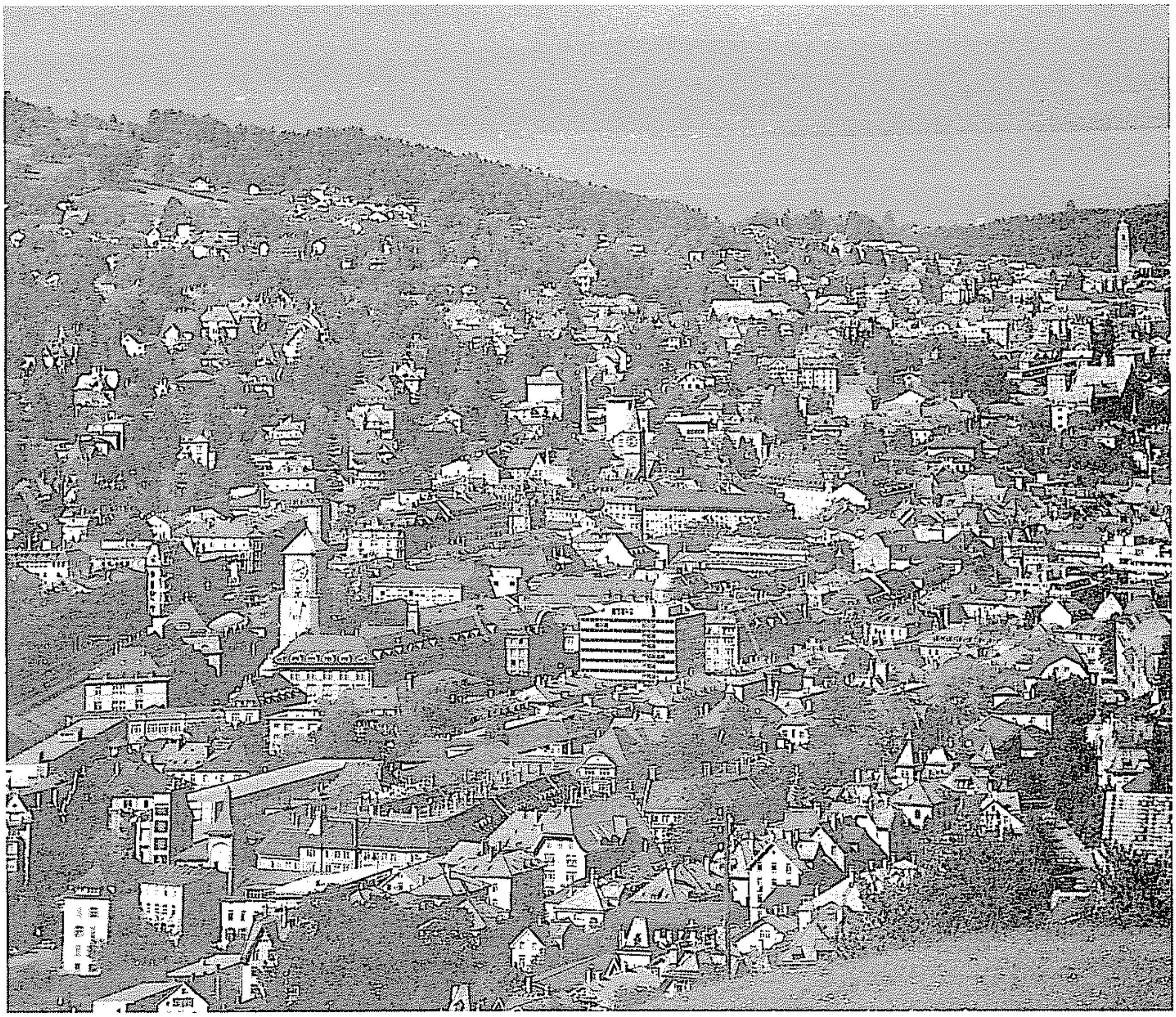
EAWAG

EAWAG news

35 E February 1994

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



Dear Readers,

EAWAG news has a new look and a new layout. We hope these changes will enable us to communicate more effectively with you. The first page will inform you of the contents at a glance. We have given serious thought to a new name for the EAWAG **news**. In an internal contest, the name EAWAG impulses was the winner. Nevertheless, we are sticking to the old name in order to publish our paper twice a year in German, French and English under the same title. A consultation with our French and English speaking co-workers made it clear that in these languages "impulses" does not mean only positive, forward looking initiatives. On the other hand, "news" is also not ideal. As a word, however, it exists in all languages and has the same meaning for everybody.

The first of two issues per year of EAWAG **news** will inform you about new aspects and developments in our scientific activities. In this number you will find three such articles. One is on the theme of the materials turnover and metabolic processes in metropolitan private households, a highly current theme. A second article introduces a new working group in the department of microbiology. It has the future task of contributing to the molecular biological aspects of environmental research. Since the middle of the eighties, work has been carried out at the EAWAG on the subject of atmospheric chemistry. Photochemical summer smog is the theme of the third article.
The secon issue will be concerned with our yearly Information Day. In the next number the topic "From Environmental Protection to Integrated Management: Systemsoriented Approaches in Theory and Practice" will be discussed. To find out more, turn to page 29.
Both numbers feature information about further training and other events at the EAWAG, as well as internal developments and changes.

The EAWAG also has a new logo. You will find it in the top left hand corner of the front page and on this page. Our "new symbol" consists of three rectangles, which symbolize our activities in the areas of water, soil and atmosphere. At the same time they represent our activities areas: research, teaching and consulting. The dynamic interaction of these areas, symbolized by the crescent moon, points to our efforts in interdisciplinary cooperation. This new logo makes possible a uniform presentation and makes our publications more easily recognizable.

I hope that you will enjoy reading this EAWAG **news** and that we can count you among our future reading family and friends of the EAWAG.

A. Zehnder

Alexander J.B. Zehnder

EAWAG

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Title page picture
Urban settlements are complex anthropological structures and networks whose personal and material transport is determined largely by their private households. The turnover of goods and metabolic processes in the households of the city of St. Gall are being studied in the project "Metapolis".

Peter Baccini, Hans Daxbeck, Emmanuel Glenck, and Georg Henseler

METAPOLIS

Material fluxes and processes in private households of a city

Introduction

Private households are usually depicted as economic, demographic or structural entities. In this study, however, they are also understood to be the conveyors of important metabolic processes. Their significance is based on the fact that they determine public transport and the transport of goods within an urban system – both quanitatively and qualitatively. This study is predicated on three main issues:

1. The reason for waste management systems is not just to provide sanitation, hygiene and aesthetic surroundings, but to produce environmentally friendly products. Such a mandate can only be carried out efficiently if waste managers have an early warning system – early enough that they know which goods they are to collect and treat and in what amounts.
2. From the scientific point of view, this work presents a challenge to the methods applied. For the first time, market data on the importation of goods into a city have been combined with data on the disposal of wastes.
3. The long-term development of urban systems must be based on an economy committed to sustainable resource management. This, in turn, requires a fundamental change in socio-political decision making for which constantly updated information on the behavior of resources in urban systems is essential.

The METAPOLIS study was carried out as part of the Swiss National Science Foundation project entitled "The City and Transportation" (NFP-25). The work was conducted by EAWAG's Department of Resources and Waste Management in collaboration with the City of St. Gall and the Institute for Market Analysis AG (IHA) in Hergiswil.

1. The urban system as an anthropogenic ecosystem

Urban systems are the most complex of anthropogenic structures and networks. For both supplies of goods and disposal of wastes, urban entities depend primarily on large neighboring agricultural areas within a continental environment of geogenic ecosystems and global trade networks. As a consequence of the increased density of transportation routes and the sharp growth in mobility over the past several decades, this "urban character" not only applies to cities with population densities ranging from thousands to tens of thousands per square kilometer. It now includes areas with a few hundred people per square kilometer and even greater per capita energy and materials fluxes.

In this study, we treated the city as a biological and cultural organism whose smallest units of metabolism ("cells") are the private households. Today's market researchers investigate a city's supply of goods by various means, while managers of waste treatment plants (e.g., waste incineration plants, waste disposal sites and sewage treatment plants) volunteer information on the quantities of disposed materials that they receive. Unfortunately, there are large gaps in what is known about the composition of goods supplied, goods disposed of and their respective residence times in a domestic household.

2. Questions which this study investigated

Answers to the following questions were discussed and sought during the course of this project:

1. Quantitatively speaking, which are the most important goods needed by the urban person in his/her private household? (i.e., "NOURISH", "CLEAN", "RESIDE and WORK", and "TRANSPORT and COMMUNICATE")
2. Which goods contain resources and environmentally relevant elements which are eventually transferred to waste disposal systems? How do they become distributed in the air, water and ground; that is, how are they returned to the anthroposphere?
3. How do the metabolic processes change as a function of time, and on which variables do they primarily depend? (e.g., storage time, residence time of goods, principles involved, etc.)
4. Can future needs for waste disposal plants and regulatory measures (e.g., laws, economic tools, taxation, information, education) be evaluated by using a metabolic model of individual households?

3. Methods

The city of St. Gall was chosen as the subject of our research because it met three main criteria: (1) its infrastructure for supply; (2) its infrastructure for waste disposal; and (3) its political framework. The metabolic processes were assessed by flux analysis. Initially, six major categories of processes were chosen: (1) private households; (2) collection of household trash and commercial solid waste; (3) separate collection of residential solid waste; (4) sewers; (5) waste incineration of municipal solid waste; and (6) sewage treatment plant. The input and output goods were identified for each process (summarized in larger categories for a number of mixed goods) and were compared in a flux system (see Fig. 1). The non-metals carbon, phosphorus, sulfur and chlorine and the metals aluminum, iron, copper and zinc were chosen as indicator elements. Even though the economic and temporal framework of the project limited our choice to these eight elements, the selection was based on consideration of important physical, chemical, biological and process engineering criteria to ensure a broad spectrum of behavior patterns.

For the key component of the system – the private household – data on the input of goods were collected from three sources:

1. Data on consumer goods obtained from the Institute for Market Analysis AG (IHA)
2. Data on energy sources obtained from municipal and national statistics
3. Data on the water supply extracted from municipal statistics

Data related to waste disposal were obtained from two sources: (1) municipal statistics and (2) a program established specifically for this investigation which was comprised of flux analyses of elements from sewage treatment plants, from waste incineration plants and from residential solid wastes collected from especially established routes.

In order to comprehensively describe the system of METAPOLIS, information on 43 processes and about 200 goods was needed. Their flows (according to mass) and their concentrations (by element) were measured or estimated. One necessary limitation of the study was that only the mobile goods of individual households were considered. Such goods include consumer items (e.g., water and air), goods with short and medium residence times in a household, energy sources, private modes of transportation (car, bicycle) and gaseous, liquid and solid waste products. Excluded from the analysis were physical structures (houses, apartment buildings) including sanitary and electrical installations, other permanent installations such as road and railway networks, water and sewage systems, and energy and communication infrastructure.

4. Results

4.1 The contribution of private households to the urban flow of goods (Fig. 1)

The input into private households amounts to about 100 metric tons per capita per year (t/c·a). About 80% is as tap water and 20% as air. The short-lived intermediate consumer goods and energy sources (mostly petroleum products) each contribute about 1%. The long-lived or durable consumer goods such as cars, furniture and household appliances also make up about 1% or 100 kg/c·a.

Approximately 75% of the city's flow of goods into waste disposal systems is through the private household (about 100 t/c·a), while the proportion originating from the city's industries is about 30 t/c·a. The total turnover of the city of St. Gall (METAPOLIS system), however, is much greater than sum of these two, totalling about 270 t/c·a. Roughly 95% of this amount may be attributed to rainfall and other drainage water into the city's sewer system. The balance originates from input of air into the municipal solid waste incineration plant and from the importation to the incineration plant of residential solid wastes from neighboring communities. Solid wastes from private households in St. Gall, on the other hand, make up only about 20% of the material received by the waste incineration plant, while the sewage treatment plant receives municipal wastes almost exclusively

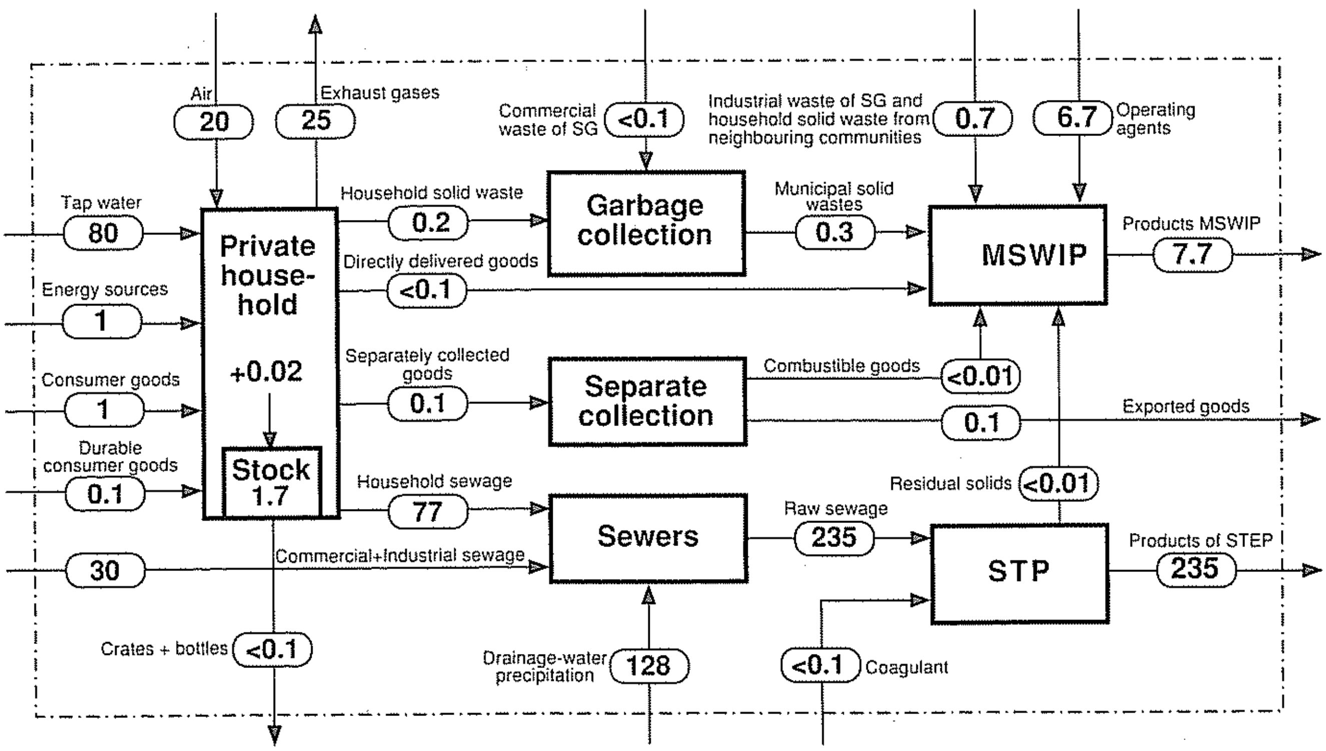


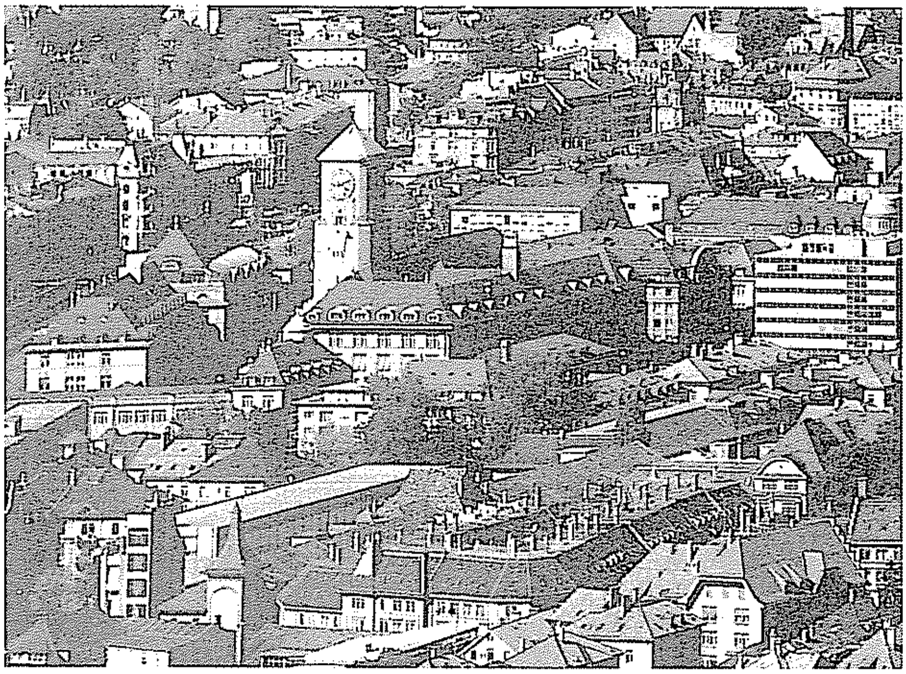
Fig. 1
The flux of goods through the METAPOLIS system in tons/capita/annum (t/c·a). (ind & trade: wastes from industrial, trade, agricultural and public buildings' households)

As a consequence, the quantitatively most important product of the municipal waste disposal system is the treated wastewater, totalling about 230 t/c·a. In second place are exhaust gases amounting to 0.7 t/c·a. Only about 200 kg/c·a (about 30%) are being reused (recycled), mainly for recovery of raw materials (e.g., paper, composted biogenic wastes, glass, metals). The only sink of materials in the system appears to be the private household. The stock of consumer goods stored in 1990 amounted to about 2 tons per person. An annual growth rate of around 1% was noted for the period of 1990–91.

4.2 The relative importance of the various activities in the private household

About 75% of the total flow of materials through residential households is categorized as "CLEAN" as determined by water consumption of about 75 t/c·a. The water is used to transport the relatively small amounts of human waste and dirt (about 0.6 t/c·a or 100 times less than the amount of water) into the flushing sewage system. The annual flow of goods for the activity "RESIDE and WORK" amounts to around 10 t/c·a or about 10% of the total. It is primarily use of air for burning heating oil followed by the amounts for water and energy. The activity category "NOURISH" amounts to an annual total of 9 t/c; two-thirds of it (or about 10% of the total) consists of air for the oxidation of foodstuffs (respiration). The rest consists of water. The activities "TRANSPORT and COMMUNICATE" fall in the same range at about 8 t /c·a; again the air plays the most important role as it is required to oxidize fuels.

The stocks of goods on hand sorted according to activity demonstrate the following: the car (activity "TRANSPORT and COMMUNICATE" equals the sum of the furniture plus appliances in the activity category "RESIDE and WORK" (about 0.5 t/c·a). If the permanent stock of fossil fuels (0.5 t/c·a) is ignored, then the automobile is the most important commodity based on its mass equal to about 50% of all stored goods.



Private households are important contributors to the flux of materials in the city of St. Gall.

4.3 Selected materials fluxes in the private household

Eight indicator elements were chosen for the METAPOLIS study. The results of their balances for the private household are summarized in Fig. 2 and Table 1.

The following metabolic characteristics of the various elements are obvious from this analysis:

- 90% of the carbon, mainly imported in the form of fossil fuels, is transferred as CO_2 to the category exhaust gases.
- Sulfur is is mainly imported in the form of intermediate consumer goods (e.g., foodstuffs and cleansing agents) and is exported mainly as sewage and exhaust gases.

	C	S	P	Cl	Al	Fe	Cu	Zn
Input	[kg/c·a]							
Durable consumer goods	30	0.1	0.03	**3.1**	**3.1**	**38**	0.76	0.49
Consumer goods	240	**1.7**	0.82	**5.4**	**3.5**	3.8	0.03	0.25
Energy sources	870	1.3	0.03	0.2	0.1	0.5	<0.1	<0.01
Tap Water	<10	**0.9**	<0.01	1.2	<0.1	<1	<0.1	<0.01
Air	<10	0.2	<0.01	<0.1	<0.1	<1	<0.1	<0.01
Total	1150	4.2	0.89	10	6.7	42	0.79	0.75
Output	[distribution in %]							
Stock	<1	<1	1	10	13	**25**	**29**	26
Exhaust gases	**90**	**34**	<1	2	<1	<1	<1	<1
Sewage	2	**47**	**76**	45	8	<1	<1	3
Seperately collected goods	3	9	6	25	**39**	**62**	**56**	**48**
Household solid wastes	5	8	17	18	**40**	13	15	**33**
Stock on hand	[kg/c]							
Durable Consumer goods	400	21.7	0.96	**30**	33	**420**	**7.4**	**5**
Buildings	**2500**	n.d.	n.d.	**10**	**3000**	**800**	**10**	**5**

Table 1 n.d.: not determined

Overview of the fluxes of the elements in imported goods of the private household and their distribution among the output goods given in percent. The most important fractions are printed in bold type; the distributions within the output refer to the calculated fluxes of elements.

- Phosphorus is imported in the form of foodstuffs; 80% of it is exported in sewage. The flow of P through residential sewage may, therefore, be an accurate indicator of the activity "NOURISH".
- Chlorine is mainly imported in the form of consumer goods (foodstuffs containing chloride ions) and in final consumer goods (e.g., in polymers containing chlorine such as PVC plastics). The output of chlorine is mainly in sewage and secondly through separately collected solid waste products and to a smaller extent in residential solid wastes (i.e., PVC plastics).
- The assessment of the four selected metals – aluminum, iron, copper and zinc – exhibit some similarities. They are imported to a large extent in the form of long-lived consumer goods, most significantly as automobiles. (Aluminum is the exception; its fraction in packing materials is equal to its content in automobiles.). Significant amounts also flow into stored goods, which remain in the private household. When these metals leave the private household, they usually do so through the separate collection of garbage. However, large amounts of aluminum and zinc remain present in wastes from residential sources.

Summarizing the results of this study, we can postulate that the separate collection of residential solid waste already represents the most important output of quantitatively significant resources from private households (metals, organic polymers). This raises the question as to whether the respective reserves within the buildings themselves (not a study subject of METAPOLIS) are not even more important. In Table 1, comparative amounts are listed on the last line. First approximations of fluxes coming from buildings (only for private households, data from [2]) suggest, however, that the consumer goods in private households, with the automobile in first place, are more significant as carriers of resources; that is, for iron the ratio of the fluxes from buildings compared with those from final consumer goods is 1:2, for zinc it is 1:5, and for chlorine it is 1:15.

In summary, the choice of a few indicator elements allowed for a preliminary balance on the most important carriers of resources in the complex metabolism of the private household. It is obvious that the final consumer goods are significantly more important than the short-lived intermediate consumer goods, although the latter seem to play a larger perceived role in daily life. The most important transformations of energy sources, the fuels, occur as exhaust from heating systems and combustion engines. Solid waste from residential sources, still an important commodity in political discussions, is of secondary importance according to this comprehensive assessment of the resource potentials of materials.

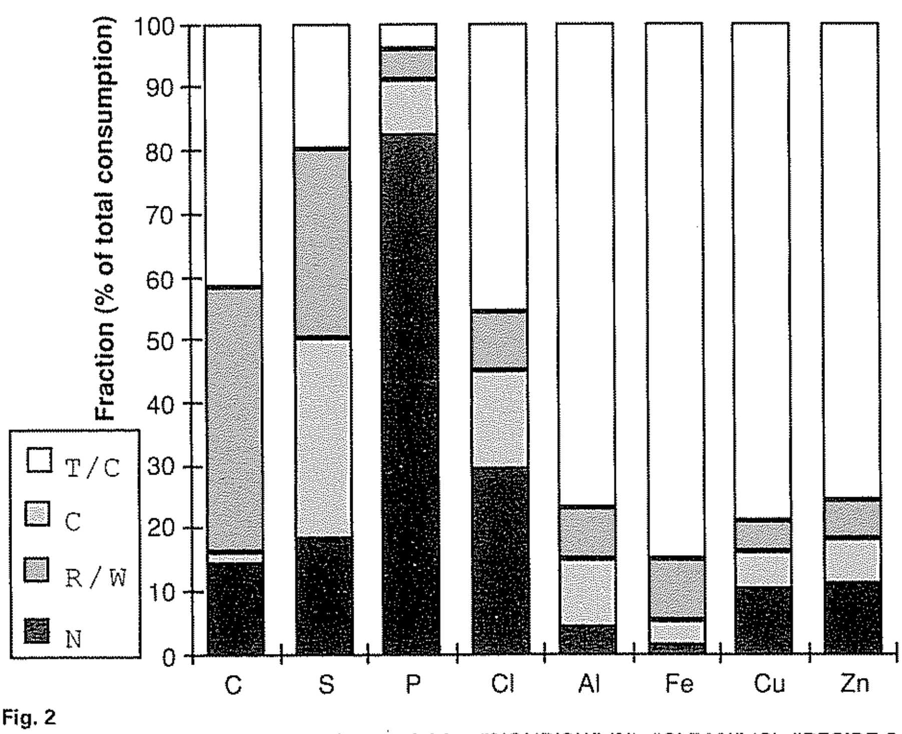


Fig. 2
The relative contributions of the four activities "NOURISH" (N), "CLEAN" (C), "RESIDE & WORK" (R/W), and "TRANSPORT & COMMUNICATE" (T/C) to the fluxes of eight selected elements in a the private household.

4.4 Changes in the fluxes of goods and elements as a function of time

The fluxes of goods and the metabolic phenomena presented here represent a momentary situation.. The calculated growth ratios, however, do not permit any conclusions to be made about past or future development. Investigations on the consumption of energy sources (fuels) in the 1980s provide conclusive evidence that' the consumption of energy under the category "RESIDE and WORK" has decreased slightly in spite of the increased demand for living space per capita, but that the consumption of fuel has continually increased with an annual growth rate of 3%. As physical structures themselves were not taken into consideration, the observation of that development within the system of METAPOLIS was not possible. The observation of the growing fluxes of goods through the activity "TRANSPORT and COMMUNICATE" in this study parallels similar trends in national statistics.

Water consumption, which has leveled out over the last decade, and the production of sewage sludge, which has remained constant, seem to suggest that the concentration of elements like copper and zinc are increasing slightly in sewage sludge.; however, the evidence for such a development cannot be found. It is possible though that reductions in use of these metals have been made in the industrial sector. An obvious decrease in P concentrations by about 30% since 1985–6 clearly corresponds with the ban on phosphates in detergents; a concomitant increase in aluminum concentrations is also evident, presumably due to the introduction of zeolites as phosphate substitutes.

During the past decade a growth in both intermediate and final consumer goods in private households has been observed. This development is consequently mirrored in the wastes that are produced. The amount of residential solid waste stagnated between 1982 and 1986, but the separately collected residential solid wastes increased to a new level until around 1987, after which the mixed residential solid wastes increased again suggesting that the sum of the waste fluxes are constantly increasing.

5. Conclusions and hypotheses

The results of this study support the following general statements or hypotheses:

Cities are flow-through reactors

The rapid turnover of goods in private households is characteristic of urban systems in affluent societies. From an ecological point of view, the most important goods with respect to their metabolism are water, air and fuels. Communities like St. Gall are found in the thousands throughout the First World, but do not yet embrace an economic system based on recycling. They require a large geographical area from which to both obtain supplies and to dispose of wastes. With respect to the flow of elements, St. Gall has not yet reached steady state; the growth of the urban stock of stored goods during the past 10–20 years is the result of an increased flow of goods on a per capita basis and is not due to an increase in the population.

Energy resources are key factors

From an ecological point of view (i.e., demand for resources and contamination of the environment), the most significant goods in the metabolism of private households are the energy resources that involve the activities "RESIDE and WORK" and "TRANSPORT and COMMUNICATE". If the fluxes of elements that are associated with these activities cannot be reduced, then all other efforts to protect natural resources and reduce environmental pollution resulting from individual households will remain of secondary importance. This is mainly so because residual emissions are no longer in first place due to improvements in waste treatment technologies. Above all, the strong area of growth within the activity category "TRANSPORT and COMMUNICATE", with its dominant source and user of energy, the automobile, begs for new limitations – both structural and in energy use. Without such measures, the nature of all other corrections will remain superficial. The development of an environmentally-oriented resource economy for cities must thus be carried out through changes in the urban structure. Strategies for reducing distances between supply centers and waste disposal plants are needed as well as shorter distances between living and working sites. In short, the cycle of resources should take place within smaller geographical areas. Such changes will require plans for revamping the physical, economic and social structures of the urban system within a time space of several decades. If we choose to remain within the existing structures or to continue the recent trend of expanding resource cycling dependence to even larger geographical areas, then we can already predict that those nonrenewable natural resources (e.g., metal ores, synthetics), which are being protected through recycling, will have to be reclaimed at a higher price through the use of nonrenewable energy resources.

Separate collection is a resource

Comprehensively viewed, the separate collection of residential wastes is already the most significant pathway employed for the disposal of most other important resources (metals and synthetic materials); therefore, it should be investigated alongside the disposal pathways from industry since, with the exception of carbon as an indicator of energy use, private households produce the smallest fraction of the total flow. The separate collection of residential solid waste has, however, not yet been sufficiently studied and the area of structures also needs to be considered in future investigations. Before efforts are made to promote the differentiated separation of wastes in private residences, we should consider shifting the emphasis towards the development of more efficient recycling processes.

Water use revisited

The urban flushing sewage system with subsequent sewage treatment is only efficient with regard to the treatment of phosphorus. For all other elements, this step in the handling of resources is one of low importance. The urban sewage transportation and treatment system can only be substantiated with regard to hygiene and water pollution control. The undifferentiated way in which water is used should be critically questioned since the near-term improvement in the quality of sewage sludge and treated wastewater cannot be achieved without changing the infrastructure of a populated area (i.e., supply, waste disposal, building techniques and installations in households).

Annual bookkeeping on energy and element balances are essential tools

The question as to whether a metabolic model for private households would be suitable for prediction of the future demand for waste disposal installations and accompanying regulations can basically be answered as "yes". Such predictive value would, however, require annual bookkeeping on energy and element balances which, in turn, would depend both on market research for the region and accurate records kept by waste disposal plants. Assessing the situation at a given moment in time as this study did was necessary in order to develop the methods used; however, it did not permit the development of a predictive model for near-term use in this region.

[1] RESUB (1990): Der regionale Stoffhaushalt im unteren Bünztal, P.H.Brunner (Ed.), Die Entwicklung einer Methodik zur Erfassung des regionalen Stoffhaushaltes, Abt. Abfallwirtschaft und Stoffhaushalt, EAWAG, 8600 Dübendorf

[2] Baccini P. und Brunner P.H. (1991): Metabolism of the Anthroposphere, Springer-Verlag, Berlin–New York

Jan Roelof van der Meer, Johan Leveau, and Christof Werlen

Genetic adaptation of microorganisms to environmental pollutants

Are microorganisms able to degrade all xenobiotic chemicals in the environment or can they adapt to do so? How important are genetic mechanisms of adaptation? Owing to the use of recently developed molecular genetic tools, microbiologists have obtained new insights into understanding adaptive processes in microbes, which may lead to better predictions on the biodegradability of compounds in the environment. However, even though many genetic techniques have reached a state of routine use, the puzzle of adaptive strategies that microorganisms display in a changing natural environment is far from completely solved.
The authors make up a new research group "Molecular Microbiology" in the Department of Microbiology at the EAWAG. This article will encapsulate some molecular genetics concepts and methods and describe the current status of ideas on how microorganisms can adapt to xenobiotic chemicals in the environment.

1. Adaptation of microorganisms

If one places microorganisms in an environment with a strong selective pressure, mutants will appear within a relatively short period of time that have adapted to this particular condition and which outgrow the original population. Well-known and at the same time unpleasant examples of such rapid adaptations are the acquisition of resistance to antibiotics by pathogenic bacteria in clinical environments, or the continuously changing surface structures of other pathogens (e.g. *Borrelia* species) by which they can evade host-defense mechanisms. Perhaps less well-known are the adaptations of bacteria to recognize and digest novel food sources. The food palette of microorganisms in general consists of small molecules like sugars, amino acids or carboxylic acids, although they have probably evolved the most diverse ways within the living world of using carbon compounds as food and energy sources [1].

We are interested in investigating the possibilities and the molecular mechanisms for "food" adaptation of microorganisms so that they can use environmental pollutants as novel food and energy sources – sources which previously may have been non- or poorly digestible. In several recent studies it was shown that microbial communities became "suddenly" able to degrade pollutants after a long period in which nothing appeared to be degraded, suggesting such an adaptation [2]. Also in the laboratory itself, pure cultures of microorganisms can be grown, and selection for new metabolic capabilities appears to be possible.

How do microorganisms adapt to use pollutants as novel carbon and energy sources which they previously did not consider edible? We must first consider the reasons why some hydrocarbons would not function as food for microbes. Food molecules have to enter the cell. This can take place either by an active uptake mechanism or by a passive diffusion process. Sometimes larger molecules are first broken down outside the cell into smaller pieces, which are then subsequently taken up. Unfortunately, not so much is known about the possibilities for (passive or active) uptake of environmental pollutants. Secondly, when a compound has entered the cell, it has to be recognized as a digestible food source. This task within the cell is normally performed by specialized sensor or regulator proteins that can interact with the food molecule and then stimulate the expression of genes encoding the enzymes needed for conversion of the compound. However, when a compound does not give such a response with existing sensors, it is not considered a useful food source and is not subjected to transformation by metabolic enzymes. A third possibility for an incomplete digestion can be that the existing metabolic enzymes are not suitable for catalyzing the transformation reactions. However, if a novel molecule looks enough like a digestible compound there is a chance that existing enzymes will partially metabolize the compound but at a very low efficiency. If suitable enzymes are not present at all, not even for nonspecific side reactions, the compound simply cannot be used by the organism.

Two different ways for adaptation of microorganisms to pollutants can occur. If the compound is, in principle, recognized as a food source and the necessary genes only have to be switched on, we speak of "biochemical adaptation". If there is a missing link in one of the possibilities described above, then changes or additions are needed in the existing genetic information so that altered enzymes or proteins can be synthesized that accomodate the novel substrates. In this case we speak of "genetic adaptation".

2. Molecular genetics in a nutshell

2.1 Genes And Gems (Gemmos)

Bacteria carry their hereditary information on a single chromosome in the form of a closed circular DNA molecule. On the DNA are the regions for the different genes, the basic elements of the genetic information, which encode the enzymes, proteins and ribosomal RNAs required for a a cell to function. This chromosomal DNA molecule in bacteria has a size of between 2 and 4 million nucleotide base-pairs. Genes can be as small as 100 base-pairs (e.g., holding the information for a bacterial toxin protein of approximately 30 amino acids) or as large as several thousands of base-pairs (e.g., coding for very large extracellular proteases). Reading the genetic information ("transcription") and subsequent synthesis of functional proteins ("translation"), involves a complex interplay between DNA and various proteins, binding or modifying the DNA molecule. On the DNA itself, all kinds of signals in the form of specific short sequences of nucleotides are present to regulate, activate or repress transcription and translation – the simplest ones being the "start" and "stop" signals for protein synthesis.

In growing bacterial cells, the chromosome is continuously being duplicated; therefore, at various states of replication, cells have multiple copies of their chromosome. In some bacteria, two different chromosomes have been detected, a larger one and a smaller "mini-chromosome". In addition, most bacteria have other non-chromosomal DNA molecules which are called "plasmids". Plasmid DNA may range in size from 2000 to more than 700,000 base-pairs. In the latter case, the distinction between a "mega-plasmid" or a "mini-chromosome" is rather artificial. What is the natural function of plasmids? The genetic information on the bacterial chromosome, at least in theory, is sufficient for replication, growth, activity and survival of the bacterial cell. Plasmid DNA molecules, on the other hand, can contain the genetic information for additional properties, such as resistance to antibiotics or heavy metals, or specialized metabolic traits, such as degradation of aromatic compounds like xylene and naphthalene. Other interesting features of plasmids are that they can be present in more than one copy per cell (up to several hundred copies), and that they are sometimes able to transfer themselves – even other plasmids – from one bacterial cell to another. This process is called conjugation. We will discuss later how important these features of plasmids may be in the process of microbial adaptation.

When it is isolated from an organism and carefully purified, the DNA molecule can be investigated, characterized and manipulated in the laboratory. One of the most important techniques to do this makes use of so-called restriction enzymes which cut the DNA at specific positions. Other enzymes called ligases can be used to glue two ends of a DNA molecule back together again. In doing so, researchers can isolate small fragments of a particular DNA molecule which contain the coding region of a single gene. This DNA fragment can then be attached to a plasmid DNA molecule and introduced into a different bacterial cell. The plasmid and its foreign DNA fragment will be replicated like a normal DNA molecule, and the genetic information present on the plasmid can be expressed by the bacterial cell. The function of the gene on the foreign DNA fragment can then be investigated (e.g., by looking at the synthesis of a protein or by measuring its enzymatic activity in the new host bacterium). A bacterium that contains a DNA fragment derived from another DNA molecule by *in vitro* genetic techniques is called a Genetically Modified Microorganism (abbreviated as GEM or GEMMO). Most often these techniques are used as tools in the laboratory to investigate the genetic characteristics and biochemical properties of a particular organism; however, applications of these techniques in biotechnology are manifold, varying from the high-scale production of particularly interesting proteins or enzymes to the construction of "Superbugs", which are intended to degrade a wide variety of toxic compounds at high rates [3].

2.2 Blobs And Flops: Techniques In Molecular Genetics

Interpretation of genetic data can be quite different from analyses carried out by physicists or chemists, or even other biologists. Although the concepts of genetic experiments are quite often complicated and require substantial background information, the actual data consist mainly of banding patterns. These bands are, for example, fragments of DNA, proteins, proteins interacting with DNA, or DNA

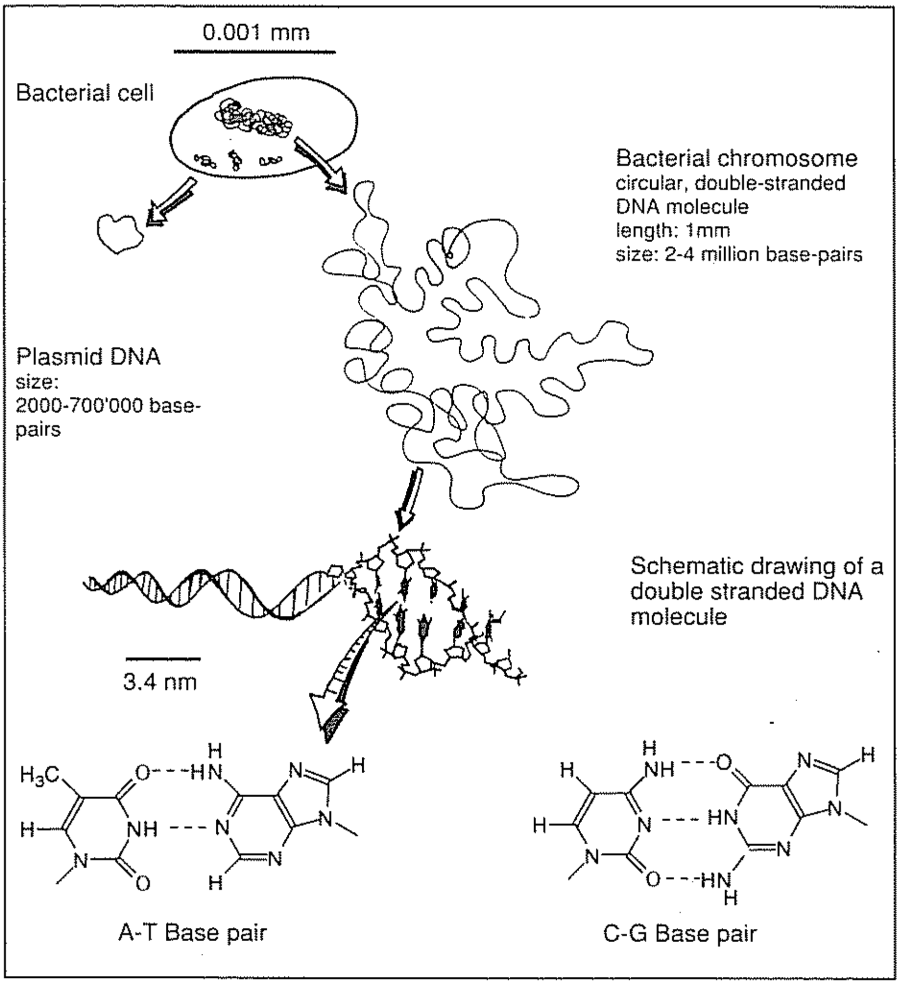


Fig. 1
Schematic visualization of the molecules that make up the genetic material in bacteria.

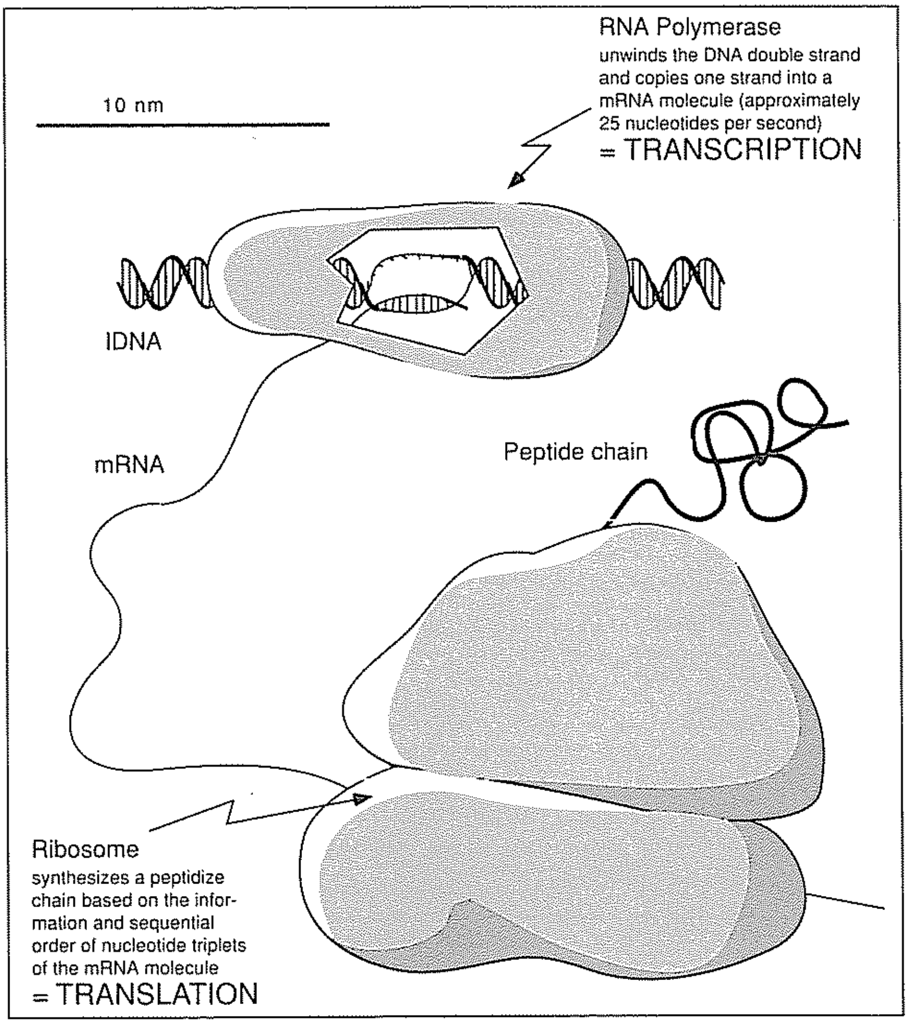


Fig. 2
Genetic information present on the double-stranded DNA molecule is continuously "read" (copied) and "translated" into proteins within the living cell.

fragments interacting with RNA. They can be made visible by various staining techniques including the use of radioactive labeling and subsequent X-ray photography. The different protein or DNA fragments are separated from one another by electrophoresis, mostly performed by running the samples in gel matrices, such as agarose or polyacrylamide, on which an electrical current is applied between a negative and positive pole. DNA fragments with sizes between 50 base-pairs to more than 100,000 base-pairs can separated. Separation can be so sensitive that DNA fragments differing by only one base-pair in size appear as discrete bands on a gel. This sensitivity is required when the sequence of base-pairs on the DNA is to be determined – a technique called "DNA sequencing".

Two methods that are widely used are DNA–DNA hybridization and PCR (which stands for Polymerase Chain Reation). By using DNA–DNA hybridization, it is possible to test whether an unknown fragment of DNA has a homology in its sequence of base-pairs to another known DNA fragment. This technique is based on the principle that two single-stranded DNA molecules can form a double-stranded molecule (the *hybrid*) when the nucleotides in both molecules form base-pairs. The hybrid, however, does not need to be perfect; that is, not all the nucleotides need be complementary. Some mismatches are allowed, since the stability of the hybrid molecule depends on temperature and ionic strength. Under experimental conditions, one of the two DNA fragments is bound to a carrier, typically a nylon or nitrocellulose sheet, in single-stranded form. The other fragment is added in single-stranded form in solution carrying a detection label (e.g. ^{32}P-radioactive nucleotides) and allowed to form hybrids with the bound fragment. The positions where the fragments have reacted with one another can then later be made visible by, for instance, X-ray photography.

Polymerase chain reaction (PCR) is an enzymatic reaction used for amplifying DNA fragments by use of a DNA-synthesizing enzyme – DNA polymerase. The DNA polymerase will synthesize a new strand of DNA from a single-stranded DNA molecule that functions as its template. For this synthesis, DNA polymerase needs a starting-point (a primer), which is usually a short piece of single-stranded DNA hybridized to the template at a specific position. The reaction is carried out in cycles, in which the DNA is made single-stranded, primers are allowed to hybridize and DNA synthesis takes place. In 30 such cycles, specific sequences can be amplified from perhaps a few copies to several million, thereby facilitating their detection. The specificity of the detection, however, is determined to a large extent by the binding of the primer to the template. If the primer binds to more regions on the template, false amplification products occur. PCR has many different applications, but one of its powerful characteristics is that it allows the detection of minute amounts of a specific DNA sequence. These sequences may be amplified in DNA derived from a single contaminating microorganism in, for example, a food product, or from traces of human blood in forensic samples.

3. Horizontal and vertical evolution

3.1 Evolving Enzymes and Proteins

Which genetic mechanisms play a role in the evolution of enzymatic specificities which may then result in adaptation of the cell? To obtain novel enzymes, changes or additions in the existing genetic material have to take place. The cellular processes that lead to changes in DNA sequences are often named *vertical evolutionary processes*. The simplest of these are single base-pair changes in a DNA sequence. This can be a spontaneous process, due to mistakes which take place during replication of the DNA molecule. Frequencies of spontaneous mutation are, in general, very low – approximately 10^{-10} per nucleotide per replication round. This means that the frequency of a spontaneous mutation occurring somewhere in the whole genome of a bacterial cell is between 0.1% and 1% per generation. Most spontaneous mutations will pass unnoticed for a bacterium, leading to an accumulation of individual changes and slow process of divergence of DNA sequences. Sometimes, mutations are directly beneficial for the cell (see below); at other time, they may be lethal, for instance, if they disrupt the coding sequence of an essential gene. Mutations can, of course, also be induced by toxic agents which interact with the DNA or by events causing damage to the DNA (e.g., UV radiation). In these cases, mutation frequencies can be much higher, although the cell have various mechanisms to repair damage to the DNA. Changes in the DNA sequence are not limited to single base-pair changes; larger deletions, duplications, or inversions of short sequences may also occur, all resulting in the continuous change in sequence information.

Can we find evidence that enzymes with altered substrate specificities to xenobiotic compounds have indeed evolved in bacteria? The effect that single base-pair changes can have is best exemplified on the metabolic pathway for toluene and xylenes in the bacterium *Pseudomonas putida* mt-2. This organism carries a relatively large plasmid DNA molecule which contains the genes for the degradation of methylated benzenes [4]. The plasmid is self-transmissible, meaning that it can transfer itself to other bacterial cells – not necessarily of the same species!. The bacterium and the catabolic genes for toluene degradation have been manipulated extensively in the laboratory in order to determine their limitations and potentials for biodegradation. Mutants of the strain could be easily generated that contained enzymes for toluene degradation with other substrate specificities as the wild type enzymes [5]. Furthermore, mutant bacteria were isolated with altered food recognition properties. This appeared to be due to changes in the regulator protein XylS.

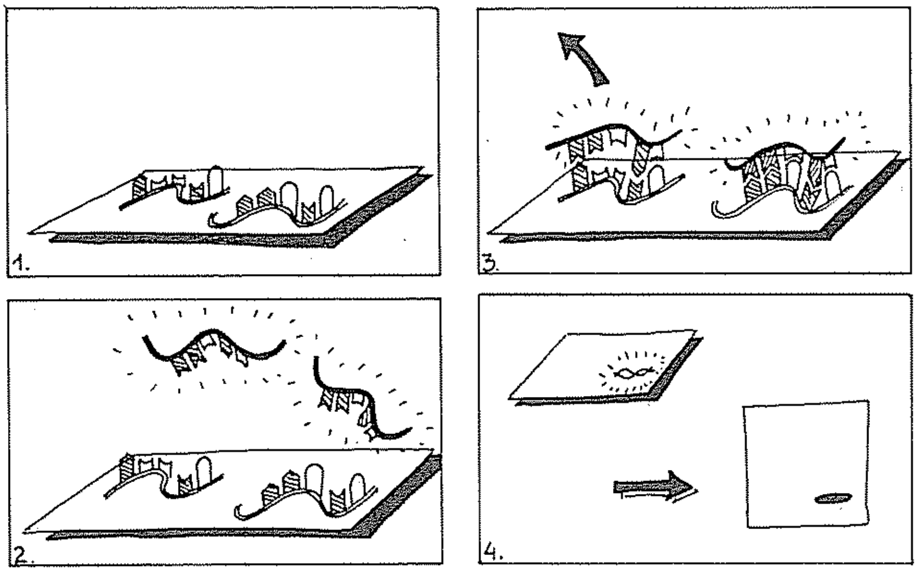


Fig. 3
DNA–DNA hybridization.
1) **Single-stranded DNA molecules are bound to a nylon membrane (nucleotides are drawn schematically as different geometric forms).**
2) **The "probe-DNA" molecule is labelled and added into solution in single-stranded form as well.**
3) **Complementary nucleotides between the probe-DNA molecule and the bound target molecules can form base-pairs. When too few base-pairs are formed, the hybrid molecule is not stable and the probe-DNA molecule is washed off.**
4) **The site where the stable hybrids are formed can be visualized due to the label of the probe-DNA resulting in a black band on an X-ray film.**

The XylS protein helps to express the genes for toluene degradation when the proper food molecules are present in the cell. Remarkably, mutant XylS proteins could be found which responded to other inducer molecules, or which were able to switch on the degradative genes without the need for such an inducer. Similar observations with other bacterial enzymes support the view that changes in digestive enzymes or food recognition proteins allow bacteria to use pollutants as novel food sources. All of these altered proteins were found to be the product of genes which had acquired small mutations in their DNA sequence – sometimes as a single base-pair change!.

The effects of sequence changes are not always so directly observed. Part of our own research effort is focused on a halogen-specific enzyme, chlorocatechol 1,2-dioxygenase, which belongs to a family of related enzymes, the intradiol dioxygenases. These enzymes are the products of a group of related genes which have acquired and accumulated so many changes in their sequence material that they only share 30 to 60% identical nucleotides on the DNA. This has lead to completely different substrate specificities of the individual enzyme members of this family. Chlorocatechol 1,2-dioxygenase, for instance, is much better suited to catalyze the conversion of chlorinated catechols than catechol 1,2-dioxygenase, which is a more common enzyme among aerobic bacteria. Furthermore, we are investigating a regulatory protein which is needed for the expression of the chlorocatechol degradation genes. This regulatory protein belongs to a protein family called the "LysR-type transcriptional activators", a group of proteins with extensive amino acid sequence identity, similar in function and size, and with a similar mode of action. These proteins have diverged in the course of a long evolutionary process to such an extent that they now fulfill rather specific roles in gene activation.

3.2 Gene Transfer and Composition of Metabolic Pathways

In contrast to vertical evolution, other mechanisms exist – so-called *horizontal evolutionary processes* in which DNA fragments are not changed in their order of nucleotides, but exchanged from their position either within or between two different DNA

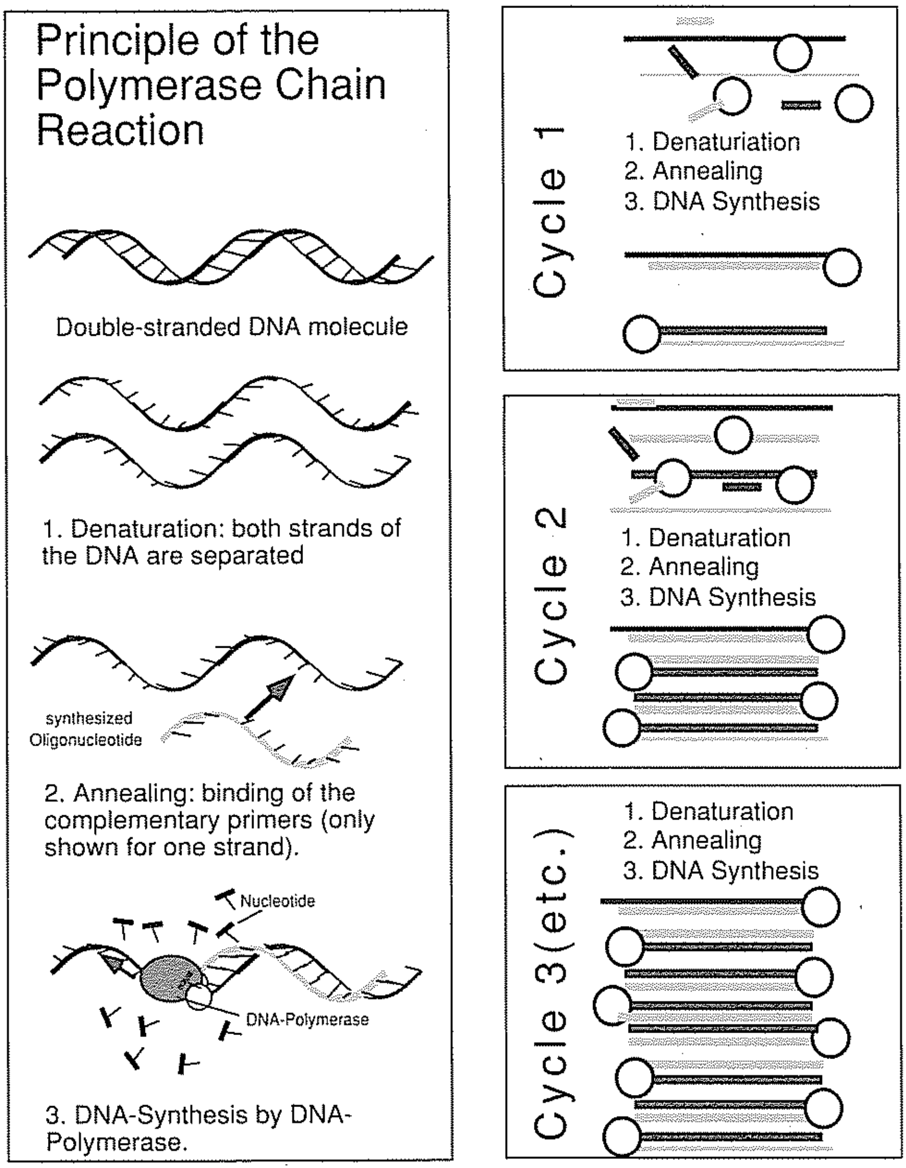


Fig. 4
Millionfold amplification of a DNA molecule by means of an enzymatic process: the polymerase chain reaction (PCR).

molecules. This exchange can occur inside the same organism or between two different organisms. In the latter case, the exchange of a DNA fragment (and of the genetic information present on it), can lead to additions of new information to the other cell, giving it the possibility to synthesize proteins which it previously could not. That this process can result in adaptation of microorganisms to novel substrates will be further illustrated below. Exchange of DNA fragments between different DNA molecules or between different sites on the same molecule can be brought about by the activity of recombination enzymes in the cell. Some of these enzymes are encoded by genes present on so-called mobile genetic elements, such as transposons or insertion sequences. These elements are able to duplicate themselves and to insert a second copy at another position in the chromosomal DNA or in another DNA molecule. It is thought that insertion elements can in this way "trap" other genes between the two copies, which can then also be mobilized.

In our own research, we have obtained strong evidence that such "gene trapping" occurs during the adaptation of bacteria to novel substrates [6]. The bacterium which we mainly study, a *Pseudomonas* strain which degrades chlorinated benzenes, contains part of its catabolic genes for chlorobenzene degradation on a transposon. These genes, encoding the enzymes chlorobenzene dioxygenase and benzene glycol dehydrogenase, are flanked on both sides by a copy of an insertion sequence. The DNA element, composed of both insertion sequences and the catabolic genes between them, has experimentally been shown to insert into other DNA molecules, proving that it is mobile. Interestingly, in the *Pseudomonas* strain, this mobile element is located on a plasmid DNA molecule. Elsewhere on this plasmid are other genes involved in the degradation of chlorobenzenes. However, it is this combination of genetic information – present on both a plasmid and on a transposon – which is necessary for the complete degradation pathway. We do not yet know, the origin of this transposon. We have reason to believe, however, that the catabolic genes may have come from toluene degrading microorganisms. The first enzyme in the pathway is toluene dioxygenase that has been shown to be a relatively nonspecific enzyme, capable of oxidizing several other substrates including chlorobenzenes. DNA sequence analysis of the chlorobenzene dioxygenase genes, which is currently in progress in our group, indicates that these genes have a high percentage of homology to the genes encoding toluene dioxygenase, lending additional support to our position that toluene degradation genes may have become "trapped" by insertion sequences and subsequently transferred to another organism on a plasmid.

Gene exchange mechanisms are not limited to DNA molecules inside a single organism. Many elements exist which can transfer DNA sequences from one organism to another – even to organisms in different genera. Plasmid DNAs are important gene transfer elements that reside in many bacteria-though not all plasmids are alike. Some small plasmids cannot be transferred to other cells, while some others can transfer themselves. Others can be (co)transferred together with another plasmid that transfers itself. Some plasmids are able to participate in a process known as retrotransfer; that is, they "pick up" genes from another microbe, but return to their original host bacterium.

Gene transfer is not limited to plasmid DNAs, but also occurs with some transposons and bacteriophag-

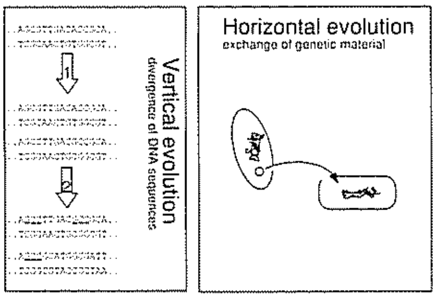


Fig. 5
Horizontal and vertical evolution
Vertical evolution refers to a collection of genetic processes leading to changes in base-pair sequences. For example, replication errors can result in single base-pair substitutions (arrow 1), or in small deletions (arrow 2). Horizontal evolution refers to genetic processes leading to mobilization of DNA fragments or molecules from one position to another or from one bacterial cell to another.

es. In addition, many self-transferable plasmids have been found over the past two decades that carry the genetic information for degrading aromatic compounds, halogenated compounds or pesticides, which makes them interesting for our adaptation studies. The genetic information present on plasmids can thus be spread among a wider population of bacterial species. The plasmid for chlorobenzene degradation, which was described above, has been detected in various other soil bacteria from the same environment, suggesting it is widely distributed in microbial populations. Some investigators have looked for the presence of "TOL"-plasmids in soil bacteria (plasmids containing the information for toluene degradation) [7]. They have been able to isolate such plasmids from various soil microorganisms. Though not all plasmids were identical, similar genes for toluene degradation were present in all cases. Sometimes, though, these genes were present two-fold on the plasmid or in an inverted orientation again suggesting that many genetic processes operate under natural conditions which cause exchanges of DNA sequences within DNA molecules or between bacterial strains.

Evidence is now accumulating that metabolic pathways are perhaps composed of different "gene cassettes" occurring in different combinations and orders [8]. The existence of a number of these putative cassettes has been proposed as a result of comparative genetic studies with various aerobic bacteria containing the genes for (i) aromatic ring dioxygenases, (ii) a *meta* cleavage pathway of catechol degradation, and (iii) an *ortho* cleavage pathway for chlorocatechol degradation. How may such gene cassettes be combined? Until now, very little evidence existed to attempt to answer this questoin. But as described above, we believe that trapping of genes and subsequent movement by mobile genetic elements may be one explanation for the occurrence of novel combinations.

3.3 Timescales in Evolution

One of the major problems in "evolutionary" research is that it is not possible to look at an individual microbe and wait until it adapts or evolves to use xenobiotic compounds. To a great extent, our research concentrates on the description of bacterial species that have been previously isolated from the environment and which degrade a particular environmental contaminant. Comparisons made between such bacteria on the genetic level are the main source of information about their evolutionary relationships. These relationships are usually expressed as the degree of similarity or identity in amino acid sequences of proteins, suggesting divergence from a common ancestor. However, this approach does not yield much information about the actual mechanisms which take place during adaptation. The advantage of using microorganisms, however, is that they multiply rapidly and selection for mutations is facilitated by easy screening of large populations of cells. It is possible then to perform a kind of "forward evolutionary search" by selecting for mutant bacterial strains with altered enzymatic activities. Similarly, gene exchange experiments can be performed to study transfer of plasmids from one strain to another and to see whether novel metabolic pathways can be combined inside bacteria.

Current interests in the field of microbial genetics is focused on whether genetic mechanisms leading to adaptation in bacteria are truly spontaneous processes or if they are not, to some extent, regulated by environmental conditions. It has been shown recently that bacteria facing particular stress conditions (such as

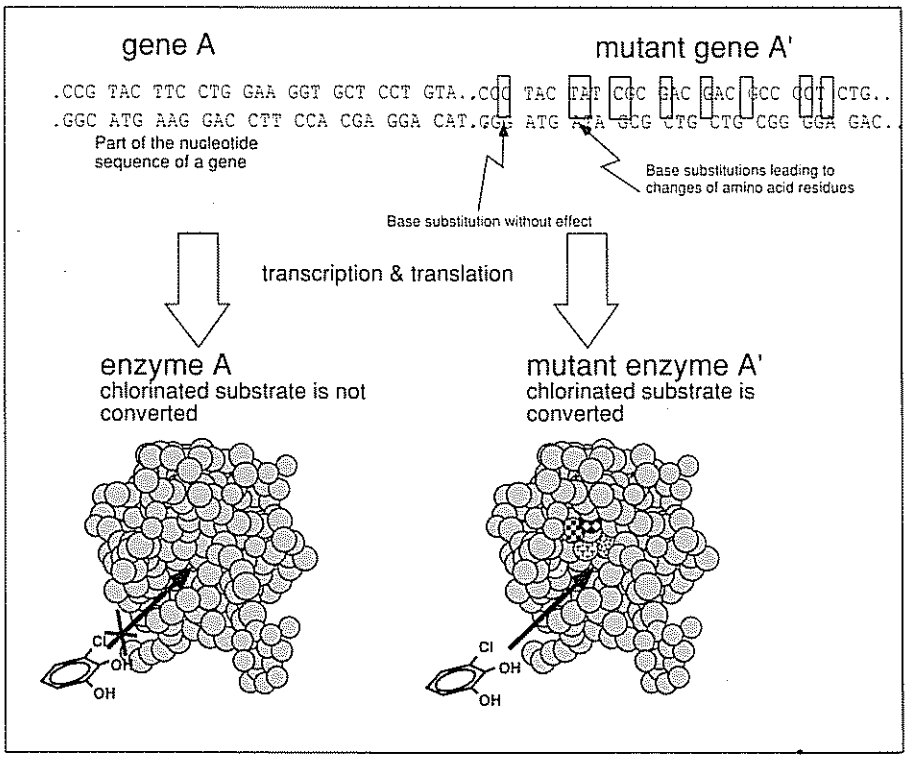


Fig. 6
Two related enzymes have evolved different substrate specificities by changes which accumulate in the DNA sequences of their genes (vertical evolution). The enzymes are drawn schematically as a folded chain of beads (representing the amino acid residues of the polypeptide). Only the residues which changed as a result of base substitutions in the DNA sequence have been given a separate shading.

presence of toxic agents, or starvation for food or nutrients) have a higher rate of mutation. There are additional indications that mutations causing single base-pair changes or the activity of insertion sequences may be "environmentally-induced" [9]. This would suggest the existence of regulatory systems by which microorganisms increase their rate of mutation under poor living conditions, thereby increasing the probability of a favorable mutation. In this context, it is even proposed that "evolutionases", enzymes or regulators promoting DNA sequence changes, could exist [10].

Another question is whether or not better adapted bacterial strains and novel metabolic pathways became selected for only after the large-scale introduction of pollutants into the environment. Research conducted with microorganisms which degrade chlorinated aromatics such as chlorobenzene suggests that these strains may have adapted under the selective stress of the chlorobenzenes. The "trapping" of toluene dioxygenase genes by insertion elements, as described above, could have been such a "recent" evolutionary event. On the other hand, our studies and those of other groups have made clear that specific enzymes for degradation of halogenated compounds are probably much "older" on the evolutionary time scale. Perhaps these enzymes have evolved as an adaptation to naturally occurring chlorinated compounds. The chlorocatechol 1,2-dioxygenase and its regulatory protein will be used in future work by our group as models for the study of genetic mechanisms which may take place inside the cell in the development of specialized proteins for the degradation of chlorinated compounds. We will also use them to investigate the possibilities that environmental stress influences adaptation of key proteins for degradation pathways.

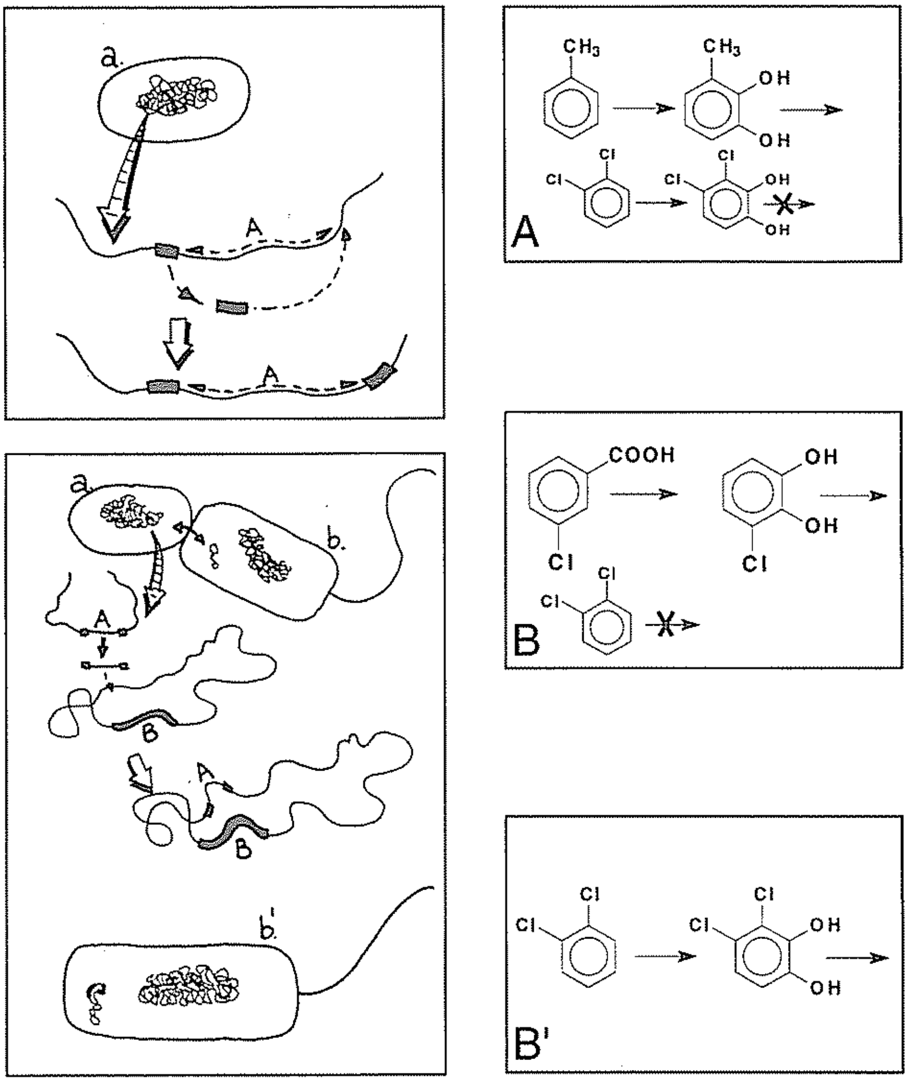


Fig. 7
Possible events in the evolution of the metabolic pathway for degradation of chlorinated benzenes.

Bacterium "a" metabolizes toluene as shown in panel A on the right side. The enzymes which catalyze the first steps in this pathway can also convert dichlorobenzene; however, the dichlorinated intermediate which is then formed cannot be further metabolized by this bacterium.

Bacterium "b" is able to degrade the compound 3-chlorobenzoate; chlorinated intermediates occur in these metabolic reactions but are converted by the existing enzymes without problems. This bacterium, however, does not have enzymes to perform the necessary initial oxidation of the chlorobenzene.

The left panel of the figure depicts the possible horizontal transfer of necessary genetic information from bacterium "a" to bacterium "b", so that the latter acquired the possibility to completely degrade chlorinated benzenes. The genes encoding toluene metabolism are located in bacterium "a" on its chromosome (shown as A). Accidentally, an insertion element (here shown as a black bar) replicates itself and the copy inserts in the chromosome on the other end of the A-genes. Bacterium "a" and "b" come in cell-to-cell contact. Bacterium "b" carries a plasmid-DNA molecule which is able to transfer itself to another bacterium. On the plasmid are the genes (shown as B) which allow bacterium "b" to degrade chlorobenzoate and the chlorinated intermediates. During cell–cell contact, the plasmid transfers to bacterium "a", and the A-genes are copied and mobilized by means of the insertion elements on the plasmid DNA molecule. The plasmid transfers back to bacterium "b" taking a copy of the A-genes on it. This now provides strain "b" with the genetic information to (first) oxidize chlorobenzenes with the A-genes encoded enzymes and transform the chlorinated intermediates with the help of the B-genes encoded enzymes.

4. Looking for microbes in the environment

Until now, most information about the catabolic potential of microorganisms has come from studies with bacterial strains isolated from environmental samples by enrichment techniques. As more genetic data become available, it is increasingly feasible to screen samples for the presence of specific bacteria. This will initiate a new field within microbial ecology including the study of population dynamics and genetic variability. It is now possible to isolate bacterial strains from environments not only on the basis of their

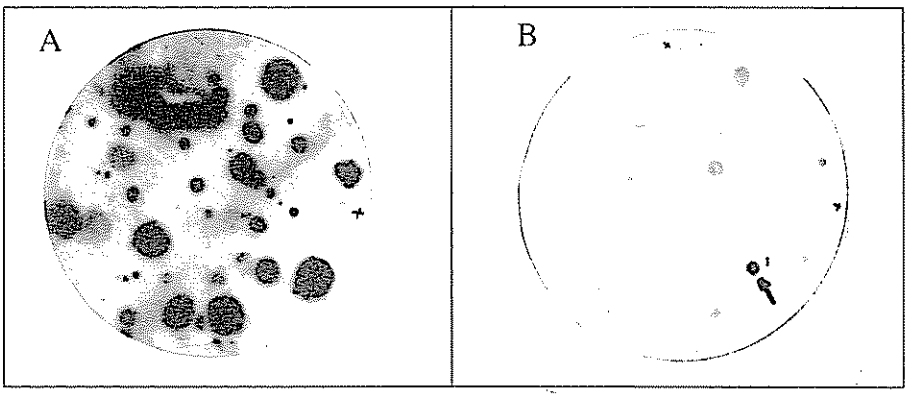


Fig. 8
Identification of a specific bacterial colony among a diversity of other colony types by means of DNA-DNA hybridization. Panel A shows a "reprint" of the bacterial colonies grown from an environmental sample on an agar surface. Panel B shows the results of the DNA-DNA hybridization of this reprint with a DNA probe for chlorocatechol dioxygenase genes under conditions where all nonspecific reactions are washed off (see Fig. 3).

phenotypic properties, but also according to genotypic characteristics.

How are these studies accomplished? In a number of laboratories, including our own, screening techniques have been tested and optimized which make use of DNA–DNA hybridization and PCR (see above) [11, 12]. Our main interests at the moment are in screening samples from environments polluted with chlorinated aromatics for bacteria which carry genes for degradation of these compounds. In order to do this, we have isolated and obtained several genes encoding key enzymes in the breakdown of chloroaromatics, such as aromatic ring dioxygenases and (chloro-)catechol dioxygenases. These DNA fragments will be used directly in hybridization experiments with DNA derived from colonies of microorganisms which have been grown on agar plates (so as to be able to isolate positively reacting bacteria afterwards). Furthermore, oligonucleotides have been developed and synthesized on the basis of DNA sequence information of these fragments which can now be used in PCR experiments in order to detect and possibly quantify the number of these sequences in environmental samples. This information can then be correlated to the degree of pollution of the sample, for obtaining further evidence for the selection of novel bacterial genotypes in nature under pollutant stress.

5. Autoregenerative capacities of polluted environments

What is the role and importance of genetic adaptation in bacteria for the degradation of environmental pollutants? It is clearly evident that if bacteria present in the environment do not have the proper genetic information for a degradation pathway, it will limit biodegradation. On the other hand, if the "right" bacteria are present, it does not necessarily mean that the pollutants are degraded at optimal speed, since the activity of microorganisms in the environment is determined by many physical and chemical factors (e.g., bioavailability, temperature, presence of nutrients) [13]. With the increasing costs of cleaning up waste disposal sites, practical and acceptable solutions need to be developed. The application of microorganisms for remediation of contaminated sites is certainly an important technique in this respect, although there are numerous options for its execution. For example, in situ microbial activity may be stimulated by the addition of nutrients, pollutants may be extracted and treated in reactors, or specialized microbes may be introduced into the site so as to improve biodegradation rates. It is even possible to construct novel bacteria by genetic techniques, in order to speed up evolutionary processes which will result in the degradation of a variety of difficult pollutants simultaneously. However, the application of such bacteria is not without technical, political and ethical problems. Another solution which will perhaps take the longest is one to prevent further transport of the pollutants and wait for spontaneous biodegradation processes to develop. For this, it is necessary to know better what the autoregenerative capacities of environments are to clean themselves up. Analysis of the diversity of catabolic genes among microbial populations and of adaptive processes under environmental conditions are essential links in a proper assessment of such strategies.

[1] Margulis, L. (1993) *Symbiosis in cell evolution*. Freeman Co., New York.
[2] Barkay, T. and Pritchard, H. (1988) Adaptation of aquatic microbial communities to pollutant stress. Microbiol. Sci. 5, 165–169.
[3] Rojo, F., Pieper, D.H., Engesser, K.-H., Knackmuss, H.-J. and Timmis, K.N. (1987) Assemblage of ortho cleavage route for simultaneous degradation of chloro- and methylaromatics. Science 238, 1395–1398.
[4] Burlage, R.S., Hooper, S.W. and Sayler, G.S. (1989) The TOL (pWW0) catabolic plasmid. Appl. Environ. Microbiol. 55, 1323–1328.
[5] Ramos, J.L. and Timmis, K.N. (1987) Experimental evolution of catabolic pathways of bacteria. Microbiol. Sci. 4, 228–237.
[6] van der Meer, J.R., Zehnder, A.J.B. and de Vos, W.M. (1991) Identification of a novel composite transposable element, Tn5280, carrying chlorobenzene dioxygenase genes of Pseudomonas sp. strain P51. J. Bacteriol. 173, 7077–7083.
[7] Williams, P.A., Assinder, S.J., De Marco, P., O'Donnell, K.J., Poh, C.L., Shaw, L.E. and Winson, M.K. (1992) *Catabolic gene duplications in TOL plasmids*. In: Pseudomonas: Molecular biology and biotechnology (Galli, E., Silver, S. and Witholt, B., Eds.), pp. 341–353. American Society for Microbiology, Washington, DC.
[8] van der Meer, J.R., de Vos, W.M., Harayama, S. and Zehnder, A.J.B. (1992) Molecular mechanisms of genetic adaptation to xenobiotic compounds. Microbiol. Rev. 56, 677–694.
[9] Cairns, J., Overbaugh, J. and Miller, S. (1988) The origin of mutants. Nature (London) 335, 142–145.
[10] Harayama, S. and Timmis, K.N. (1992) *Aerobic biodegradation of aromatic hydrocarbons by bacteria*. In: Degradation of environmental pollutants by microorganisms and their metalloenzymes (Sigel, H. and Sigel, A., Eds.), pp. 99–157. Marcel Dekker, Inc., New York.
[11] Steffan, R.J. and Atlas, R.M. (1991) Polymerase chain reaction: applications in environmental microbiology. Annu. Rev. Microbiol. 45, 137–161.
[12] Sayler, G.S. and Layton, A.C. (1990) Environmental application of nucleic acid hybridization. Annu. Rev. Microbiol. 44, 625–648.
[13] van der Meer, J.R., Bosma, T.N.P., de Bruin, W.P., Harms, H., Holliger, C., Rijnaarts, H.H.M., Tros, M.E., Schraa, G. and Zehnder, A.J.B. (1993) Versatility of soil column experiments to study biodegradation of halogenated compounds under environmental conditions. Biodegradation 3, 265–284.

Christopher Rösselet[1], David Stocker and Alistair Kerr

Summer Smog Formation

Computer Modelling Studies of Photochemical Ozone, Peroxyacetyl Nitrate (PAN) and Hydrogen Peroxide Formation Over the Swiss Plateau

Photochemical summer smog

Photochemical summer smog is formed by the action of sunlight on air masses containing nitrogen oxides (NO_x) and volatile organic compounds (VOC). It is characterized by the presence of high concentrations of photochemical oxidants such as ozone (O_3), peroxyacetyl nitrate (PAN) and hydrogen peroxide (H_2O_2) as well as by reduced visibility. Exposure to high levels of photochemical oxidants is known to harm the respiratory systems of mammals and cause damage to vegetation [1,2]. In addition, PAN is known to cause eye irritation and H_2O_2 plays an important role in acid rain formation [2]. The processes involved in the formation and removal of photooxidants are shown schematically in Fig. 1.

Photochemical summer smog production is controlled by the emissions and abundance of primary pollutants, meteorological conditions, and by chemical processes in the atmosphere. A comprehensive database of atmospheric parameters including the meteorological conditions and pollutant concentrations in Switzerland has been established as a result of the Pollumet Experiment (Pollution and Meteorology in Switzerland) and the «Nationale Beobachtungsnetz für Luftfremdstoffe (NABEL)» [3]. Pollumet is an intensive monitoring program designed to study the transport and production of pollutants in Switzerland under summer smog conditions. The NABEL program was established to monitor air quantity and to study the formation of air pollutants in Switzerland. The network is operated by EMPA (Eidgenössische Materialprüfungs- und Forschungsanstalt) on behalf of BUWAL (Bundesamt für Umwelt, Wald und Landschaft). The network is comprised of 16 stations (10 were operational in 1990) in locations representative of the different land uses in Switzerland.

The primary sources of pollutants during the summer are automobile exhaust and solvent use. Other sources include stationary combustion, additional industrial emissions and natural emissions. High-pressure weather patterns suppress the vertical mixing and dilution of pollutants released at the surface. The associated cloudless skies provide maximum light intensity to initiate smog formation. The potential of an organic compound to generate ozone in the troposphere depends on the rate at which it is oxidised, the presence of nitrogen oxides and the nature of the oxidation products formed.

The relationships between the emission rates of the precursor compounds to smog formation and the levels of photochemical oxidants produced are not linear. At present, the only effective way to investigate these relationships is with the use of models combining the meteorology and chemistry of air parcels. Some models calculate pollutant concentrations at a fixed geographical location (Eulerian models), while others determine the pollutant concentration in a column of air and follow its trajectory as predicted by prevailing metoreorolgical conditions (Lagrangian models). The pollutant concentrations predicted by an Eulerian model pertain to a specific location. Lagrangian models predict the pollutant concentration in a moving air parcel. Comparison with measured pollutant concentrations is only possible as the air parcel passes by a monitoring station. These models are less expensive to operate than Eulerian models.. Subject to certain condition, both types of modesl can be used to predict the change in photo-oxidant production brought about by various emission reduction scenarios. The requirements, limitations and applica-

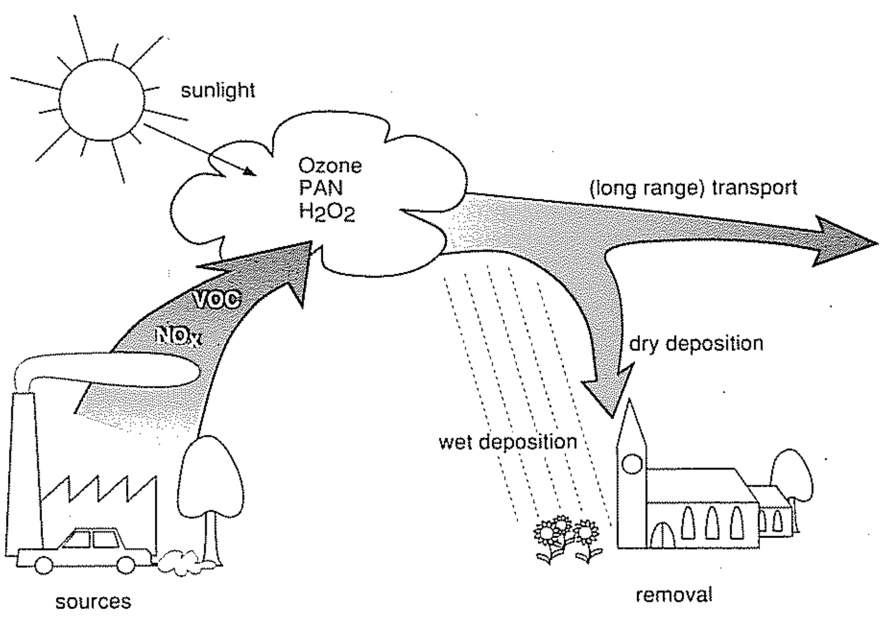


Fig. 1
Schematic diagram of the formation of photochemical summer smog.
Sources of primary pollutants include anthropogenic and natural processes. Removal processes include dry and wet deposition. Dry deposition involves transport of gas and particle pollutants to surfaces in the absence of precipitation.

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tions of such models will be discussed with reference to the development of a Lagrangian model to simulate photo-oxidant production over the Swiss plateau (Schweizer Mittleland). Full details of the model are published elsewhere [4, and Rösselet and Kerr, manuscript in preparation].

The model

The photochemical model describes the chemical development in a parcel of boundary layer air and was developed to simulate the production of photo-oxidants over the southern United Kingdom [5]. The model has been adapted for conditions found during a typical summer smog episode in Switzerland. High pressure weather patterns over Europe generate light north easterly (Bise) winds across the Swiss Plateau. The air parcel starts at 18:00 on 25 July 1990 from a point approximately 15 km northeast of Ravensburg in Germany. The air parcel travels at 2 ms^{-1} (7.2 km hr^{-1}) following a trajectory from Lake Constance, passing Zürich and Bern to Lake Geneva (see Fig. 2). As the air parcel proceeds, it collects the peak NO_x and VOC emissions produced during the morning rush hour in Zürich. The diurnal variations in temperature, humidity and insolation are included in the model.

The air parcel is divided vertically into two boxes and has an effective lateral cross section of 50x50 km^2. Complete and instantaneous mixing within each box is assumed. At sunrise, the lower box contains a turbulent mixed layer with a mixing depth of 300 m. The upper box contains a reservoir layer with a mixing depth of 1000 m. During the morning, the depth of the mixed layer increases, driven by convection and entraining air from the reservoir layer. The maximum mixing depth of the mixed layer (1300 m) is reached after noon. The depth of the lower box falls to 300 m, isolating air above in the reservoir layer as sunset approaches. The shallow surface layer persists through the night, and the process repeats itself on subsequent days. The total height of the air parcel, 1300 m, remains constant throughout.

The choice of initial species concentrations for the model is important as they may influence the chemical development. The initial conditions were established in a model pre-run over southern Germany.

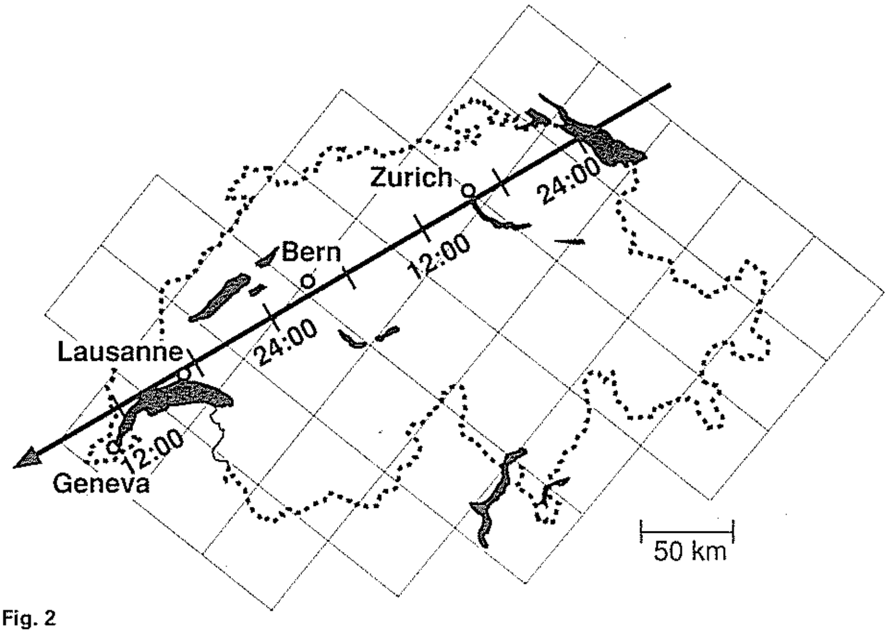


Fig. 2
Map of Switzerland showing the trajectory of the air parcel from Lake Constance to Lake Geneva. The trajectory starts at 18:00 h on 25 June 1990 and ends at 16:00 h on 27 June 1990. The OECD-MAP emission grid is also shown.

Source	VOC	NO_x
Vehicle exhaust from gasoline engines	115.4	211.2
Vehicle evaporation from gasoline engines	62.93	
Vehicle evaporation from gasoline engines	38.2	118.3
Stationary combustion sources	57.6	113.6
Industrial sources	23.8	23.1
Solvent use	493.3	
Natural gas leakage	9.92	

Table 1
Emission inventory for Switzerland
Emission rates in kTon day^{-1} over the Swiss Plateau during a photochemical episode in 1990

Emissions Inventories

The model requires the pollutant injection rates for NO_x and 68 individual VOCs. An emission inventory of NO_x and VOC emissions during a photochemical smog episode in 1990, based on the OECD-MAP grid having a 50 x 50 km resolution, was prepared by Filliger and Ballaman of BUWAL [personal communication]. To calculate the emission rates of the individual VOCs, the emissions of the updated inventory were divided into eight source categories using the national total estimates for each category in Switzerland [Filliger and Ballaman, personal communication]. Table 1 shows the total emissions from each source type over the Swiss Plateau. The emissions from each source were then broken down on a mass basis by species using the estimation procedures of Derwent and Jenkin [6]. The emissions over southern Germany used in the pre-run to calculate the initial concentrations were based on the OECD-MAP inventory [7]. Emissions were released to the lower box of the model, and the rates varied to reflect the diurnal traffic patterns and industrial activity during the work day. CO emissions are closely correlated with NO_x emissions [8]. The background CO levels in the present study were calculated as a fixed ratio of the NO_x levels. However, emissions from natural sources have been omitted in the inventories used in this study since the magnitude of natural emissions is largely uncertain. Natural VOC emissions, however, comprise about 10% of the total VOC emissions [7].

Chemical mechanisms

The photochemical degradation of volatile organic compounds is principally initiated either by reaction with hydroxyl (OH) radicals or by photolysis. Hydroxyl radicals are generated by the photolysis of ozone in the presence of water vapor. In either case, a chain reaction ensues involving reactive intermediate radical species in which nitric oxide is converted to nitrogen dioxide. Nitrogen dioxide photolysis is the only known source of ozone in the lower atmosphere. The general reaction scheme for the oxidation of an organic compound initiated by the OH radical reaction is shown in Fig. 3. At several points in the reaction scheme, more than one reaction channel is available. The partitioning between the reaction channels influences product distribution and, as a consequence, ozone production. The parent organic compound is oxidized to form secondary carbonyl products, the photo-oxidation of which leads to the generation of peroxyacyl nitrates (PAN) (see Fig. 3). Hydrogen peroxide is formed by the interaction of two HO_2 radicals which competes with the reaction of HO_2 with nitric oxide (see Fig. 3).

The model used for the photochemical reaction mechanism contains 384 species, including reactive intermediate radical species, and involves 684 reactions. The reaction rate coefficients were taken from an evaluation of laboratory data measured under simulated atmospheric conditions [9]. The photolysis rates were calculated as a function of the solar zenith angle. The loss of chemical species to water droplets has not been included as the simulation is for clear sky conditions. The heterogeneous removal of species at the surface by dry deposition has been included as a diurnally averaged deposition velocity.

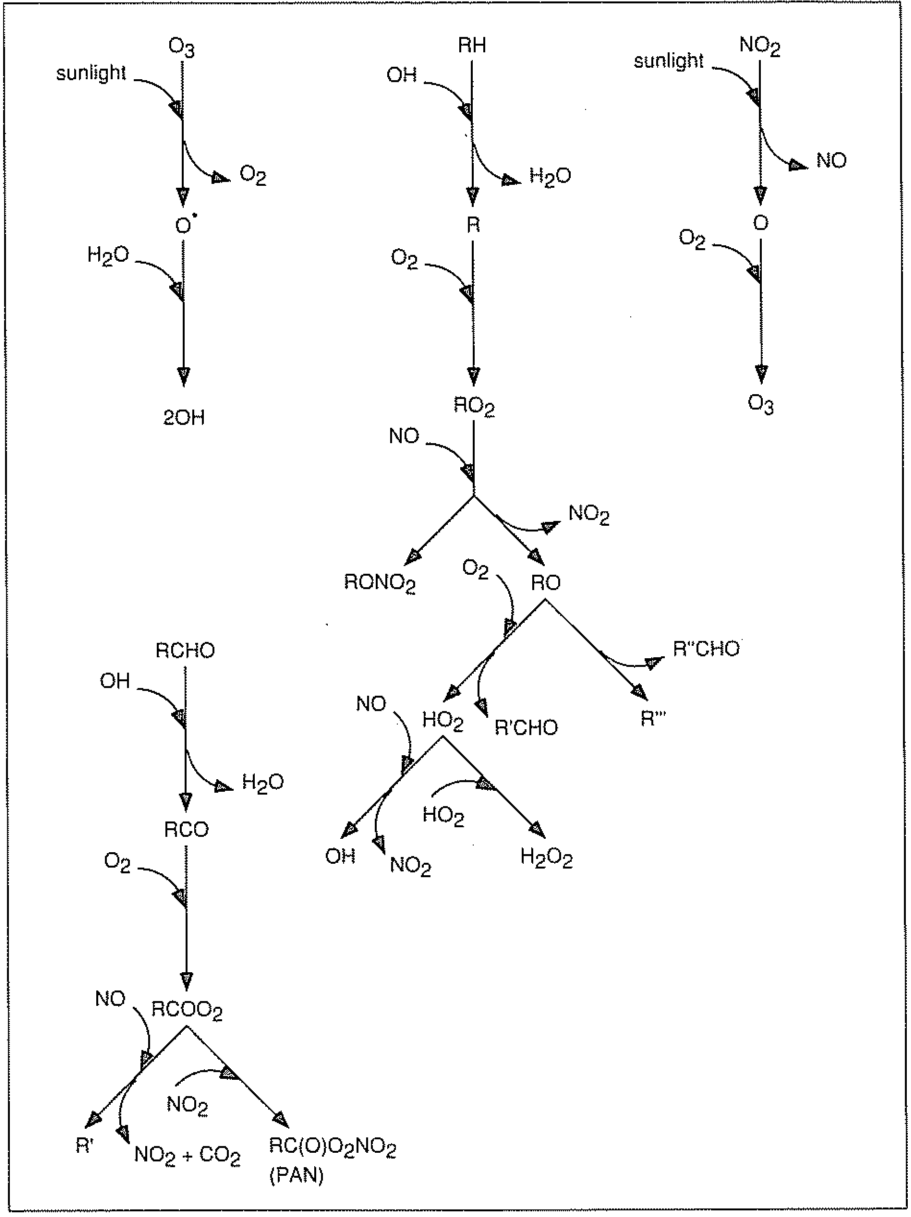


Fig. 3
Schematic representation of the photo-oxidation of a general organic compound RH showing the formation of reactive intermediates and the oxidation of nitric oxide (NO) to nitrogen dioxide (NO_2).
Hydroxyl radicals (OH) are regenerated allowing the reaction cycle to be repeated. Products include water (H_2O), carbon dioxide (CO_2), carbonyl compounds (RCHO), organic nitrate ($RONO_2$), peroxyacyl nitrate ($RC(O)O_2NO_2$) and hydrogen peroxide (H_2O_2).
Atom and radical intermediates include oxygen atoms (O), alkyl radicals (R), alkylperoxy radicals (RO_2), alkoxy radicals (RO), hydrogen peroxy radicals (HO_2), acyl (RCO), and peroxyacyl radicals ($RCOO_2$).

Model Applications and Limitations

The complex nature of atmospheric interactions and the computational limitations of computers require that the models incorporate significant simplifications and assumptions. In addition, such models require substantial input data, including meteorological measurements and emission data. Uncertainties in the input data, as well as the approximations in the model itself, can lead to major uncertainties in the model predictions. In spite of their limitations, models are valuable tools, aiding in the interpretation of field measurements and in providing qualitative predictions of photo-oxidant concentrations in response to different VOC and NOx emission scenarios.

The mathematical parameterization of the transport of chemical species represents a simple physical model of the planetary boundary layer under very specific conditions. Deviations from actual conditions will be particularly large at sunrise and sunset as the ground-level nocturnal layer breaks up and re-forms.

The model reports the average ozone concentration in the lower box, which is assumed to be homogeneously mixed. Near major urban centers and point sources, the model is not be able to reproduce ambient concentrations as there are significant horizontal and vertical concentration gradients. In rural areas, however, where the approximation that the air in the box is well mixed is more realistic, the

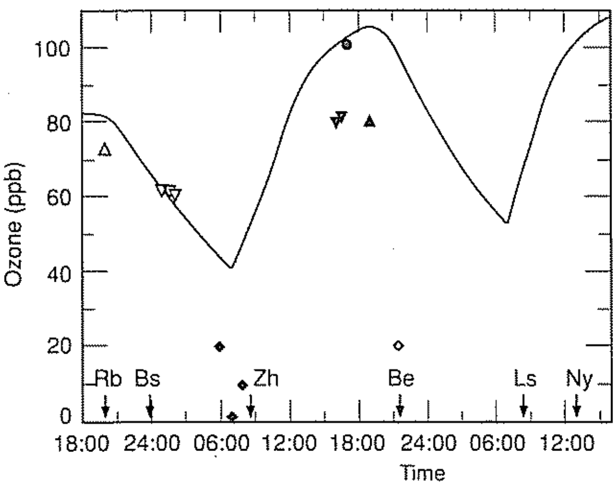


Fig. 4
Predicted and measured ozone concentrations along the modelled trajectory.
Location of the monitoring stations:
△ Friedrichshaven, [D. Ahren, Baden-Würtenberg, D, personal communication],
▽ Bichelsee, [B. Buchmann, EMPA Dübendorf, personal communication],
◆ Dübendorf [11],
▼ Langenthal [12],
◉ Günsberg, [R. Stampfli, Solothun, personal communication],
▲ Grenchen [R. Stampfli, Solothun, personal communication] and
◊ Berne [12].
1 ppb ozone corresponds to 1.96 μg m^{-3} at 25°C and 1 atmosphere pressure.
Key Rb, Ravensburg; Bs, Bodensee; Zh, Zürich; Be, Bern; Ls, Lausanne; Ny, Nyon.

performance of the model should be better. In addition, omitting natural VOC and NO_x emissions biases the emission inventory. Although natural emissions do not comprise a large proportion of the total emissions, they do include reactive species (e.g., isoprene).

It is not possible to include the complete chemical mechanism in the model. The rates of many of the chemical reactions included in the model have been measured; however, there are a significant number of reactions for which scant or no experimental data are available. The estimated error limits for the evaluated rate coefficients are at least 20–30%. Furthermore, kinetic data have been determined in laboratory experiments simulating atmospheric conditions; though because of analytical constraints, the concentrations of the precursor compounds used are often up to 1000 times greater than found under ambient conditions which may lead to systematic errors. The dry deposition rates in the model are daily averages. In reality, the daytime dry deposition velocity is much greater than that at night. The use of deposition velocities averaged over 24 hours will cause an over-estimate of nocturnal removal and an under-estimate of the day time removal rate. The dry deposition velocities are also averaged over the path of the air parcel, even though experiments have shown that dry deposition rates vary with the nature of the surface receptor [10].

The approximations and assumptions outlined above restrict the performance of the model. The results of the model calculations are, therefore, illustrative rather than quantitative. Models are best used as comparative tools to predict relative changes in photo-oxidant concentrations in response to hypothetical changes in emission rates. The results of the present model are only applicable along the trajectory under summer smog conditions.

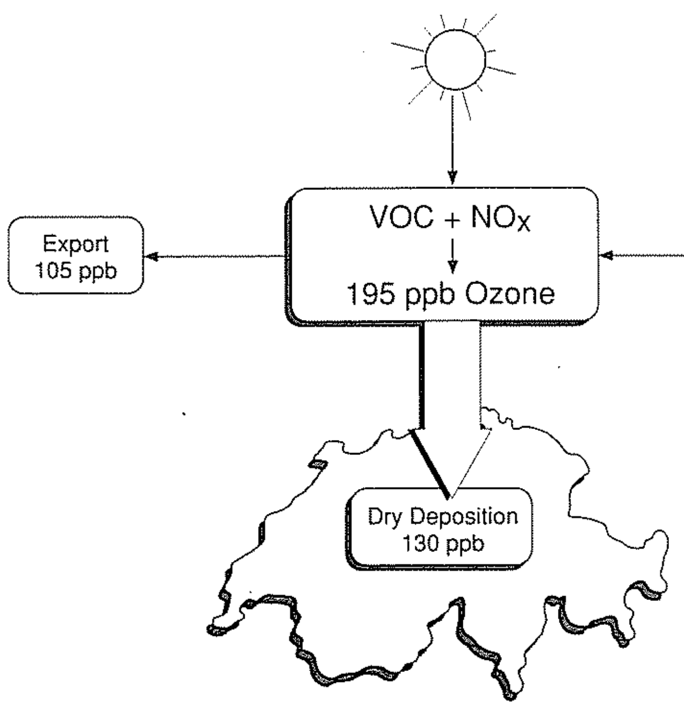


Fig. 5
Ozone budget predicted by the model showing the amounts imported, produced, deposited within Switzerland and exported.

Results of model calculations

Ozone

Ozone formation calculated by the model as it traverses the Swiss Plateau is shown in Fig. 4. The predicted ozone concentration is approximately 65 ppb (parts per billion by volume) as the air parcel enters Switzerland at midnight over Lake Constance. The ozone concentration decreases during the night to a minimum of approximately 40 ppb before sunrise the next morning. In the lower box, dry deposition and reactions of ozone with NO_x and alkenes deplete the ozone. During the morning hours, the ozone concentration increases. Overnight the inversion boundary has isolated ozone-rich air aloft in the reservoir layer. After sunrise the mixing height of the lower box increases entraining air from the upper box. In addition, solar radiation initiates photochemical reactions leading to ozone generation in the air parcel. The maximum predicted ozone concentration, 106 ppb, occurs near Burgdorf (BE) at about 19:00. The ozone concentration decreases as the intensity of solar radiation decreases, and the nocturnal surface layer is re-established.

The model calculations predict a net production of ozone in the air parcel as it passes over Switzerland as shown in

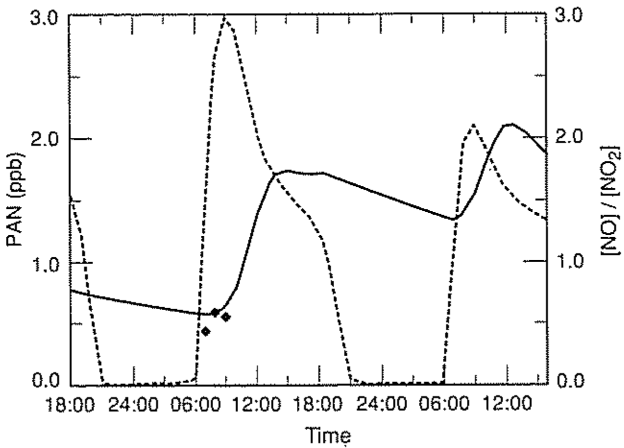


Fig. 6
— Predicted PAN concentration profile and
--- NO/NO$_2$ ratio
Also shown are measurements determined during the Pollumet experiment at Dübendorf (◆) [11].
1 ppb PAN corresponds to 5.0 µg m^{-3} at 25°C and 1 atmosphere pressure.

Fig. 5. Most of the ozone produced is deposited locally, and the exported concentration is about 60% greater than that that is imported.

The ozone concentrations predicted by the model can be compared with measurements conducted during the Pollumet research effort and as part of the NABEL network. The ozone concentrations predicted by the model agree reasonably well with those measured at locations along the trajectory. Measurements near urban areas are somewhat lower than those predicted by the model, presumably due to reaction of ozone with NO. Ground level measurements of the ozone concentration will be heavily influenced by nearby NO sources, while the ozone concentration predicted by the model is averaged over the height of the boundary layer and is not strongly affected by NO sources localized at the surface. This is particularly noticeable when comparing the data at Bern and Dübendorf. The ozone concentration measured at Bern is influenced by increasing cloud cover which is not accounted for in the model. Downwind of Bern, comparison of the modelled and measured concentrations is not possible because of changing weather patterns. Agreement of the concentrations predicted by the model with ambient levels should not be taken as validation of the model, but rather as an indication that under specific conditions the model is capable of simulating atmospheric conditions.

PAN

PAN concentrations along the trajectory are predicted to show a diurnal variation (Fig. 6). The maximum predicted PAN concentration occurs mid-afternoon on 26 July and slowly declines through the evening and overnight to reach a minimum before dawn. The maximum predicted PAN concentration occurs at noon on the second day. The concentrations of peroxyacetyl radical precursors to PAN formation are highest when the sunlight intensity is greatest. Reaction of peroxyacetyl radicals with NO_2 to generate PAN competes with the reaction of peroxyacetyl radicals with NO to form NO_2 plus CO_2 and an alkyl radical (see Fig. 3). PAN formation depends, therefore, not only on the peroxyacetyl radical concentration, but also on the NO:NO_2 concentration ratio. The predicted NO:NO_2 concentration ratio is also shown in Fig. 6. As the air parcel passes Zürich, it gathers the morning rush hour emissions which are rich in NO, possibly causing the delay in the peak PAN concentration on 26 July.

The predicted PAN concentrations can be compared with measurements conducted during the Pollumet experiment [11]. The modelled concentrations agree well with measurements conducted at Dübendorf. Measurements of PAN at Lägern and Dübendorf during July, August and September in 1987 and 1988 [13] show that the monthly mean and maximum PAN concentrations were 0.28–0.45 ppb and 1.43–4.40 ppb, respectively. The model predictions are consistent with these observations.

Hydrogen peroxide

Hydrogen peroxide generation is shown in Fig. 7. The maximum concentration due to photochemical reactions is predicted to occur late in the afternoon and persist into the early evening. The hydrogen peroxide concentrations on 27 July are greater than on 26 July. The NO_x emissions from Zürich have probably depressed and delayed the predicted peak concentration on 26 July. Hydrogen peroxide production decreases as the intensity of sunlight decreases.

The H_2O_2 concentrations predicted by the model show a similar diurnal variation, but is greater than ground level measurements conducted during the Pollumet experiment at Schüpberg located northwest of Bern [14]. The measured concentrations reach a maximum late in the afternoon (1–2 ppb) and are near zero overnight. Altitude profiles of the H_2O_2 concentration increase with height [15]. As for the measured ozone concentration, the measured H_2O_2 concentration at ground level is more strongly influenced by surface NO sources and by dry deposition than the concentrations calculated by the model.

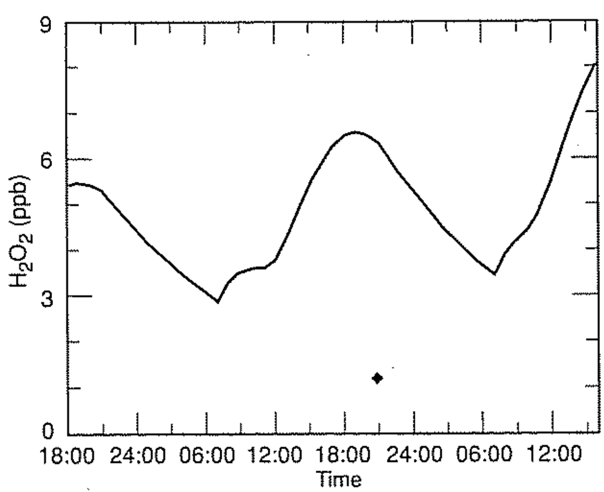


Fig. 7
H_2O_2 concentrations predicted along the trajectory. The H_2O_2 concentration measured at Schüpberg (◆) is shown [14].
The average daily maximum H_2O_2 concentration at Rigi occurs at about 15:00 h and is ca. 2.5 ppb.
1 ppb H_2O_2 corresponds to 1.4 µg m^{-3} at 25°C and 1 atmosphere pressure.

Hypothetical Emissions Reduction Scenarios

The formation of ozone and hydrogen peroxide depend on the absolute VOC and NO_x emissions as well as the VOC:NO_x emissions ratio. PAN production depends additionally on the ratio NO_2:NO. Isopleths of the predicted photo-oxidant concentrations can be used to predict the relative effectiveness of different hypothetical emission reduction scenarios. In these scenarios, the total VOC emission is reduced, regardless of the different potentials individual organic compounds may have for photo-oxidant generation, and the NO_x:CO ratio remains constant.

Isopleths are contour diagrams showing the variation in ozone concentration with the emissions of NO_x and VOC. Such diagrams can be used to predict the ozone concentration in response to changes in the emisson levels of NO_x and VOC. Isopleths of the maximum ozone concentration are shown in Fig 8. If the isopleths were constructed in three dimensions, a ridge would be observed along the diagonal line marked on the plot. When VOC and NO_x emissions are reduced such that their emission ratio follows the gradient of the ridge, the predicted ozone concentration also decreases. If the VOC:NO_x emission ratio is greater than the ridge line value, as is the case for the present study, the predicted ozone concentration is not very sensitive to the VOC emission levels,though lowering NO_x emission levels reduces the modelled ozone concentration. Lowering the emission rates of both VOC and NO_x simultaneously, reduces the predicted ozone concentration. Whereas if the VOC:NO_x emission ratio is less than the ridge line value, the predicted ozone concentration decreases if the VOC emissions are reduced and increases as the NOx emissions are decreased. The results of the emission reduction scenarios apply only to the calculated maximum concentration under the specific conditions of the model. Fig. 9 shows how emission reductions are predicted to affect the ozone concentration at different points along the trajectory.

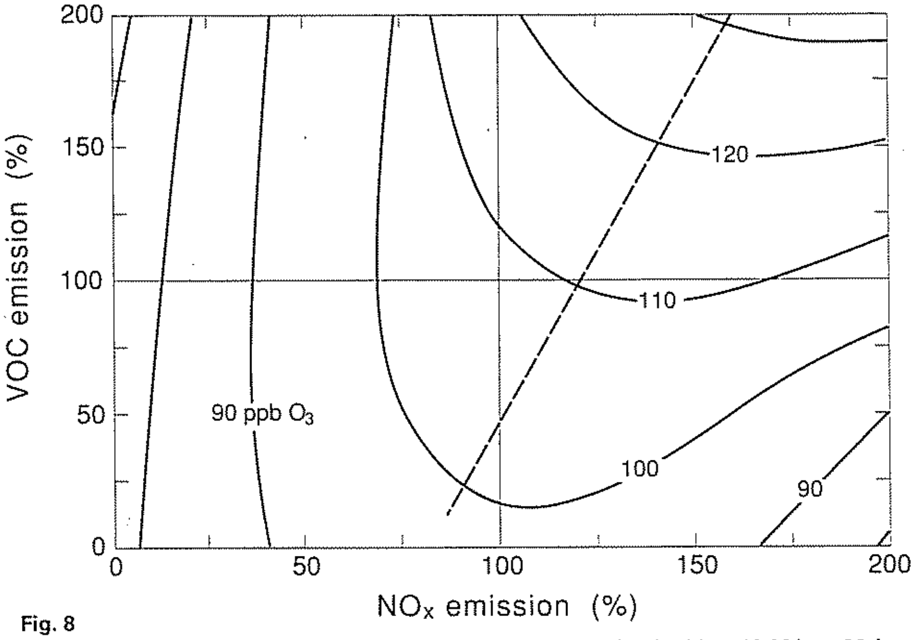


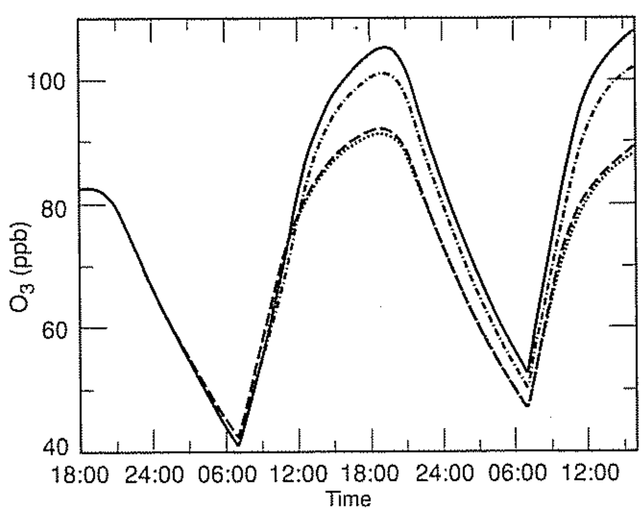
Fig. 8
Ozone concentration isopleths of the peak ozone concentration (ppb), at 19:00 h on 26 June as a function of VOC and NO_x emissions.

PAN formation is reduced as the ratio NO:NO_2 is increased, as shown in Section 4b above. Owing to the cyclic nature of atmospheric reaction mechanisms (Fig. 3), it is not possible to control PAN production by manipulating the NO:NO_2 concentration ratio. The PAN concentration is predicted to decrease with lower VOC (peroxyacetyl radical precursor) and lower NO_x emissions.

The highest concentrations of H_2O_2 are generated at the highest levels of VOC emission, and the peak hydrogen peroxide concentration increases as NO_x emission levels are decreased (see Fig. 10). This happens both because larger VOC emissions lead to increased HO_2 generation and because of the competition between the interaction of two HO_2 radicals leading to H_2O_2 and the reaction of HO_2 with NO (see Fig. 3). According to the model calculations, the most effective control strategy to reduce H_2O_2 formation is to reduce VOC emissions.

The photo-oxidant concentrations predicted by the model are not very sensitive to emissions reductions. For example, halving the VOC and NO_x emissions reduces the peak ozone concentration by only 13%, while the peak hydrogen peroxide concentration remains almost unchanged. If emissions over the Swiss Plateau could be completely eliminated, the peak ozone concentration would still be 70–80 ppb. These predictions point to the need for pan-European action to reduce photo-oxidant levels over the Continent.

Fig. 9
The influence of hypothetical precursor emission reductions in Switzerland on the predicted ozone concentration along the trajectory.
— 100% VOC and 100% NO_x emissions
--- 50% VOC and 100% NO_x emissions
-·- 100% VOC and 50% NO_x emissions
··· 50% VOC and 50% NO_x emissions



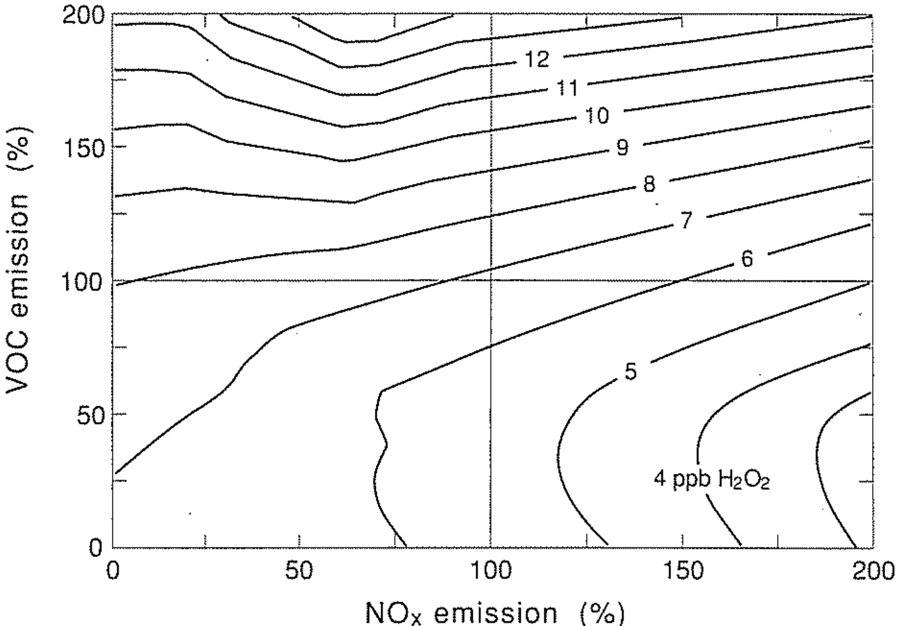


Fig. 10
H_2O_2 concentration isopleths of the peak H_2O_2 concentration (ppb) at 19:00 h on 26 June as a function of VOC and NO_x emissions.

These predictions concern only summer smog conditions on the Swiss Plateau, because other conditions may bring a different pollutant matrix into Switzerland at other times of the year. For example, Föhn winds may carry pollution from northern Italy to the Swiss Plateau.

Conclusions

The results and conclusions from this modelling study apply to summer smog conditions on the Swiss Plateau under high pressure weather systems with weak northeasterly winds. The results of the model calculations show reasonable agreement with concentrations measured during the Pollumet experiment. While the absolute magnitude of the concentrations was not always accurately reproduced, the model faired better as far as the diurnal patterns were concerned. Calculations conducted with hypothetical emissions reduction scenarios demonstrate that European-wide action to control VOC and NO_x is necessary to achieve significant reductions in the concentrations of ozone, PAN and hydrogen peroxide.

In response to emissions reductions, the predicted ozone concentration decreases if NO_x emissions are reduced while the predicted H_2O_2 concentration increases with decreasing NO_x emissions. The model results indicate that VOC and NO_x emissions should be reduced simultaneously to improve air quality. When considering the most effective measures to combat summer smog, the production of all photochemical pollutant compounds must be taken into account as action taken to reduce the level of one component may lead to enhanced levels of a second component.

Acknowledgements

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1 BUWAL (Bundesamt für Umwelt, Wald und Landschaft), Ozon in der Schweiz, Schriftenreihe Umweltschultz Nr. 101, Bundesamt für Umwelt, Wald und Landschaft, Bern, 1989.

2 Sakugawa, H., I. R. Kaplan, W. Tsai, and Y. Cohen, Atmospheric hydrogen peroxide, *Environ. Sci. Technol.*, 1452–1462, 1990.

3 BUWAL (Bundesamt für Umwelt, Wald und Landschaft), Luftbelastung 1989, Messresultate des nationalen Beobachtungsnetzes für Luftfremdstoffe (NABEL), Schriftenreihe Umweltschultz Nr. 122, Bundesamt für Umwelt, Wald und Landschaft, Bern, 1990.

4 Rösselet C. M., and J. A. Kerr, Photochemical modelling of photo-oxidant levels over the Swiss Plateau and emission reduction scenarios, PSI Report No. 93-03, Paul Scherrer Institute, CH-5232 Villigen.

5 Hough A. M., and R. G. Derwent, Computer modelling studies of the distribution of photochemical ozone production between different hydrocarbons, *Atmos. Environ.*, **21**, 2015–2033, 1987.

6 Derwent R. G., and M. E. Jenkin, Hydrocarbon involvement in photochemical ozone formation in Europe, AERE-Report R-13736, H. M. Stationary Office, London, 1990.

7 Lübkert B., and S. de Tilly, The OECD-MAP inventory for SO_2 NO_x and VOC in western Europe, *Atmos. Environ.*, **23**, 3–15, 1989.

8 Buhr M. P., M. Trainer, D. D. Parrish, R. E. Sievers, and F. C. Fehsenfeld, Assessment of pollutant emission inventories by principal component analysis of ambient air measurements, *Geophys. Res. Lett.*, **19**, 1009–1012, 1992.

9 Atkinson R., D. L. Baulch, R. A. Cox, R. F. Hampson Jr., J. A. Kerr, and J. Troe, Evaluated kinetic and photochemical data for atmospheric chemistry. Supplement IV, *J. Phys. Chem. Ref. Data*, **21**, 1125–1568, 1992.

10 Davidson C. I., and Y.-L. Wu, Dry deposition of particles and vapors, in *Acidic Deposition, volume 3: Sources, Deposition, and Canopy Interactions*, edited by S. E. Lindberg, A. L. Page, and S. A. Norton, pp 103–216, Springer Verlag, New York, 1990.

11 Buchmann, B., and P. Filliger, Das nationale Beobachtungsnetz für Luftfremdstoffe (NABEL), presented at 1. Pollumet-Kolloquium, Zürich, 19 April 1991.

12 Neu, U., H. Wanner, T. Künzle, T. Brunner, B. Steisslinger, G. Baumbach, K. Baumann, A. Neftel, B. Lehmann, M. Lehmann, A. Sigg, H. Mathys, and G. Nejedly, Berner Querschnitt: zur Meteorologie und Luftchemie der IOP 90, presented at 1. Pollumet-Kolloquium, Zürich, 19 April 1991.

13 Wunderli S., and R. Gehrig, Influence of temperature on formation and stability of surface PAN and ozone. A two year field study in Switzerland, *Atmos. Environ.*, **25A**, 1599–1608, 1991.

14 Sigg A., A. Neftel, B. Lehmann, and M. Lehmann, Peroxide als Tracer für Luftchemie und Transportvorgänge, presented at 1. Pollumet-Kolloquium, Zürich, 19 April 1991.

15 Sigg A., A. Neftel, B. Lehmann, W. Graber, W. Portmann, H. J. Fröhlin, and B. Neininger, Gasballon-Fahrten, presented at 1. Pollumet-Kolloquium, Zürich, 19 April 1991.

Focus of EAWAG Research[1]

Sustainable Management of Resources

– set on the example of natural waters and anthropogenic sediments

Status quo

Since the middle of the last century, industrialized countries have faced ever more complex environmental problems. Specific concerns that were once confined to a limited area – such as community hygiene, contamination of natural waters or localized air pollution – received priority. Technical remedial measures were developed, which, to some extent, were quite successful. But the dynamic developments in technology and the economy continuously created new and unforseen environmental challenges.

In recent years, it has become evident that environmental problems affect all parts of the natural environment and that they have often become far-reaching with respect to area and time. Development in the past decades has occurred to a large extent at the expense of natural resources. Several regions of the world are already subjected to disastrous environmental conditions and many areas are afflicted by famine. Population explosions and economic repercussions will continue to exert pressure on the environment. If we are unable to change the course of recent developments, we must be prepared to reckon with catastrophic regional and global collapses.

Today, the idea that sound strategies for environmental protection and long-term sustainable development are indispensable, seems to be generally accepted. Despite this knowledge, however, attempts at environmental protection are predominantly aimed at single threats. There is a general lack of concrete ideas about the kind of development we can sustain, and, in turn, the ways by which basic human needs (and those of other forms of life) can be satisfied in the short- and long-terms. Taking into account that the natural environment, resources and society are mutually linked, it is clear that new approaches are needed.

Various principles have been postulated as the starting points for sustainability – for example, from the point of view of the management of resources and of environmental problems (Herman Daly):

- The rate of exploitation of renewable resources should not exceed their rate of regeneration.
- The rate of reduction of exhaustible raw materials should not exceed the rate of synthesis of raw materials by regenerative resources.
- The rate of emission of pollutants should not exceed the capacity of the environment to remove pollutants.

Motivation and Objectives

This postulate and the principles of sustainability are valid globally, nationally and regionally. Special importance is attached to the *region*. This is where people live and orient themselves; where they are directly and actively in touch with their environment. Concrete approaches for sustainable management of resources can, therefore, better evolve within the limits of a region rather than globally. If there is no sustainability in a region, it will have adverse effects on other regions. If many regions do not exhibit sustainability, the consequences will affect the networks of nations, continents and the world as a whole.

Sustainable development touches on a problem of the highest complexity; on an existential matter of civilization. Tackling this problem is a major challenge for society and science. The *EAWAG wants to make a contribution to it through its focus of research.* The EAWAG starts within its own sphere of competence – which should be expanded through cooperation with other institutions and groups. Research shall be concentrated on small, surveyable territorial units, viz. regions of limited dimension (dozens – hundreds of square km). With regard to the manifold requirements of sustainability, research will be undertaken from the point of view of the natural, engineering and social sciences, and the humanities.

Focus of EAWAG Research: 1993–1997

The EAWAG wants to make a contribution to solving urgent environmental problems and help to put the concept of sustainable resource management into practice. The planned projects are consistent with current activities of the EAWAG, but require additional expertise as well; consequently, a strong participation from external partners from research centers, government agencies and the private sector is sought. Such cooperation is indispensable in the development of new approaches for the protection and management of environmental resources.

Considering the complexity of this endeavor, the description presented here is meant to serve only as a "definition of limits". The concepts will be developed as the process evolves; the projects of research shall be conceived, carried out and mutually linked through an intensive interaction between the project managers and researchers – an approach deemed vital in the successful execution of this mission.

Ueli Bundi

EAWAG Focus of Research: There is a wide spectrum of factors that are relevant to the sustainable development of a region. The environmental problems and management concepts for waste sites, contaminated soil and

[1] The program description was developed by Ueli Bundi (project coordinator), together with Peter Baccini, Markus Boller, Roland Schertenleib, Wolfgang Schilling, René Schwarzenbach and Alexander Zehnder

The 3 Subtopics		Integration
Subtopic	**Research Areas**	**The Subtopics are linked by:**
Formation, sanitation and utilization of anthropogenic sediments	Old and new waste sites, contaminated soils and sediments	• the common research regions • the medium of water, which demonstrates the relationship between humans and their environment • the parallel development of research questions with respect to social sciences and the humanities • the mutual linking of results and the development of regional strategies for development
Impairment, protection and utilization of ground water	Ground water and its relationship to adjacent areas	
Function of natural waters in the natural materials balance and in the human-environment relationship	Natural waters as a medium for life and as an element of ecosystems and human resources	

Table 1
The EAWAG Research Focus "Sustainable Resource Management – the example of water and anthropogenic sediments", organized in three subtopics and one integrative part.

sediments, and polluted ground water shall be dealt with specifically. The general aims of this research are:

- To develop directly applicable methods and generalizable principles in order to solve and prevent environmental problems, as well as for sustainable regional management of resources
- To develop the impetus for overall sustainable regional development

Contents and Structure of Research

A Swiss region will serve as the object of the research. An intensive exchange of scientific ideas shall be maintained with analogous bodies inside and outside of Switzerland. The following criteria should be met by the region:

- Presence of subregions that are close to natural areas and presence of subregions that are used intensively
- Prevalence of typical problems associated with waste sites and the contamination of ground water as well as conflicts regarding the use of natural waters
- Little influence from neighboring regions
- Presence of a sound basis of data about anthropogenic activities and natural resources and their historical development
- Interest shown in the project by regional and cantonal authorities
- The possibility of participation of regionally important companies

If necessary, other regions shall be included to clarify the general applicability of the results from this research.

The investigations will be divided into three subtopics and one integrative area (see Table 1).

Integration

Project management and coordination constitute the integration. The general concepts will be formulated and data for a complete description of the region will be acquired. Findings from the subtopics with regard to the outlining of strategies for sustainable management of resources and regional development will be combined with respect to the following interrelationships and investigations:

- Deduction of common principles for sustainable management of resources
- Analysis of historic and current examples of the nonsustainable usage of resources and regional development
- A systems analysis of the area of research: description and quantification of the development of anthropogenic activities, natural resources and their usage, as well as of the hydrological and material cycles
- A complete description of the regional interaction between human activities and needs, the state of natural resources and the hydrological and material cycles
- Combining the knowledge gained from the subtopics for the conceptualization of sustainable management of resources
- Development of options and strategies for regional development

Subtopic 1: Formation, Sanitation and Use of Anthropogenic Sediments

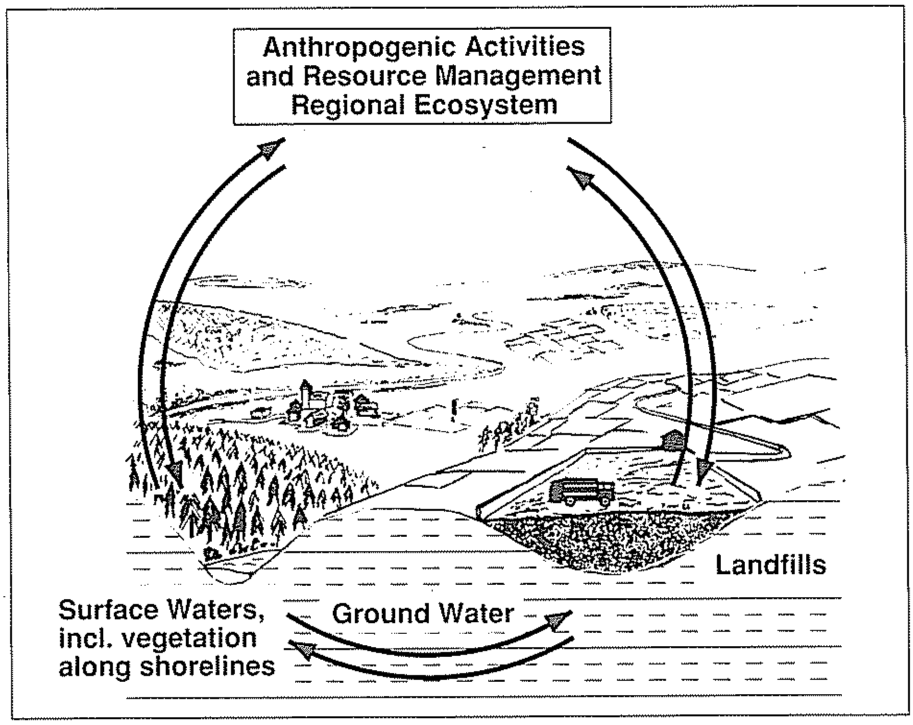
Motivation and objectives

In the past several decades, all industrialized countries have produced wastes and contaminated soils. As waste disposal sites exhibit a potential to release hazardous chemicals, they pose an acute or latent threat for the local and regional biosphere. Initial estimates conclude that in the 1990s, 1000–10,000 Sfr per capita will have to be spent on the sanitation of waste disposal sites, depending on the region. At present, the market offers a wide range of solutions in the field of process and construction engineering; however, there are not enough ecological concepts and criteria available to judge whether these methods and their combinations are suitable and efficient.

New waste disposal sites are continuously created in many countries as the waste processing there does not yet produce deposits entailing qualities of "final storage"; therefore, there is a danger that the sanitation of waste sites may become a permanent, exponentially growing problem. This is because measures are taken solely to solve acute problems (e.g., Superfund program in the USA), whereas long-term problems are being underestimated.

Another important and equally underestimated problem is the social compatibility of sanitation projects and new waste sites. The investigations shall result in basic principles and approaches founded on environmental sciences; namely:

- Criteria for the deposition of materials in a given area and for assessment of technical procedures for the sanitation of waste sites
- Methods and strategies for the design of environmentally acceptable waste disposal sites, the components of which can be used again as resources



The three subtopics of the EAWAG Research Focus and their interrelationships.

Methods

Waste sites – selected existing waste disposal sites and planned waste disposal sites will serve as research objects. Various research groups from universities, research and development groups of the private sector and the community shall participate. What is essentially being referred to is to achieving the aims by way of an iterative method including field studies, process engineering and computer modelling of processes – to aim at creating and using synergisms between groups working in the fields of sanitation and and new deposits (which are still operating separately).

Expected results and effects

We anticipate the acquisition of knowledge for future sanitation of waste disposal sites and formation of new deposits on the basis of sound criteria and methods in the fields of natural, engineering and social sciences. In addition, the objects worked on may serve as models and exemplary studies for educational purposes.

Subtopic 2: Impairment, Protection and Utilization of Ground Water

Motivation and objectives

Ground water is formed by the natural and artificial infiltration of rain and surface waters. In many places, it is the only source of drinking water. The increasing pollution of the atmosphere, soil and surface waters with anthropogenic inorganic and organic materials has led to a seriously reduced quality of ground water. Moreover, quantitative impairment exists in many areas because new ground water supplies have been decreased due to the sealing of the surfaces of infiltration (settlements, roads, silting of river beds). The effects of anthropogenic material fluxes on the quality of ground water depend on many physical, chemical and biological processes influencing one another. There is still insufficient knowledge of these processes to be able to assess the potential danger of different sources of contamination.

This research project shall provide data and methods to assess anthropogenic damage and protect ground water; namely:

- A better understanding of the mechanisms and interactions of major processes influencing the distribution and fate of pollutants in the soil
- Development of methods to estimate the consequences of different sources and types of contamination
- Establishment of criteria for groundwater compatibility of soil usage and contamination under different natural conditions
- Institution of measures for the protection of ground water and for the sanitation of impaired aquifers

Topics of research

- Chemical and biological processes at interfaces: processes of sorption, dissolution and precipitation; abiotic and biological transformation processes
- Geological, geochemical and hydrodynamic characterization of aquifers and zones of infiltration (in saturated and unsaturated soil)
- Influence of soil utilization and damage on the physical, chemical and biological processes in zones of infiltration
- Influence of soil usage on the formation of ground water
- Development of models to describe underground chemical and biological processes; linkage of these models with physical models of transport.

Practical applications

- Delivering a basis for decision-making with regard to the artificial infiltration of meteoric waters
- Counseling on judgement and risk analysis of contaminated conditions of ground water (accidents, deposits, impaired surface waters), on planning measures for the protection of ground water and on groundwater sanitation
- Identifying the requirements for the groundwater-compatible management of soil under different conditions

Subtopic 3: Functions of Natural Waters in the Natural Environment and in Human/Environment Relations

Motivation and objectives

Drinking water and natural waters play a very essential role in the natural balances, economy and human well-being. During the course of time, the natural water balance, the quality of water and the network of natural waters have been markedly changed. Until now, methods to protect natural waters concentrated on the reduction and prevention of local problems; in view of a sustainable regional development, hardly any knowledge of the functions and forms of hydrological and aquatic systems exists. Research should include the following:

- Analysis of relations between anthropogenic activities, the natural water balance, and the state and function of natural waters in regions under the influence of different geographical, economic and socio-cultural conditions
- Identification of the requirements of sustainable use and development of natural waters
- Development of methods for the integral protection and environmentally friendly utilization of natural waters

Contents of research

- The significance of natural waters as a network of habitats and for the natural environment of regions
- The role played by natural waters in the economy and for human well-being
- Meeting ecologically and ethically motivated requirements with regard to natural waters and hydrological systems
- Direct and indirect effects of the usage of natural waters and of anthropogenic activities on the regional water balance and the state and function of natural waters
- Significance of changes in natural waters for the planning of anthropogenic activities and for human well-being
- Economic and socio-cultural implications of attempts at a sustainable development and usage of natural waters
- Options for sustainable interaction between society and natural waters. (Research shall at first be done in a Swiss region)

Analogous studies will be launched and supported in foreign regions (e.g., Eastern Europe, Third World countries).

Expected results and effects

- Formulation of the characteristics and possibilities of interpretation of sustainable utilization of natural waters
- Establishment of criteria for the assessment of the regional ecocompatibility of the usage of natural waters
- Concepts for the planning of regional ecological networks
- Impulses to initiate sustainable regional strategies for the protection and usage of natural waters

Schedule and Financing

1993 Formation of committees for project management. Choice of region and object of research. Publishing of the research program. Review by experts and granting of project requests. Formation of teams including external participants. Making requests for funds by other means. Launching of research projects (pre-projects and main projects) in the integrative part and three subtopics.

1994–1996 Work on the main project. Parallel to research experiments in the subtopics – research on their mutual connections will continue in the integrative part.

1997 Concluding syntheses, (i.e., formulation of concepts for the sustainable management of resources and for regional development.)

The EAWAG intends to invest approximately 1–2 million Swiss francs (10–15 person-years per year plus expenses) for its focus of research every year. In addition, requests for other means worth 0.3–0.5 million francs shall be made at institutes encouraging research, and other interested official agencies, also in the private sector. We want to foster active participation from external groups of research institutes and the private sector – for those parts of research that lie outside EAWAG's sphere of competence. It is assumed that contributions by external partners will be made at their own expense.

Management

Each subtopic will be accompanied by a committee of 2–4 persons. The tasks of these committees will include the following:

- detailed description of the contents and topics of research
- establishing and maintaining contacts with external partners
- assessment of project requests to the care of the project management
- coordinating projects by encouraging an exchange of information between various teams
- professional assessment of results of the projects

Integration

The project management for the entire project will be comprised of delegates from the subtopics and 1–3 other individuals. Their tasks include the following:

- Granting requests for research (including the "EAWAG Conference")
- Coordinating the external financing of projects
- Coordinating subtopics and encouraging the mutual exchange of ideas
- Conceiving and supporting the integrative projects and research work
- Distributing assignments in order to work on specific aspects of the entire project (including the EAWAG Conference)

The project management will be supported by one individual who will accomplish the task of coordination and integration, as well as maintaining good relations with external authorities.

Advisory committee

An advisory committee comprised of approximately five experienced scientists will assist the the project management team.

Cooperation and participation

Research will be intiated by the EAWAG. Its expert groups will all participate in at least one of the subtopical areas. A participation of other authorities is imperative including universities, research centers, government agencies and private companies. Scientific contacts with analogous institutions abroad will be established. External partners will participate in the research with their own sources of financial support. They should be represented in the managing committees of the subtopics and of the entire project.

Coordination: Walter Wagner

PEAK[1]: EAWAG's Environmental Education Program

In September, the Swiss Federal Institute for Environmental Science and Technology (EAWAG) and the Swiss Federal Institute of Technology in Zürich (ETHZ) jointly initiated a new training program: courses in environmental science offered to specialists from industry and government. The courses aim to transfer state-of-the-art knowledge obtained from research at the EAWAG and ETHZ to professionals working on environmental issues. The objective of the program is to integrate environmental protection and collaboration beyond the boundaries of disciplines and institutions.

Participants: Scientists, consultants, engineers, administrators, and managers from government and industry working in environmental protection. The official language for all courses is German.

Purpose and topics: The objectives of the program are to communicate knowledge and skills from science to those working on practical environmental problems and to enhance the dialogue between researchers at the EAWAG/ETHZ and environmental specialists working in industry and administrative posts as well as between the participants themselves. The course topics reflect the current research activities and aim to keep pace with the newest developments.

Participation and credit: Enrollees are given the opportunity to communicate their experiences to their colleagues and to the lecturers and to discuss problems. Examinations may be given in order to prove acquired knowledge and obtain credits comparable to those of the European Credit Transfer System (ECTS). Ten hours of course time corresponds to one credit. Each course announced in the PEAK-program can be attended independently, provided the specific requirements for that course are fulfilled. The participants receive documentation for each course.

Types of courses

PEAK offers three types of courses: basic, advanced and applied as described below.

Basic courses

Mainly lectures (1–3 days)

Objectives: Lectures on basic science needed to understand environmental problems as well as structures and processes of natural and artificial ecosystems. Contents are comparable to those of graduate courses in environmental curricula at universities.

Participants: Environmental specialists wishing to refresh their knowledge of environmental topics.

Advanced courses

Lectures, exercises, practical work and excursions (2–5 days). A limited number of participants is given the opportunity to add a week of practical work.

Objectives: Examples and case studies are used to present an integrated view of environmental problems. The recognition of stress symptoms as well as the understanding of their causes and effects are shown. Preventive measures and technical solutions to the problems are discussed.

Participants: Environmental specialists wishing to further their understanding of specific problems and to learn more about integrated environmental management.

Applied courses

Lectures and practical work in the laboratory and field (1–2 weeks). The number of participants is usually limited to 20.

Objectives: The participants will gain knowledge and practical abilities to recognize, prevent and reduce environmental degradation.

Participants: Applied courses are for specialists working in the field covered by the course topics. The course contents should be of direct practical use in the daily work of the participants.

In addition to these three types of courses there is a so-called "Info-day", a one day meeting at which EAWAG researchers from various groups present study results pertaining to a current environmental problem. Proceedings of this annual conference are published in EAWAG news.

Research areas at EAWAG

It is anticipated that most of the research activities of EAWAG will eventually be developed into PEAK courses.

1. *Fundamental Sciences in Environmental Protection*
   Aquatic chemistry, physics, biology, microbiology, modeling, statistics, ecology, ecotoxicology, civil and chemical engineering.
2. *Methods to Assess and Characterize Natural Systems*
   Chemical, biological, and microbiological sampling and analysis, data analysis, material and energy flow analysis, physical measurements, interpretation of results.
3. *Environmental Technologies*
   Water resources management, waste disposal, wastewater pu-

[1] **PEAK** stands here for the acronym of the german expression for the courses at EAWAG: **P**raxisorientierte **EA**WAG-**K**urse

Permanent Education

Permanent Education

PEAK Program for 1993–94

13–17 September 1993	**The significance of stream morphology and typology of water for organisms**
Applied course A1/93	Lectures and practical fieldwork to assess the importance of stream morphology for stream dwellers and its interconnections with the surrounding landscape. Course directors: Tom Gonser, Rudolf Müller, Armin Peter
14–16 September 1993	**Development and implementation of new quality criteria in waste management**
Advanced course V1/93	The final storage quality of municipal solid waste bottom ash. Course director: Peter Baccini
21 September 1993	**From environmental protection to integrated environmental management**
Infoday 1993	Systems oriented approach in theory and practice Conference directors: Theresa Büsser, Peter Huggenberger
16–17 November 1993	**Structures and processes in aquatic systems**
Basic course B1/93	Actualizing the relevant chemical, physical, microbiological, and biological knowledge for practical problems. Course directors: Elisabeth Meyer, Alfred Wüest
23–25 March 1994	**Analytical chemistry of pollutants: concepts and methods**
Applied course A2/94	State-of-the-art chemical analyses of water, soil and air: from sampling to data processing. Course director: Walter Giger
12–14 April 1994	**Metals in the aquatic environment**
Advanced course V2/94	Fundamentals of chemistry and ecotoxicology of metals in aquatic systems. Behavior of heavy metals in waters and landfills. Evaluation of metal pollution. Course directors: Renata Behra, Annette Johnson, Laura Sigg
15–16 June 1994	**Integrated environmental protection: basic principles, uncertainties and management scenarios**
Basic course B1/94	Knowledge gained from the natural sciences are combined with approaches in the social sciences and the experience from water protection practice. Together they lead to new concepts in environmental protection. Course directors: Ueli Bundi, Giulio P. Genoni, Bernhard Truffer
6–8 September 1994	**Organic pollutants in the environment**
Advanced course V3/94	Transport and transformation processes of organic chemicals in aquatic systems. Ecotoxicological effects of these chemicals. Course directors: Werner Angst, Hanspeter Kohler
20 September 1994 Infoday 1994	**Natural and anthropogenic deposits – consequences for environmental development and technology**

rification, drinking water preparation, remediation.

4. *Current Environmental Problems*
Accidental spills and catastrophes (scientific evaluation), legislative changes, social and political aspects, concepts and solutions for current problems.

5. *Goals and Strategies of Environmental Protection*
Case studies, environmental quality criteria, legislation, planning and implementation, free market instruments in environmental policy, implementation aspects of sustainability.

Information

PEAK was first announced in July 1993. The program will be updated every year and each course will be announced separately a few months ahead of time. The program is also accessible via Videotex (*6622# or *agora#), the Swiss telecommunications network. Those who are connected to the ETHZ network can use the "ezinfo" system for their inquiries.

For more information call or write:

Herbert Güttinger 01/823 50 23
Heidi Gruber 01/823 53 98
FAX 01/823 53 98
PEAK, c/o EAWAG, Überlandstr. 133, CH–8600 Dübendorf.

Events

EAWAG Information Day 1993

"From Environmental Protection to Integrated Management: Systems-Oriented Approaches in Theory and Practice"

This year the Swiss Federal Institute for Environmental Science and Technology (EAWAG) again hosted an "Infoday" which took place on 21 September 1993 at the ETH in Zürich.

Presentations focused on current developments in fundamental and applied aspects of environmental science. In pursuing its role of linking research with practice, EAWAG co-workers discussed general experiences as well as the results of specific projects to an audience engaged in practical work and interested members of the scientific, economic and political communities.

In the next issue of the EAWAG news, you will find the condensed presentation of the lectures.

Infoday 1993: Lecturers and topics

Demands and Theses for the Future Environmental Development
Alexander J.B. Zehnder

Risk Communication: The Example of Climate Change
Claudia Pahl, Carlo C. Jaeger

How much Stress can Organisms and Ecosystems tolerate? Ecotoxicological Considerations
Herbert Güttinger

The Significance of Stream Morphology for Ecosystem Functions
Tom Gonser

First Steps to a Sustainable Regional Resource Management
Peter Baccini

Water Quality Criteria for Metals in Running Waters
Renata Behra, Giulio P. Genoni, Laura Sigg

Possibilities and Limitations of Biotechnology in Environmental Remediation
Jan Roelof Van der Meer

Detergents and the Environment: From End of Pipe to Preventive Measures
Walter Giger, Alfredo Alder

Environmental Problems in Developing Countries: A Question of Survival
Roland Schertenleib

Insight Demands Action - Consequences for the EAWAG
Ueli Bundi

Canton Representatives Meet at EAWAG

In Switzerland, the "practice" of environmental conservation is principally incumbent on the cantons; therefore, it is important that the partnership between the responsible cantonal departments and the EAWAG functions well. In order to strengthen this relationship, the EAWAG organized a one-day information and discussion conference on 27 May 1993. This event evoked positive interest and about 70 participants from nearly every canton took part.

Through various presentations, the participants were afforded insight into the organization and areas of activity of the EAWAG. Understanding of roles on both sides and strengthening of their work together were the chief topics of the discussion. It was clear from the meeting that lasting progress in environmentally friendly development can be achieved only by the cooperation of government, business, industry and science.

Departments

New at the EAWAG

The Human Ecology Research Group

Once upon a time, there was a scientific research expedition deep in the Antarctic. These courageous men and women were busy exploring the atmosphere. One day they discovered a "hole" in the ozone layer. When they published this discovery it caused great anxiety everywhere. All over the world, other research groups were put into action to investigate the causes and possible effects of ozone depletion. The researchers found that it was caused by chlorofluorocarbons and that it caused serious damage to health. All the influential people in the world came together at a big conference and decided on an immediate worldwide ban on CFCs. As a consequence of this decisive measure, the ozone of the depleted area regenerated again and everyone lived on (and did research) happily and contentedly.

We all know that it doesn't exactly work like this. More unclear, however, is how it really works. More concretely, we are talking about what causes the global destruction of the environment and how a conversion to environmentally more friendly economies and lifestyles can be realized. Of course, most people suspect now and then that others are to be blamed for this miserable situation. Researchers suspect that the results of their work are not carried out in the right way by the politicians. Politicians criticize the omission of social acceptability in the solutions to these problems as proposed by the scientists. The public feels it is "out of its league" in the world of scientific jargon. So no one feels responsible and all continue as before, even if so with a growing feeling of anxiety. Once in a while a single effort enables one to come closer to a solution to a certain environmental problem, but at the same time, two new ones crop up somewhere else.

Formulating research Questions in Human Ecology

It is natural that one does not only investigate environmental problems from the point of view of the environment but also from that of the people who perceive, cause and maybe even solve the problems. This is where our working group in human ecology comes in. We investigate questions such as: "When and by whom is a phenomenon perceived as an environmental problem?" "How does environmentally relevant information get disseminated?" "What triggers environmentally relevant behavior?" "Under what conditions do environmentally relevant processes of innovation get initiated?" These questions refer to systems of human ecology; that is, systems which include people, social structures and cultural rules which are embedded in a specific area of material reality and encompass a dynamic diversity of human relationships to the environment.

Such systems are best studied within the context environmental problems. Currently, we are investigating the social aspects of impending climatic change. In working on the social aspects of climatic risks, we intend to contribute to the competence of the EAWAG to present viable and consolidated propositions in the debate centering around global change and thus facilitate the development and implementation of solutions.

We assume that, although impending climatic changes are a global problem, real solutions can only partly be achieved through global decision-making. This is so because, among other reasons, the solution to the environmental problems of today requires a transition to a sustainable economy which cannot just be developed on the drawing board. It is more important to try out diverse strategies and to facilitate the breakthrough of viable concepts for solutions by means of an evolutionary process. Single nations and regions are more often able to undertake such a step than the so-called "global community".

The concept of a regional focus fits in well with the EAWAG's priority research program on sustainable water management, which also encompasses the possibility of developing collaborations with various other departments of the EAWAG. One such collaboration already exists with the Department of Environmental Physics on the investigation of environmental risks. There is also a natural affinity to the IRCWD with which the Human Ecology group shares the C-floor in the Chriesbach building. For both groups, environmental problems are closely linked to the fate of the affected peoples.

Current projects

Two specific research projects concerning climatic risks have been initiated. The first investigates the perception of climatic risks in the Ticino and the Surselva within the framework of the Swiss National Research Program No. 31 "Climatic Changes and Natural Catastrophes". Private households, companies and political institutions are being asked to complete a questionnaire that asks the respondents to evaluate how they perceive environmental risks and in which way do possible pathways of communicating risks appear through which politics, business and private life can work together at solving a problem.

In another project, innovative processes are being investigated using the examples of "Electric Vehicles" and "Decentralized Working Places" which are relevant with respect to the reduction of CO_2 emissions. This project is also based on a regional viewpoint. It is a part of the project package "CLEAR - Climate and Environment in Alpine Regions" within which questions of climatic change are being investigated in the framework of Module 1 of the National Priority Program Environment. Researchers involved come from the fields of atmospheric physics and climatology, biology and systems ecology, the social and economic sciences from the EAWAG, the ETHZ and cantonal universities and research institutes. The Human Ecology working group at the EAWAG has taken over the coordination of the whole research effort.

Members of the Human Ecology Research Group

The Human Ecology Research Group is interdiscipinary. The current team consists of nine individuals, four women and five men, each of whom is briefly introduced below.

Carlo Jaeger, the head of the Human Ecology research group, is a sociologist who graduated in economics and is a university lecturer in human ecology. He has worked on several research projects on the social aspects of new information technologies and has long been interested in questions of social theory. He heads the teaching committee in the ETH Department of Ecological Sciences and is a member of the board of the department. He is married and the father of two children. He likes to be with nice people at work and in his free time.

Gregor Dürrenberger is the operational head of research of the Human Ecology research group. He is a geographer, having studied natural sciences at the ETH. After his dissertation on territoriality, he spent a postdoctoral year at the University of Newcastle upon Tyne (UK). His research focuses on the regional aspects of global climatic problems. Over the past few years, he has been working on urban development and cultural evolution. He is a lecturer in the Department XB at the ETH. In his free time, he studies the practical aspects of enology.

Joan Davis moved to Switzerland after receiving a Ph.D. in chemistry in the USA. Subsequently she began her work at the EAWAG on the aquatic chemistry of rivers and streams. In order to be able to investigate the causes of chemical pollution and to convey this knowledge to others more effectively, she joined the Human Ecology research group this past year. Apart from her research, she lectures on problems of aquatic ecology and on environmental systems at both the ETHZ and the University of Zürich.

Bernhard Truffer is a geographer and was an assistant at the Geographical Institute of the University of Fribourg (Switzerland). His recently completed his doctoral dissertation and investigated the theoretical determination of the price of land and its significance for the development of today's cities. His scientific interest centers on economic, technological and social potentials for change which could lead to the sustainable development of a region. His current research concentrates on potentials for change with respect to the mobility of individuals with regard to climatic risks.

Urs Dahinden is a sociologist and coordinator of the CLEAR project. He has written a diploma thesis for his undergraduate degree on the computerization of the office which will appear shortly in book form with the title "Chameleon Computer". He is currently working on a doctoral dissertation on the social aspects of the greenhouse effect. His hobbies include biking and hang gliding.

Silvia Rothen is an economist. After completing her undergraduate diploma thesis, she worked for

From left to right, in front row: Lisbeth Bieri, Silvia Rothen, Joan Davis, and Marina Hubbuch
Back row: Bernhard Truffer, Gregor Dürrenberger, Matthias Wächter, Urs Dahinden, and Carlo Jaeger.

a year on the development of the Impulse Program on Microelectronics at the Federal Office for Economic Policy. Over the last three years she held an assistantship under Prof. Gunter Stephan at the Institute for Applied Microeconomics in Bern where she gained experience in research and teaching in environmental economics. Her dissertation, which has just been published, analyses the possibility of reducing Switzerland's CO_2 emissions on a longterm basis.

Lisbeth Bieri is a researcher in the Human Ecology working group and is currently working on a Swiss National Research Fund project on climatic change and regional development in mountain areas. She has been active for a number of years in the development of the Surselva mountain region. She has been involved in studying the possibilities of telematics for rural areas. As a consequence, the satellite office of Sumvitg was created among other things. Further research interests concern qualitative and quantitative methods in social research. Lisbeth Bieri loves nicotine and caffeine and hates asphalt testing installations in front of her office window.

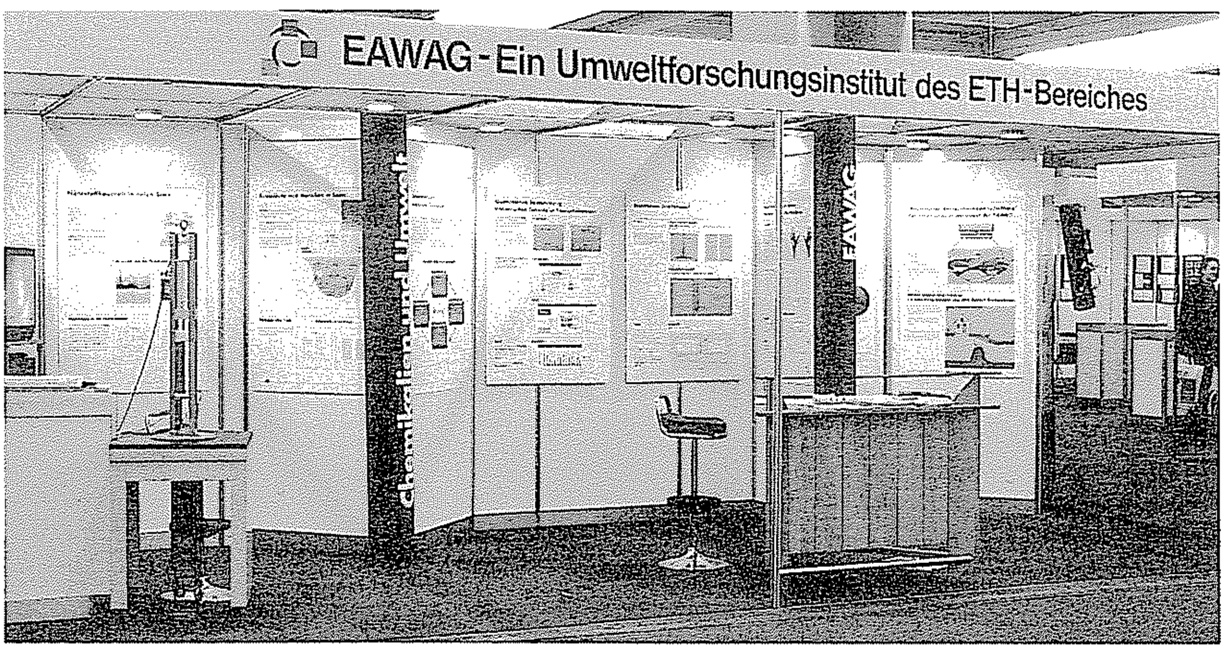
Matthias Wächter is a chemist and wrote a diploma thesis on questions of interpretation in quantum mechanics under Hans Primas. He is indebted to him for pointing attention to the strengths and weaknesses, above all to the limits of modern natural science, to its aspect as myth and to its role in today's ecological problems. His doctoral dissertation will also confront these and other related themes. Otherwise he enjoys life in a colorful mixture of conviviality and literature, mountains and rivers.

Marina Hubbuch manages the secretarial office of the Human Ecology working group. This includes a number of organizational duties; in particular, she controls the coordination of the various activities. She went to commercial school after which she had several secretarial jobs, mainly in the field of medicine. After a break of four years as a housewife and mother, she has been working in the Human Ecology research group since the end of 1992.

Ilmac 1993

The Ilmac is an international professional exhibition for technological and analytical methods in chemistry and chemical biotechnology which is held annually in Basel. Ilmac '93 took place from 19–22 October 1993. The organizers wanted to put an emphasis on "teaching and research" and so invited some 160 university and research institutes from all over Europe to make presentations on their study and research goals. EAWAG showcased some sampling techniques and analytical procedures which were specifically developed for use in applied ecology.

During Ilmac '93, the Analytical Chemistry section of the new Swiss Chemical Society organized three specialists' conferences. The symposium, which was held 21–22 October, was entitled "*Polar organic pollutants in the aquatic environment: automated monitoring at the trace level and fate studies*" and was largely based on research carried out in the so-called *Rhine Basin Program*. In addition to speakers from industrial laboratories, universities and government institutions, EAWAG researchers spoke about the results of their investigations, the central theme of which was water-soluble pollutants, some of which are found in detergents.



New EAWAG Ordinance

On 4 October 1991, the Swiss Parliament passed a new Law concerning the Swiss Federal Institutes of Technology (ETH Gesetz). This Law went into effect on 1 February 1993, after the legal referendum period had expired. In the meantime, the Federal Council's legislation for implementing the new law in the ETH Domain had to be revised and brought in line with the new law.

In this context, the following ordinances were drafted:

- Ordinance relating to the Domain of the Swiss Federal Institutes of Technology (Verordnung ETH-Bereich)
- Ordinance relating to the Swiss Federal Institutes of Technology (ETH-Verordnung)
- Ordinance relating to the Lecturers of the Swiss Federal Institutes of Technology (Dozenten-Verordnung)
- Ordinance relating to the Swiss Federal Laboratories for Materials Testing and Research (EMPA-Verordnung)
- Ordinance relating to the Federal Research Institute for Forest, Snow and Landscape (WSL-Verordnung)
- Ordinance relating to the Paul Scherrer Institute (PSI-Verordnung)
- Ordinance relating to the Swiss Federal Institute for Environmental Science and Technology (EAWAG-Verordnung)

The EAWAG Ordinance (published in the Official Collection of Federal Jurisprudence, No. 8, 2 March 1993; SR 414.162) is printed on the following pages. The diagram below shows the position of the EAWAG in the ETH Domain and the administrative organization of the Federal Government.

Notes on the new EAWAG Ordinance

The Federal Council's legislation for implementing the ETH Law in the ETH Domain is simply organizational legislation. It establishes the framework within which the EAWAG can fulfill its duties under optimal conditions. The EAWAG Ordinance is not concerned with scientific issues; these are up to the ETH Board to decide. In passing the ETH Law, the Parliament imposed on itself great legislative restraint, which was also reflected in the implementing ordinances. These ordinances grant the EAWAG a large degree of autonomy in day-to-day decisions; they contain nothing which is already governed by law, but only that which is legally required to be regulated by the Federal Council. Wherever the law provides for delegation of responsibility to the ETH Board, this is done.

Article 1
Legal status

The EAWAG is a legal entity, as are the two universities and the other three research institutes.

Article 2
Duties

Paragraph 1 sets out the research areas of the EAWAG. The terms used are relatively broad. Paragraphs 2 through 4 stipulate that the EAWAG shall support the institutes of higher education and other institutes of learning in the their teaching and research, shall give educational and training courses and shall provide services in its area of competence.

Article 3
Cooperation with the institutes of higher education

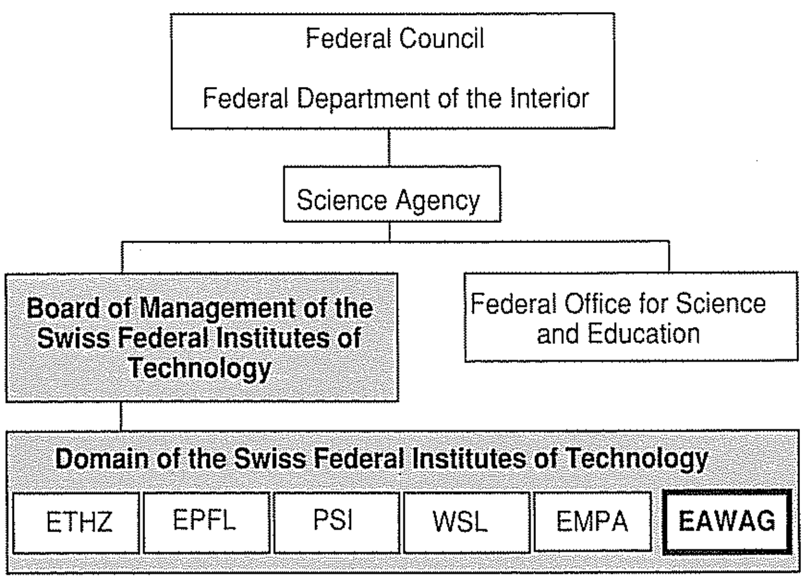
This article establishes the principle of cooperation between research institutes and institutes of higher education.

Article 4
Cooperation with the public and private sectors

Paragraph 1 lays down the principle of cooperation between the EAWAG and the public and private sectors in research projects. In Paragraph 2, it is made clear the the EAWAG is principally a research and teaching institute and cannot be required to accept every assignment. This applies especially to assignments that could be taken on by other public or private bodies.

Article 5
International cooperation

The EAWAG's research shall be at an internationally high level.



The relative position of the EAWAG in the ETH Domain and in the Federal administrative organization.

Inside EAWAG

Ordinance relating to the Swiss Federal Institute for Environmental Science and Technology (EAWAG-Verordnung)

of 13 January 1993

The Swiss Federal Council,

on the basis of Article 39, Paragraph 2 of the Federal Law of 4 October 1991 relating to the Swiss Federal Institutes of Technology (ETH Law),

hereby ordains:

Art. 1 Legal status

1 The Swiss Federal Institute for Environmental Science and Technology (EAWAG) is an autonomous federal research institute under public law and is a legal entity.

2 The EAWAG shall be subject to the authority of the Board of the Swiss Federal Institutes of Technology.

Art. 2 Duties

1 The EAWAG is a national, multidisciplinary research institute for environmental sciences, especially for hydro-ecology, hydro-technology and the interactions between water, soil, air, the biosphere and man.

2 It shall support the institutes of higher education and other institutes of learning in teaching and research.

3 It shall give training and further education courses in its areas of competence.

4 It shall provide scientific services in its areas of competence.

Art. 3 Cooperation with the institutes of higher education

1 The EAWAG shall cooperate with the federal and cantonal institutes of higher education.

2 It may arrange with the responsible authorities for the common use of facilities with the institutes of higher education.

Art. 4 Cooperation with the public and private sectors

1 The EAWAG may carry out research projects together with the public and private sectors.

2 It shall undertake assignments for scientific services, provided the necessary means are available.

Art. 5 International cooperation

The EAWAG shall cooperate with the international scientific community, especially within the framework of common research and development programs.

Art. 6 Communication of knowledge and technology, dissemination of research results

1 The EAWAG shall further the conversion of research results into practical applications.

2 It shall release the results of its research to the public, provided there is no conflict with more important public or private interests.

Art. 7 Education and training

The EAWAG shall participate in education and training within the institutes of higher education and other institutes of learning by giving lectures and seminars as well as assisting with diploma work and doctoral theses.

Art. 8 Organization

1 The EAWAG shall be divided into research departments and administrative divisions.

2 The Board of the Swiss Federal Institutes of Technology shall govern the organization of the EAWAG.

Art. 9 Administration

1 The Administration shall consist of a Director and the heads of the research departments and administrative divisions determined by the Board of the Swiss Federal Institutes of Technology.

2 The Director shall be the head of the EAWAG and shall have overall responsibility for directing the institute. He shall be responsible to the Board of the Swiss Federal Institutes of Technology.

3 The Board of the Swiss Federal Institutes of Technology shall decide the responsibilities and powers of the Administration and its members.

Art. 10 Advisory Committee

1 The Advisory Committee shall advise the Board of the Swiss Federal Institutes of Technology and the Administration on all matters relating to the activities of the EAWAG.

2 The committee shall have between five and nine members.

3 The Board of the Swiss Federal Institutes of Technology shall elect the chairman and the committee members for a four-year term of office.

Art. 11 Participation

1 The Board of the Swiss Federal Institutes of Technology and the Administration shall consult the personnel through the personnel representatives, before making decisions that are of general interest to the EAWAG. These include the planning, creation and abolition of departments and matters concerning the structure.

2 The personnel representatives shall be elected by the personnel themselves.

3 The Administration shall ensure that every employee has sufficient information to exercise his rights regarding participation.

Art. 12 Cooperation with the staff associations

The EAWAG shall cooperate with the staff associations in matters regarding personnel according to the guidelines of the Board of the Swiss Federal Institutes of Technology.

Art. 13 Use of research equipment

1 Researchers in Swiss institutes of higher education and public reseach institutes may use the research equipment of the EAWAG free of charge.

2 If the private sector works on a project jointly with the EAWAG, it shall pay a proportional part of the project costs.

3 In cases other than those cited above, the Director shall decide on the conditions for using the equipment.

Art. 14 Payment for services rendered

1 Fees shall be charged that cover the costs of services.

2 The Board of the Swiss Federal Institutes of Technology shall lay down the rules concerning fees on advice from the Federal Department of Finance.

Art. 15 Repeal of existing legislation

The Ordinance of 21 December 1970 relating to the organization and activities of the Swiss Federal Institute for Environmental Science and Technology shall be repealed.

Art. 16 Entry into force

This Ordinance shall enter into force on 1 February 1993.

13 January 1993 On behalf of the Swiss Federal Council
The President of the Confederation: Ogi
The Chancellor of the Confederation: Couchepin

Article 6
Communication of knowledge and technology, dissemination of research results

Paragraph 1 sets out the role of the EAWAG as a link between research and practice. The restriction in this paragraph does not imply any censoring or limitation of freedom in teaching and research, but relates to the interests of intellectual property.

Article 7
Education and training

This article describes how the EAWAG should fulfill the duties outlined in Article 2, Paragraph 2.

Article 8
Organization

The Federal Council only determines the principles of organization and delegates the details to the ETH Board. This delegation of responsibility corresponds to the ETH Law.

Article 9
Administration

This provision does not relate specifically to the EAWAG. It corresponds to the regulations laid down for the other research institutes and university administrations.

Article 10
Advisory Committee

Like the other research institutes, the EAWAG has an advisory committee. The number of members has now been reduced from the previous 15 to a maximum of 9.

Article 11
Participation

The rules regarding participation rights are laid down in the ETH Law. In the case of the universities, the groups which belong to the institutes of higher education (lecturers, assistants, students, administrative and technical staff) are already defined in the ETH Law. In the case of the research institutes, the personnel representative body* is new. This is a partner in discussions/consultations with the administration or the ETH Board. The Personnel Committees, governed by the regulations concerning such committees, could only function to a very limited extent in this regard.

Article 12
Cooperation with the Staff Associations

In this provision, which complements Article 11, the same conditions for cooperation with the staff associations are set out for all six institutions in the ETH Domain.

Article 13
Use of research equipment

The provisions laid down in Articles 3 and 4 concerning cooperation are put into concrete terms here with regard to the infrastructure. This provision regulates the use of the EAWAG's research infrastructure by researchers from other institutes of higher education and research institutes, as well as its use in research projects carried out together with the private sector.

Article 14
Payment for services rendered

This provision corresponds to the rules applicable to the other research institutes and maintains the principle of fees to cover costs.

* At the EAWAG, the Personnel Committee was dissolved as of Jan 31, 1993, and a new personnel representative body was chosen, which takes over starting Feb 1, 1993 (entry into force of the ETH Law). The "EAWAG Conference" is the committee that makes all decisions about important affairs of the EAWAG. It consists of the members of the board of directors, leaders of expert groups and a representative from personnel.

Changes in the organization of the EAWAG

There has been some recent restructuring in the EAWAG. Department names have changed and, as the new ordinance stipulates, the EAWAG is now reorganized into research divisions and technical and administrative services. The organizational chart below gives an overview of these changes. The most important ones are summarized below.

The research groups in the departments of "Chemistry" (including analysis) and "Multidisciplinary Limnological Research" (MLR) have been reorganized. More in line with their research, the groups have merged to form the divisions "Chemistry" and "Biogeochemistry". The research division *Chemistry* is devoted to the study of the environmental behavior of organic chemicals via process-oriented field and laboratory studies. Research in the division *Biogeochemistry* is focused on cycling of substances and the coupling of these cycles in natural

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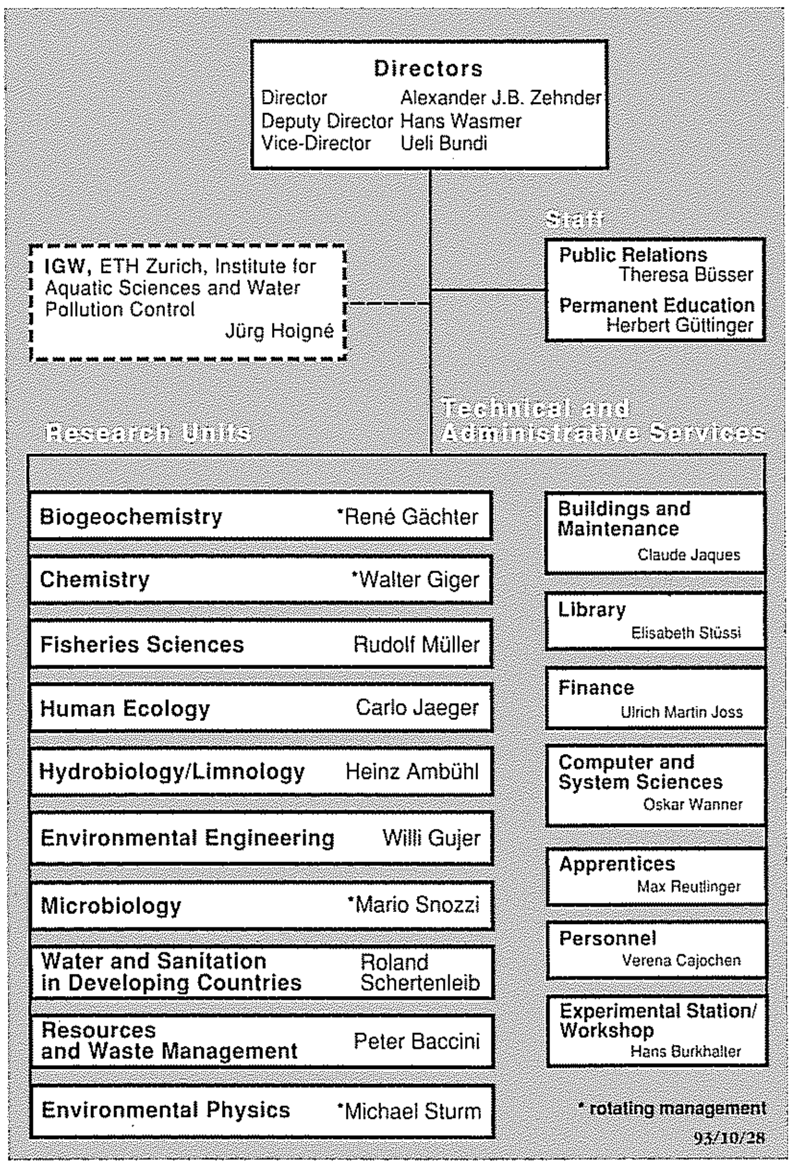


Organizational Chart of the EAWAG

Inside EAWAG

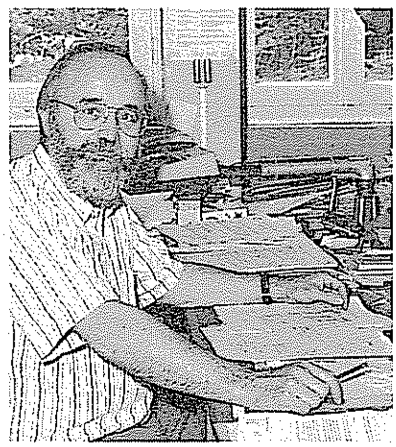
Inside EAWAG

bodies of water, as well as their effect on water quality.

Two research divisions have changed their names as announced in the last issue of EAWAG news. The research division "Technical Biology" has been renamed *Microbiology* and includes the new molecular biology group. The "Department of Waste Management and Materials Conservation" is now called *Resources and Waste Management* so that this research division has the same name as the related chair at the ETH-Zürich.

One EAWAG department is new: the *Human Ecology Group* which introduces itself in this issue, bringing interdisciplinary cooperation to the human, engineering and natural sciences – both inside and outside of the EAWAG.

New Personnel Delegation at EAWAG



From left to right: Alfred Lück, Ruth Stierli, Beate Escher, André Weidenhaupt, Vreni Graf, David Kistler, Robert Berger and Jürg Zobrist (separate).

Begun in February 1993, the new Personnel Delegation at EAWAG is a committee whose purpose is to enhance cooperation among employees. The new Personnel Delegation replaces the former EAWAG Personnel Committee.

The Delegation serves as the main contact organization for the Directors with regards to personnel matters. In addition, the committee is concerned with issues that are of general interest to employees as a whole. To ensure that these tasks are accomplished, one member of the Personnel Delegation is a delegate to the EAWAG Conference.

The members of the Personnel Delegation have diverse backgrounds and experiences. Every professional group (administrative, technical and scientific personnel and doctoral students) and all the EAWAG sites (Dübendorf, Kastanienbaum and Tüffenwies) are represented in the delegation. In accordance with the Women's Support Program, a representative from the female personnel has been elected for this and the next term of office.

The head of the Personnel Delegation is Vreni Graf (Environmental Physics), the representative of the administrative personnel. Her deputy is Beate Escher (Chemistry) who represents female personnel. The delegate to the EAWAG Conference is David Kistler (Biogeochemistry), a representative from the Dübendorf site and his deputy is Alfred Lück (Environmental Physics), the delegation member from the technical personnel. Responsible for the minutes are André Weidenhaupt (Chemistry) and Ruth Stierli (Biogeochemistry), who represent the doctoral students and the Limnological Research Center in Kastanienbaum, respectively. Other members of the Personnel Delegation are Robert Berger, representing the workshop in Tüffenwies and Jürg Zobrist (Biogeochemistry) representing the scientific personnel.

The activities of the Personnel Delegation to date are contributing to discussions about new regulations affecting employee welfare, developing new house rules for Kastanienbaum, conducting a referendum on the parking regulations, evaluating suggestions for the EAWAG-Infoday 1993, and initiating English courses. Their overall goals are to improve the working environment, to provide constructive criticism, and to present suggestions for solutions to problems.

SNS Bank Prize 1993

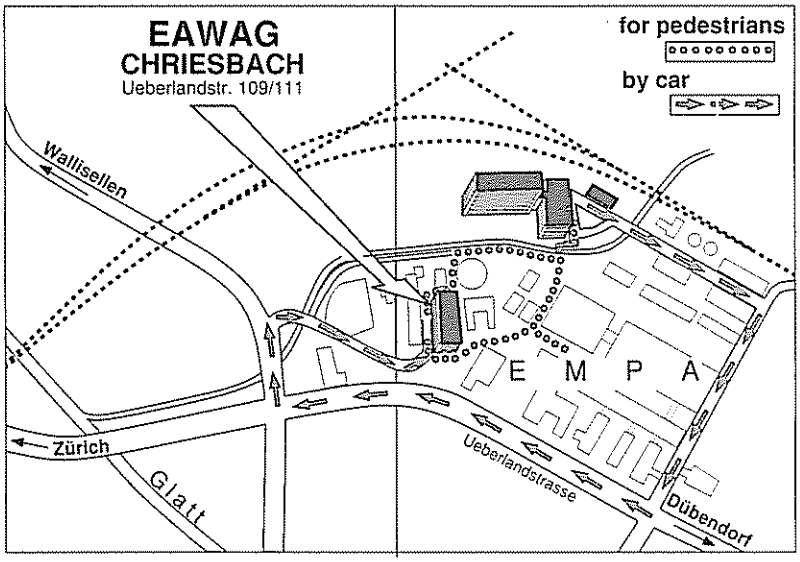
The SNS Bank Prize '93 has been presented to Dr. Jan Roelof van der Meer on 9 September, 1993 in Wageningen (The Netherlands). Each year the SNS Bank honors Ph.D. candidates upon recommendation by the Agricultural University of Wageningen, who are at the beginning of a scientific career in science and have made excellent achievements within the framework of their doctoral thesis.

J.R. van der Meer, who has been working for the Department of Microbiology at the EAWAG since August 1992, investigated the genetic adaptation of bacteria to environmental pollutants in his doctoral thesis. A half-day symposium has been organized on the theme of microbiology and the environment in the context of the festivities of presenting the prize.

Part of the EAWAG has moved

Last March, some of the EAWAG's personnel moved to the nearby "Chriesbach" building. The adjacent map should help in finding the new site.

The following departments have settled into the "Chriesbach": Directors, Staff, Financial Services, Personnel Services, Computer Services, Human Ecology, Engineering Sciences, and the International Reference Center for Waste Disposal (IRCWD)/Water and Sanitation in Developing Countries.



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EAWAG Publications

1671
Drever J.J., Zobrist. J.: Chemical Weathering of Silicate Rocks as a Function of Elevation in the Southern Swiss Alps. Geochim. Cosmochim. Acta *56*, 3209-3216 (1992)

1672
Tilzer, M. M., Bossard P.: Large Lakes and Their Sustainable Development. Aquatic Sciences *54*, 91-103 (1992)

1673
Peeters, F., Wüest, A.: Mess-System zur Erfassung dreidimensionaler Tracerverteilung in Seen. Gas-Wasser-Abwasser *72*, 456-461 (1992)

1674
Dos Santos Afonso, Maria, Stumm, W.: Reductive Dissolution of Iron(III) (Hydr)-oxides by Hydrogen Sulfide. Langmuir *8*, 1671-1675 (1992)

1675
Stumm, W.: Water, Endangered Ecosystem: Assessment of Chemical Pollution. J. Environ. Engng. *118*, 466-476 (1992)

1676
Stumm, W., Sulzberger, Barbara: The Cycling of Iron in Natural Environments: Consideration Based on Laboratory Studies of Heterogeneous Redox Processes. Geochim. Cosmochim. Acta *56*, 3233-3257 (1992)

1677
Wieland, E., Stumm, W.: Dissolution Kinetics of Kaolinite in Acidic Aqueous Solutions at 25° C. Geochim. Cosmochim. Acta *56*, 3339-3355 (1992)

EAWAG Publications

1678
Grenthe, I., Stumm, W., Laaksuharju, M., Nilsson, A.C., Wikberg, P.: Redox Potentials and Redos Reactions in Deep Groundwater Systems. Chemical Geology *98*, 131-150 (1992)

1679
Holliger, C., Schraa, G., Stupperich, E., Stams, A.J.M., Zehnder, A.J.B.: Evidence for the Involvement of Corrinoids and Factor F_{430} in the Reductive Dechlorination of 1,2-Dichloroethane by *Methanosarcina Barkeri*. J. Bacteriology *174*, 4427-4434 (1992)

1680
Holliger, C., Kengen, S. W.M., Schraa, G., Stams, A. J. M., Zehnder, A.J.B.: Methyl-Coenzyme M Reductase of *Methanobacterium Thermoautotrophicum* ΔH Catalyzes the Reductive Dechlorination of 1,2-Dichloroethane to Ethylene and Chloroethane. J. Bacteriology *174*, 4435-4443 (1992)

1681
Sinke, Anja J.C., Cornelese, A.A., Cappenberg, T.E., Zehnder A.J.B.: Seasonal Variation in Sulfate Reduction and Methanogenesis in Peaty Sediments of Eutrophic Lake Loosdrecht, The Netherlands Biogeochemistry *16*, 43-61 (1992)

1682
Frutiger, A., Gammeter, Sonja: Biologische Aspekte des Gewässerschutzes in urbanisierten Gebieten. GAIA *1*, 214-225 (1992)

1683
Bernegger, J.-C., Bloesch, J.: Der Einfluss der Trockenlegung einer Restwasserstrecke auf die Invertebraten-Besiedlung eines unbelasteten Bergbaches (Muota SZ). Wasser Energie Luft *84*, 205-211 (1992)

1684
von Gunten, U., Hoigné, J.: Factors Controlling the Formation of Bromate During Ozonation of Bromide-Containing Waters. Aqua *41*, 299-304 (1992)

1685
Pollingher, Utsa, Ambühl, H., Bürgi, H.-R.: A New Methods for Processing Clay-Rich Unconsolidated Sediments for Paleoecological Investigations. J. of Paleolimnology *7*, 95-101 (1992)

1686
Genoni, G.: Short-Term Effect of a Toxicant on Scope for Change in Ascendency in a Microcosm Community. Ecotoxicol. & Environ. Safety *24*, 179-191 (1992)

1687
Krebs, P., Vischer, D., Gujer, W.: Improvement of Secondary Clarifiers Efficiency by Porous Walls. Water Sci. Technol. *26*, 1147-1156 (1992)

1688
Häner, A.: "Aerobic Thermophilic Biodegradation of Bacterial Cells: Physiological Aspects"; Diss. ETH Nr. 9885, Zürich, 1992.

1689
Ruf, A.: "Reduktive Auflösung von Eisen(hydr)oxiden durch Ascorbat und Hydrochinone"; Diss. ETH Nr. 9892, Zürich, 1992.

1690
Biber, Madeleine Verena: "Carboxyclic Acids on Metal Oxides in Water: An In-Situ FTIR Study"; Diss. ETH Nr. 9918, Zürich, 1992.

1691
Edwards, M., Boller, M., Benjamin, M. M.: Effect of Pre-Ozonation on Removal of Organic Matter During Water Treatment Plant Operations. In: "Control of Organic Material by Coagulation and Flox Separation Processes". (Eds.) IAWQ/IWSA, Geneva 1992; 17-25.

1692
Boller, M.: Removal of Organic Matter by Physico-Chemical Mechanisms in Wastewater Treatment Plants. In: "Control of Organic Material by Coagulation and Floc Separation Processes". (Eds.) IAWQ/IWSA, Geneva 1992; 147-163.

1693
Lotter, A.F., Eicher, U., Siegenthaler, U., Birks, H.J.B.: Late-Glacial Climatic Oscillations as Recorded in Swiss Lake Sediments. J. of Quaternary *7*, 187-204 (1992)

1694
Mechsner, K., Fleischmann, T.: Vergleichende Untersuchungen zur Wiederverkeimung des Wassers nach Ultraviolettdesinfektion. Gas-Wasser-Abwasser *72*, 807-811 (1992)

1695
Dunnivant, F.M., Schwarzenbach, R.P., Macalady, D.L.: Reduction of Substituted Nitrobenzenes in Aqueous Solutions Containing Natural Organic Matter. Environ. Sci. Technol. *26*, 2133-2141 (1992)

1696
Müller, R.: Die Fischfauna im Rhein bei Basel. Verh. Naturforsch. Ges. Basel *102*, 343-356 (1992)

1697
Tremp J.: "Sources and Fate of Nitrated Phenols in the Atmospheric Environment"; Diss. ETHZ Nr. 9853, Zürich, 1992.

1698
Semadeni, M., Stocker, D.W., Kerr, J.A.: Further Studies of the Temperature Dependence of the Rate Coefficients for the Reactions of OH with a Series of Ethers under Simulated Atmospheric Conditions. J. Atmos. Chem. *16*, 79-93 (1993)

1699
Wüest, A., Aeschbach-Hertig, W., Baur, H., Hofer, M., Kipfer, R., Schurter, M.: Density Structure and Tritium-Helium Age of Deep Hypolimnetic Water in the Northern Basin of Lake Lugano. Aquatic Sciences *54*, 205-218 (1992)

1700
Müller, R., Meng, H. J.: Past and Present State of the Ichthyofauna of Lake Lugano. Aquatic Sciences *54*, 338-350 (1992)

1701
Kerr, J.A.: The Heat of Formation of the CF_3CO Radical: a Note of Caution. Chem. Phys. Lett. *201*, 391-392 (1993)

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

1703
Wüest, A., Brooks, N.H., Imboden D.M.: Bubble Plume Modeling for Lake Restoration. Water Resour. Res. *28*, 3235-3250 (1992)

1704
von Piechowski, M., Thelen, Marie-Anne, Hoigné, J., Bühler, R. E.: *tert*-Butanol as an OH-Scavenger in the Pulse Radiolysis of Oxygenated Aqueous Systems. Ber. Bunsenges. Phys. Chem. *96*, 1448-1454 (1992)

1705
Luther III, G.W., Kostka, J.E., Church, T.M., Sulzberger, Barbara, Stumm W.: Seasonal Iron Cycling in the Salt-Marsh Sedimentary Environment: The Importance of Ligand Complexes with Fe(II) and Fe(III) in the Dissolution of Fe(III) MInerals and Pyrite, Respectively. Marine Chemistry *40*, 81-103 (1992)

1706
Field, Jennifer A., Miller, D.J., Field, T.M., Hawthorne, S.B., Giger, W.: Quantitative Determination of Sulfonated Aliphatic and Aromatic Surfactants in Sewage Sludge by Ion-Pair/Supercritical Fluid Extraction and Derivatization Gas Chromatography/Mass Spectrometry. Anal. Chem. *64*, 3161-3167 (1992)

1707
Ahel, M., McEvoy, J., Giger, W.: Bioaccumulation of the Lipophilic Metabolites of Nonionic Surfactants in Freshwater Organisms. Environ. Poll. *79*, 243-248 (1993)

1708
Egli, T.: Biodegradation of Synthetic Chelating Agents with Special Reference to Nitrilotriacetic Acid (NTA). J. Chem. Tech. Biotechnol. *55*, 404-406 (1992)

1709
Fent, K., Hunn, Judith: Uptake and Elimination of Tributyltin in Fish-Yolk-Sac Larvae. Marine Environ. Res. *35*, 65-71 (1993)

1710
Behra Renata: In *Vitro* Effects of Cadmium, Zinc and Lead on Calmodulin-Dependent Actions in *Oncorhynchus mykiss*, *Mytilus* sp., and *Chlamydomonas reinhardtii*. Arch. Environ. Contam. Toxicol. *24*, 21-27 (1993)

1711
Breedveld, M.W., Zevenhuizen, L.P.T.M., Zehnder, A.J.B.: Synthesis of Cyclic b-(1,2)-Glucans by *Rhizobium leguminosarum* Biovar trifolii TA-1: Factors Influencing Excretion. J. Bacteriol. *174*, 6336-6342 (1992)

1712
Van Veen, H.W., Abee, T., Kortstee, G.J.J., Konings, W.N., Zehnder, A.J.B.: Characterization of Two Phosphate Transport Systems in *Acinetobacter johnsonii* 210A. J. Bacteriol. *175*, 200-206 (1993)

1713
Grottker, M.: Qualitative Aspekte der Meteorwasserversickerung. VSA Verbandsbericht Nr. *445*, 1-22 (1991)

1714
Van der Meer, J.R., De Vosss, W.M., Harayama, S., Zehnder A.J.B.: Molecular Mechanics of Genetic Adaption to Xenobiotic Compounds. Microbiol. Rev. *56*, 677-694 (1992)

1715
Beer, J., Shen, C., Heller, F., Liu, T., Bonani, G., Dittrich Beate, Suter, M., Kubik, P. W.: ^{10}Be and Magnetic Susceptibility in Chinese Loess. Geophys. Res. Letter *20*, 57-60 (1993)

1716
Bundi, U.: Umweltverträgliche Landwirtschaft - ein Vorhaben von vielen Weggefährten. VGL Umwelt-Information *4*, 3-4 (1992)

1717
Peiffer, S., dos Santos Afonso, Maria, Wehrli, B., Gächter, R.: Kinetics and Mechanism of the Reaction of H_2S with Lepodocrocite. Environ. Sci. Technol. *26*, 2408-213 (1992)

1718
Furrer, G., Wehrli, B.: Biogeochemical Processes at the Sediment-Water Interface: Measurements and Modeling. Appl. Geochem. Suppl. *2*, 117-119 (1993)

1719
Fent, K., Stegeman, J. J.: Effects of Tributyltin in Vivo on Hepatic Cytochrome P450 Forms in Marine Fish. Aquatic Toxicology *24*, 219-240 (1993)

1720
Kemmler Judith: "Biochemistry of Nitrilotriacetate Degradation in the Facultatively Denitrifying Bacterium TE11"; Diss. ETH Nr. 9983, Zürich, 1992.

1721
Sinniger, J.: "Die Inhibition der Auflösung von Eisen(III)(Hydr)-oxiden und ihre Beziehung zur Passivität von Eisen"; Diss. ETH Nr. 9893, Zürich, 1992.

1722
Rutishauser-Frei, Ruth Susanna: "The Behaviour of the Various Cytochromes of Paracoccus denitrificans During Transitions Between Oxic and Anoxic Growth Conditions". Diss. ETH Nr. 9875, Zürich, 1992.

1724
Siegrist, H., Renggli, Dea, Gujer, W.: Mathematical Modelling of Anaerobic Mesophillic Sewage Sludge Treatment. Water Sci. Technol. *27*, 25-36 (1993)

1725
Pahl-Wostl, Claudia, Ulanowicz, R.E.: Quantification of Species as Functional Units Within an Ecological Network. Ecological Modelling *66*, 65-79 (1993)

1726
Pahl-Wostl, Claudia: The Hierarchical Organization of the Aquatic Ecosystem: an Outline how Reductionism and Holism May be Reconciled. Ecological Modelling *66*, 81-100 (1993)

1727
Schilling, W.: The Feasibility of Real Time Control of Combined Sewer Overflows. Civil Engng. Pratice *7*, 17-26 (1992)

1728
Baccini, P., von Steiger, B.: Die Stoffbilanzierung landwirtschaftlicher Böden – eine Methode zur Früherkennung von Bodenveränderungen. Z. Pflanzenernähr. Bodenk. *156*, 45-54 (1993)

1729
Schleiniger, R., Baccini, P.: Das Verursacherprinzip: eine Anwendung bei der Siedlungsabfallentsorgung. GAIA *2*, 42-4 (1993)

1730
Wegelin, M., Schertenleib, R.: Die Kiesfiltration in der Wasseraufbereitung. Gas-Wasser-Abwasser *73*, 161-163 (1993)

EAWAG Publications

1731
Boller, M.: Filtrationsmechanismen in Kiesfiltern. Gas-Wasser-Abwasser *73*, 174-183 (1993)

1732
Wegelin, M., Schertenleib, R.: Praktische Erfahrung mit Kiesfiltern. Gas-Wasser-Abwasser *73*, 184-193 (1993)

1733
Haderlein, S.B., Schwarzenbach, R.P.: Adsorption of Substituted Nitrobenzenes and Nitrophenols to Mineral Surfaces. Environ. Sci. Technol. *27*, 316-326 (1993)

1734
Alder, A.C., Hägblom, M.M., Oppenheimer, Stephanie. R., Young, L.Y.: Reductive Dechlorination of Polychlorinated Biphenyls in Anaerobic Sediments. Environ. Sci. Technol. *27*, 530-538 (1993)

1735
Benoit, P., Hering, Janet G., Stumm, W.: Comparitive Study of the Adsorption of Organic Ligands on Aluminum Oxide by Titration Calorimetry. Appl. Geochem. *8*, 127-139 (1993)

1736
Kappeler, J.: "Populationsdynamik in Belebungsanlagen 'aerober Blähschlamm'"; Schriftenreihe Umwelt Nr. 183, 1993.

1737
Siegrist, H., Gajcy, D., Sulzer, S., Roeleveld, P., Oschwald, R., Frischknecht, H., Pfund, D., Mörgeli, B., Hungerbühler, E.: Nitrogen Elimination from Digester Supernatant with Magnesium-Ammonium-Phosphate Precipitation. In: "Chemical Water and Wastewater Treatment II". R. Klute, H. Hahn. (Eds.) Springer Verlag, Berlin 1992; 457-465.

1738
Gächter, R., Meyer, J.S.: The Role of Microorganisms in Mobilization and Fixation of Phosphorus in Sediments. Hydrobiologia *253*, 103-121 (1993)

1739
Bossard, P., Uehlinger, U.: The Effect of Herbivorous Crustacean Zooplankton on Epilimnetic Carbon and Phosphorus Cycling. Hydrobiologia *254*, 21-34 (1993)

1740
Eberhard, J., Semadeni, M., Stocker, D.W., Kerr J.A.: Photo-oxidation of VOCs under Simulated Tropospheric Conditions. In: "Proc. of EUROTRAC Symposium,92". P.M. Borrell et al (Eds.) Academic Publ., The Hague 1993; 367-371.

1741
van der Meer, J.R., Bosma, T.N.P., de Bruin, W.P., Harms, H., Holliger, C., Rijnaarts, H.H.M., Tros, Marijke E., Schraa, G., Zehnder, A.J.B.: Versatility of Soil Column Experiments to Study Biodegradation of Halogenated Compounds under Environmental Conditions. Biodegradation *3*, 265-284 (1992)

1742
Münnich, M., Wüest, A., Imboden D.M.: Observations of the Second Vertical Mode of the Internal Seiche in an Alpine Lake. Limnol. Oceanogr. *37*, 1705-1719 (1992)

1743
Boller, M.: Verfahren zur Abwasserfiltration. ATV Schriftenreihe Nr. *31*, 35-64 (1992)

1744
Tschui, M., Boller, M., Gujer, W., Eugster, J., Mäder, Claudia: Tertiary Nitrification in Aerated Biofilter Reactors. In: "Proc. of the European Water Filtration Congress", Vol. 17, Oostende, Belgium, 15-16 March, 1993.

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

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