eawag
aquatic research

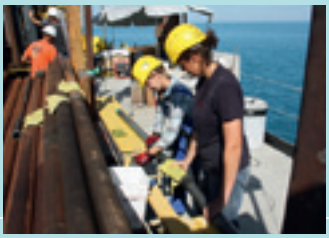
Annual Report 2010

Eawag: Swiss Federal Institute of Aquatic Science and Technology

Eawag, the Swiss Federal Institute of Aquatic Science and Technology, is part of the ETH Domain. This comprises the Swiss Federal Institutes of Technology in Zurich (ETHZ) and Lausanne (EPFL), Eawag and three other independent, application-oriented research institutes – the Paul Scherrer Institute (PSI), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and the Materials Science and Technology Research Institution (Empa). Nationally rooted and internationally networked, Eawag is concerned with concepts and technologies for the sustainable management of water resources and aquatic ecosystems. In cooperation with universities, other research centres, public authorities, the private sector and NGOs, Eawag strives to harmonize ecological, economic and social interests in water, providing a link between science and practical applications. About 450 staff are employed in research, teaching and consulting at the Dübendorf (Zurich) and Kastanienbaum (Lucerne) sites.

Cover photo
Cornelia Kienle and Tamas Mengesha of the Ecotox Centre discuss the cultivation of blue green algae; visible in the foreground is a solid-phase extraction system used for separation of compounds in water samples. The Ecotox Centre, jointly run by Eawag and the ETH Lausanne, investigates and assesses the effects of chemical substances on the environment and is also active in consulting and training (see p. 44).
Photo: Peter Schönenberger, Winterthur

Content



Solving the problems of today, anticipating the problems of tomorrow

It is one of the great challenges of our time to meet human needs for water while preserving the capacity of the water environment to provide ecosystem services. Eawag can contribute to solving today's problems through its expert consulting and applied research. Anticipating and addressing tomorrow's problems require further research as a source of innovation and education to train tomorrow's experts.

Loyal readers of Eawag's annual report will notice a change in the format of this year's report. First, a section on highlights has been added to the beginning of the report. This section creates a distinctive signature and emphasizes the outstanding accomplishments of each year. Another change has been made to the structure of the annual report, which was previously oriented along the thematic lines of Eawag's three action fields (Aquatic Ecosystems, Chemicals and their Effects, and Urban Water Systems). Now the structure corresponds to Eawag's legal mandate to conduct research, education and expert consulting in the domain of water science and technology. Although these three types of activities have distinctive aspects, they are also integrally linked with each other. Expert consulting requires research as a source of innovation and new solutions, but at the same time, provides challenges and motivation for research. Education is not only an investment in the future; it also brings fresh perspectives and new questions to research activities and provides a platform for the integration and synthesis of new knowledge.

Protecting our future by preserving our environment

One essential lesson of the International Year of Biodiversity in 2010 is the importance of biodiversity in ensuring the provision of ecosystem services, such as clean water or nutrition, now and in the future. The pressures on and loss of biodiversity in freshwater ecosystems (page 8) make it particularly important to understand how human activities affect structure and function of aquatic ecosystems. Eawag's research has demonstrated unanticipated changes in ecosystem biogeochemistry, specifically the production and release of the greenhouse gas methane, in run-of-the-river reservoirs (page 16). Several projects have investigated the occurrence and source of micropollutants (pages 18 and 19), including legacy pollutants released during the melting of glaciers (page 23). The potential for ecosystem response is illustrated by observations of the evolution of frogs exposed to varying levels of acidity (page 22). Because of the importance of ecotoxicology to stakeholders and practitioners, Eawag is particularly pleased with the portfolio of stakeholder-oriented activities developed by the Eawag-EPFL Centre for Applied Ecotoxicology and by the appointment of Inge Werner as new head of the Centre in 2010 (page 44).

There is also a strong emphasis in Eawag's research on reducing the impacts of human activities on the water environment. Localized treatment of hospital wastewater has been studied as a way to decrease the loading of pharmaceuticals to the water environment (page 10). Possibilities for the recovery of energy and nutrients

during wastewater and sludge treatment have been examined both for Switzerland (page 40) and for developing countries. In addition, Eawag has assessed a technology designed to remediate the effects of lake eutrophication (page 42).

Technical issues are not the sole determinant of success for most environmental technologies. Socio-economic and behavioural factors are often key components in their success or failure. Recent studies have examined the role of human behaviour in two very different cases: the response to elevated arsenic concentrations in groundwater in Bangladesh (page 14) and the choice between tap and bottled water in Switzerland (page 12).

A look ahead to 2011

In 2011, Eawag will celebrate its 75th anniversary. This is an opportunity not only for the celebration of past accomplishments but also for the critical evaluation of future directions. Throughout its long history, Eawag has focused on solving water-related problems faced by society in Switzerland and world-wide. The need for a strong science base to address these problems was recognized early in Eawag's development. More recently, the need to support societal decision-making and thus the importance of integrating social sciences with natural science and engineering has been recognized.

This retrospective provides an excellent backdrop for the strategic planning process for 2012 to 2016 that Eawag will complete in 2011. It is one of the great challenges of our time to meet human needs for water while preserving the capacity of the water environment to provide essential ecosystem services. Eawag will define and pursue research to ensure the provision of water for human health and the protection of water for ecosystem health and to balance the competing demands, requirements and pressures on the water environment.

I look forward to joining my colleagues at Eawag not only in celebrating our past accomplishments and contributions to science and society but also in positioning Eawag to continue this tradition into the future. It is a great privilege to be able to participate in such important and meaningful work, and I am confident that Eawag will fulfill its responsibility to society in the future as successfully as it has over the last 75 years.

Janet Hering, Director

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Highlights 2010

1 The Bill & Melinda Gates Foundation is providing a USD 3 million grant to support a project jointly run by Eawag and eThekwini Water and Sanitation in Durban, South Africa (pictured: project manager Kai Udert and Obed Mlaba, Mayor of Durban). This project is promoting innovative ways of improving sanitation and developing methods for the recycling of nitrogen, phosphorus and potassium from urine. It builds on Eawag's work in Nepal, where researchers oversaw production of the fertilizer struvite from urine.

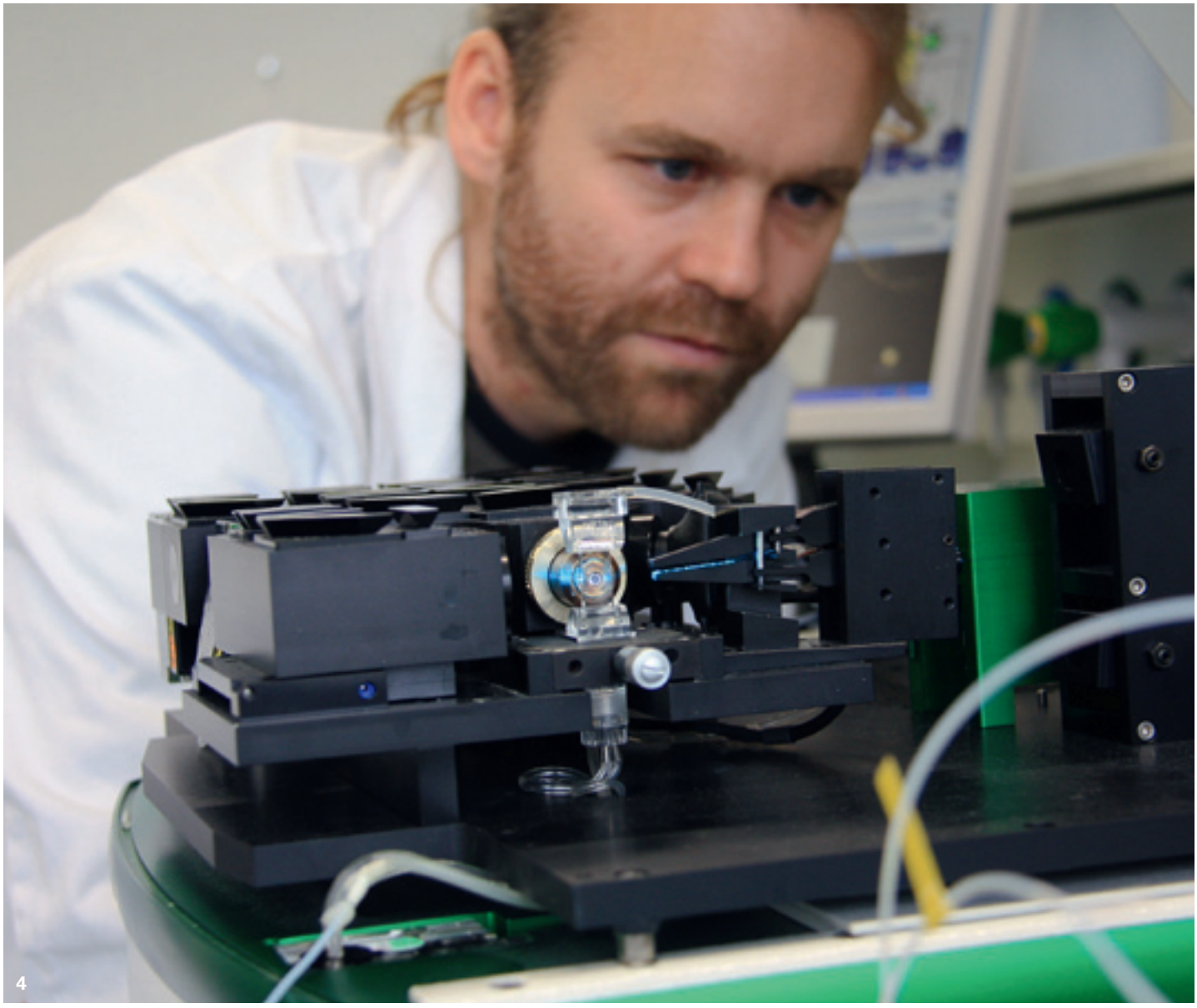
2 Eawag's annual Info Day, attended by over 200 scientists, water professionals, officials and policymakers, focused on the latest research in the area of freshwater biodiversity.

3 Four Eawag scientists have been appointed as professors by the ETH Board. Janet Hering (3rd from left) and Urs von Gunten have become full professors at the ETH Lausanne. Ecotoxicologist Kristin Schirmer (2nd from left) is now adjunct professor at the ETH Lausanne, and environmental chemist Juliane Hollender is adjunct professor at the ETH Zurich.

4 Researchers led by Frederik Hammes and Thomas Egli at Eawag received the 2010 Muelheim Water Award. In collaboration with two colleagues at Zurich Water Works, the team developed a new, practical method for the microbiological analysis of drinking water based on flow cytometry (see page 46).

5 ScienceWatch (the Thomson Reuters science trend tracking service) selected two Eawag publications as notable papers in the Environment/Ecology field. Renata Behra's study, published in Environmental Science & Technology, was concerned with the toxicity of silver nanoparticles, and Ole Seehausen's Nature paper investigated speciation in cichlids.

6 A study which appeared in Nature, co-authored by Eawag scientist Mark Gessner, assessed for the first time the threats faced by rivers on a global scale: not only is human water security at risk, but also freshwater biodiversity (see page 8).



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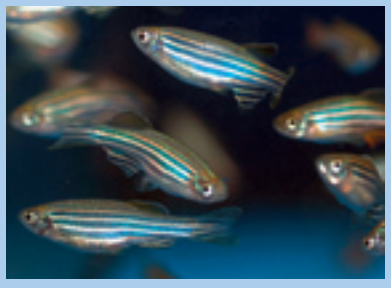
Research
Teaching
Consulting



In 2010, with research focused on understanding and practical solutions, Eawag cemented its position as a global leader in aquatic science and technology. Key areas included the promotion of health through safe water supplies and sanitation, as well as the functioning and management of ecosystems. Building on the Novaquatis urine source separation programme, various projects concerned with decentralized wastewater treatment were implemented last year in cooperation with industrial partners and users.

Spring 2010 also saw the launch of the National Research Programme on "Sustainable water management" (NRP 61), in which Eawag scientists are playing a major role. Here, the institute can exploit its strengths in inter- and transdisciplinary research. In NRP 64 on "Opportunities and Risks of Nanomaterials", Eawag's expertise has also been harnessed. This project aims to investigate the effects of nanomaterials in the environment and to develop recommendations for Switzerland. The establishment of the Centre for Ecology, Evolution, and Biogeochemistry (CEEB) in Kastanienbaum also demonstrates Eawag's commitment to research on the functioning of aquatic ecosystems. In future, the insights gained from these efforts should help to assess the environmental impacts of human activities.

Michael Berg
Detective work on soil

"Contaminated soil can be found at around 3,000 sites in Switzerland", says environmental chemist Michael Berg. In the past, chlorinated solvents were handled without due care especially at metal-processing and dry-cleaning facilities. Berg adds: "Today, we need to prevent these chemicals from getting into drinking water via groundwater." This means that soil has to be removed and rinsed or cleaned up using remediation agents and microorganisms – usually an expensive and time-consuming procedure. A less costly option is known as natural attenuation. "Here", Berg explains, "humans don't actually do anything – they leave it to nature to break down pollutants." However, depending on the soil type, this process may take decades or even centuries. Berg is therefore developing methods whereby the self-cleansing potential of soil can be assessed. With the aid of isotope analysis, it is even possible to reconstruct historical transformation processes and predict future ones: "For me, the soil is like a crime scene – I try to determine exactly what has been going on there."

Kathrin Fenner
Computer-based risk assessment

How do chemical substances behave in the environment? And how can they be sustainably managed? These questions have fascinated environmental chemist Kathrin Fenner for over ten years. Currently, she says, more than 100,000 chemicals are used worldwide: "Many of them pose a risk to our water resources." Fenner's research aims to improve the safety of drinking water and the quality of surface waters. But her work is rarely performed in the field – it is mainly computer-based. She develops mathematical models for assessing the risks of new chemicals prior to regulatory approval. "In the past," she says, "very often only the parent compounds were taken into account in models of this kind." But the substances are chemically transformed in water, especially by microorganisms: "The intermediate products arising in this process also need to be considered in the model." Thanks to cooperation with analytical chemists at Eawag, Fenner's models can be continually checked against empirical data and adjusted accordingly. As a member of expert committees in Switzerland and Europe, the researcher can also help to feed the latest scientific findings directly into official guidelines.

Katja Räsänen
Tracking evolutionary changes

The environment is constantly changing – and as it does so, organisms change too. "But not all species and individuals can do so equally well," says biologist Katja Räsänen. What explains the differences? Räsänen is studying the feeding apparatus of the three-spined stickleback in an Icelandic lake. The form of this apparatus has changed markedly since 1998. As populations of midge larvae – the stickleback's main food source – also varied significantly over this period, Räsänen suspects that the feeding apparatus of the fish adapted over time to other prey: "What we see here is probably a very short segment of evolution." But genetic factors do not account for everything. For example, the extent to which stickleback males care for their offspring is largely determined by the environment. "We find a different mechanism in the moor frog," says Räsänen. Maternal frogs from an acidic environment can give their offspring a survival advantage: by changing the jelly envelope around the eggs, they increase the embryos' tolerance to acidic water. For her research, Räsänen combines various methods, ranging from field studies through laboratory experiments to molecular genetic analysis. "That's the only way of drawing reliable conclusions – otherwise you see just part of the whole picture."

Rivers facing a global crisis

For the first time, a study has documented the extent to which rivers are under pressure worldwide. Not only are freshwater resources under threat, but also the biodiversity of river systems. The study makes it clear that the high quality of water supply and wastewater disposal systems in Western Europe and North America tends to blind the public to the dire state of aquatic biodiversity.

From water pollution, land cover change and the loss of wetlands, to the construction of dams and reservoirs, and the spread of invasive animal species – data on a total of 23 stressors was compiled by an international team of researchers in order to assess the state of rivers worldwide. The data was then processed using a complex digital model so as to produce aggregate indices of threats for the Earth's major river systems.

According to the study – published in Nature in September 2010 – nearly 80 per cent of the world's population is exposed to high levels of threat to water security. In many cases, the same stressors pose a threat to human water security and to biodiversity. For example, the disconnection of floodplains from rivers not only leads to a loss of flood protection and groundwater recharge but also to a loss of habitat for endangered species.

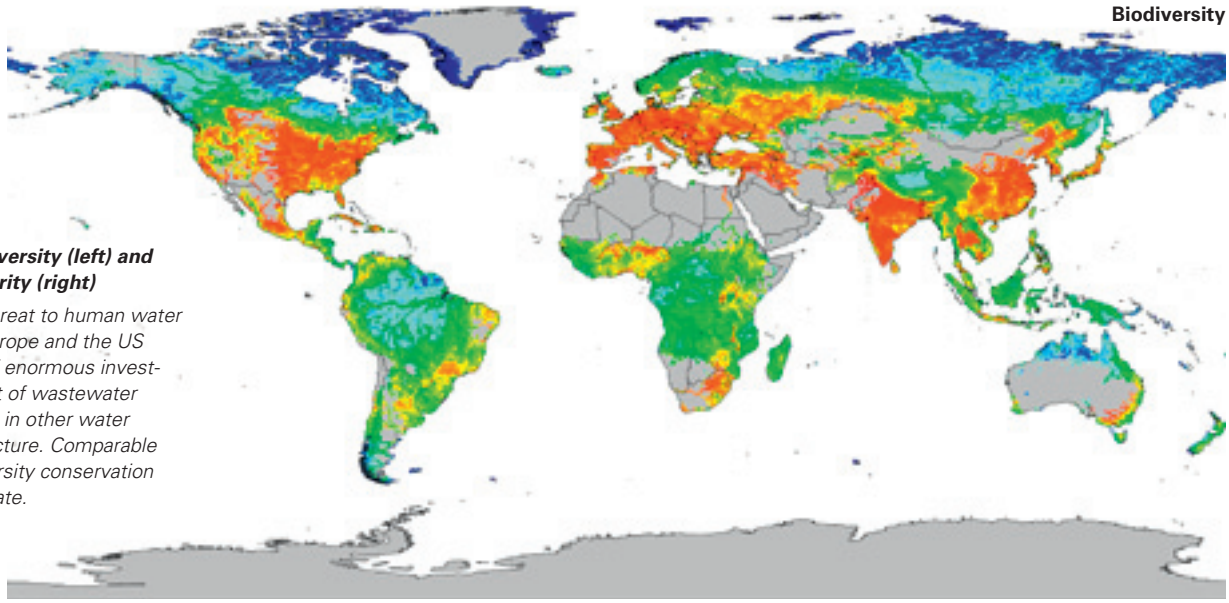
Switzerland: developing country status

"The issues of human water security and biodiversity should no longer be considered in isolation from each other," says Mark Gessner, a co-author of the study, who conducted research in the Aquatic Ecology department of Eawag until the end of 2010. The aquatic ecologist is one of the initiators of the interdisciplinary project, which was a result of collaboration between the Paris-based International Council for Science Biodiversity Programme (DIVERSITAS) and the Bonn-based Global Water System Project (GWSP).

Gessner explains: "Although the industrialized countries have been committed to water quality and the protection of water resources for several decades, our synthesis shows that rivers are also under enormous pressure in countries like the US and in Western Europe." Major investments in wastewater treatment, drinking water treatment and flood protection, he concedes, have managed to prevent a critical situation arising for the public. "But there are no comparable measures to conserve biodiversity." Accordingly, the threat to biodiversity in Switzerland, for example, is scarcely different from the precarious situation found in many developing countries.

Learning from other countries' mistakes

The lead author of the article, Charles Vörösmarty (City University of New York), uses a medical analogy: "Ultimately, our study shows that it is much less costly and more sensible to identify and limit threats at the source than to remediate the symptoms later on." The authors hope that their global analysis could help governments and planners in many parts of the world not to repeat the mistakes made by wealthy countries in water resource management, but to learn from this experience. Rather than investing billions in technologies and in fragmentary rehabilitation efforts, there is a need to develop fundamentally new concepts and strategies. These should give equal consideration to biodiversity as well as to human water security aspects. Gessner says: "With the Water



Threats to river biodiversity (left) and to human water security (right)

The apparent lack of threat to human water security in Western Europe and the US reflects the benefits of enormous investments in the treatment of wastewater and drinking water and in other water management infrastructure. Comparable investments in biodiversity conservation are largely lacking to date.

Bank stabilization, channelization and impoundment – typical characteristics of rivers in industrialized countries. The main casualty is biodiversity. Photo: the River Aare.

23 key stressors

The global threat maps are based on vast amounts of data. Modelling took account of 23 key stressors, divided into four main themes:

- Watershed disturbance, e.g. cropland, livestock density, impervious surfaces.
- Pollution, e.g. nitrogen/phosphorus loading, soil salinization and pesticide loading.
- Water resource development, e.g. dam density, river fragmentation, consumptive water loss.
- Biotic factors, e.g. percentage and number of non-native fishes, aquaculture pressure.

To produce separate assessments of the threat to human water security and biodiversity, distinct sets of weightings were applied to the same set of stressors for the two different perspectives. Even so, the global patterns of threat to human water security and biodiversity show a remarkable degree of concordance. Major shifts only arise when account is taken of the beneficial effects of investments in water infrastructure and services for human water security. This explains why, for example, the threat to human water security ends up being low in Western Europe and Eastern Australia, while remaining high in Eastern Europe, India and China.

Framework Directive, the EU has taken an important step in the right direction. Our findings now provide an improved basis for national and regional activities, and for international agreements on transboundary protection and management of water resources and aquatic ecosystems."

Lack of basic data

Despite the unequivocal results, the authors of the study are cautious in drawing conclusions, given the considerable gaps in available data. According to Peter McIntyre, a zoologist at the University of Wisconsin, "There's a lack of internationally comparable information in particular." He concludes that governments should stop the widespread cutbacks in environmental monitoring and increase investments in the collection of basic data on water quality and quantity: "You wouldn't treat patients in the emergency room without using equipment to monitor their vital functions. But that's exactly what we're doing to our rivers worldwide." However, Gessner notes that Switzerland has a good data base in the areas of hydrology and water quality, largely thanks to the federal and cantonal monitoring networks. But in the area of biodiversity, he adds, major gaps still remain. ○○○

www.riverthreat.net

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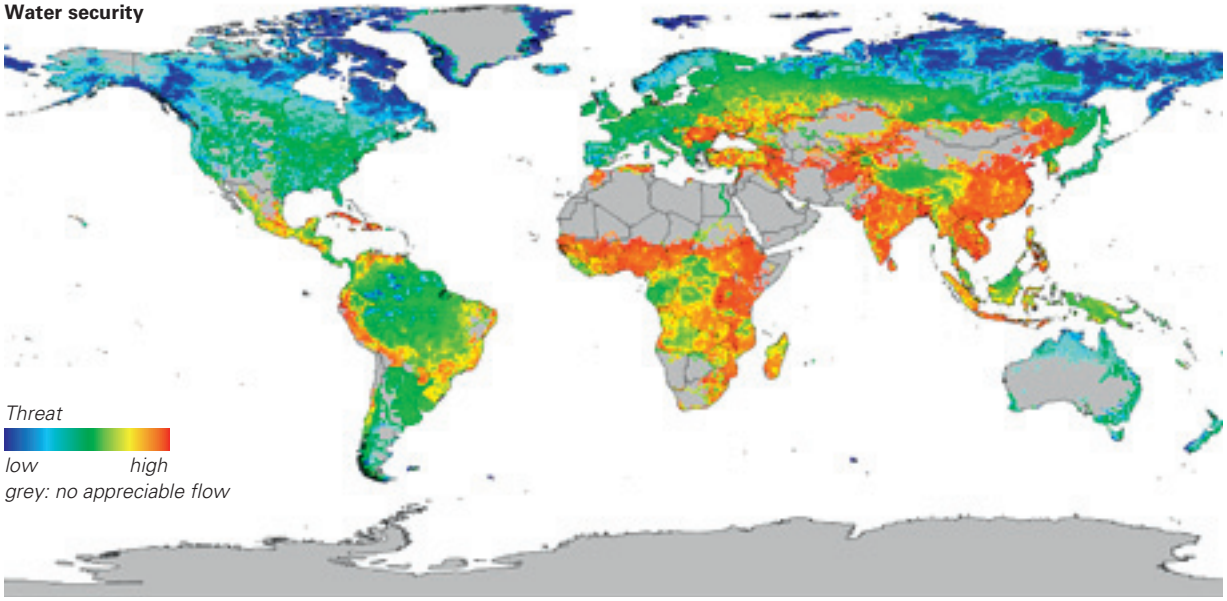
Water security



How to deal with hospital wastewater?

Hospital wastewater – like municipal wastewater – contains pharmaceutical residues which are not completely removed by treatment plants. Where high levels are discharged, it may be advisable to treat hospital wastewater separately. In specific cases, multi-criteria decision analysis with stakeholder participation can help to identify consensus solutions.

Pharmaceutical residues enter rivers and lakes via sewer systems, since in many cases they are not eliminated from wastewater by treatment plants. It remains largely unclear whether or how pharmaceutical loads affect aquatic organisms, but it is known that endocrine disruptors can, for example, impair reproduction in fish. In a variety of national and international projects (for information on project partners see the links on page 11), Eawag researchers have sought to determine the significance of pharmaceutical inputs from hospitals and to assess the suitability of technologies for on-site treatment of hospital wastewater.

Substantial differences between hospitals

Christa McArdell and her colleagues from the Environmental Chemistry department evaluated hospital use of Switzerland's top 100 pharmaceuticals and analysed wastewater at the Baden Cantonal Hospital (KSB) and the Winterthur Psychiatric Centre (IPW). "Hospitals account for about 20 per cent of the total volume of drugs administered in this country," says McArdell.

However, the amounts used vary widely, depending on the type of hospital. Thus, in 2007, total consumption was around 1,200 kilograms at the KSB, and only 50 kilograms at the IPW. The two institutions' contributions to wastewater contamination thus varied accordingly: the KSB accounted for around 40 per cent of the pharmaceutical residues at the local wastewater treatment plant, while the IPW contributed only 5 per cent. McArdell points out: "This shows that certain hospitals are major point sources of pharmaceuticals in wastewater."

The two hospitals also differed substantially in the types of agents used. At the KSB, X-ray contrast media alone made up almost 60 per cent of the total; at the IPW, the predominant agents were laxatives, analgesics and anti-inflammatory drugs. Although the drugs were administered to patients in hospital, only a proportion was excreted on site. Thus, only 50–80 per cent of the contrast media consumed was recovered in hospital wastewater; the remainder ended up in municipal wastewater.

Lubomira Kovalova climbs into a sewer at the Baden Cantonal Hospital, where wastewater is collected for the pilot plant.

Real risk potential

As shown by ecotoxicity studies carried out by Beate Escher, most of the substances detected in hospital wastewater occur in concentrations which do not pose an acute risk to the environment. "However," she explains, "the substances are not present individually, but as mixtures, so the effects are cumulative." If the ecotoxicity of cocktails of substances is considered, hospital wastewater may indeed harbour a real risk potential for the aquatic environment.

She also emphasizes that, for purposes of risk assessment, it is important to evaluate not just pharmaceuticals used in large quantities, as would generally be expected, but also those which are particularly toxic. In the KSB wastewater, for example, a mere 14 per cent of the load of pharmaceuticals were responsible for over 99 per cent of the total risk potential.

According to McArdell, local wastewater treatment would be advantageous in the case of hospitals discharging high levels of pharmaceuticals, as it would ease the pressure on centralized treatment plants. Although contrast media – the predominant substances – do not pose a direct risk to the environment, they are highly persistent and so it would be desirable, as a precautionary measure, to prevent large quantities from entering natural waters.

Additional treatment steps required

To find out which methods are most effective in eliminating pharmaceuticals from hospital wastewater, McArdell and Lubomira Kovalova – in cooperation with Hansruedi Siegrist and Jakob Eugster of the Process Engineering department – installed a pilot plant at the KSB. This

comprises a mechanical and a biological treatment step, using a bioreactor containing a membrane filter. McArdell explains: "The membrane bioreactor serves as an important pretreatment step, which can retain pathogens, such as antibiotic-resistant bacteria, but the removal of pharmaceuticals from wastewater is incomplete." For many substances, the reduction achieved with the membrane bioreactor is less than 20 per cent.

For this reason, the pre-treated wastewater was additionally treated either with powdered activated carbon or with ozone. In the former process, micropollutants are adsorbed onto the carbon particles, which are subsequently removed by sedimentation or filtration and incinerated. In the latter process, contaminants are broken down by oxidation when ozone gas is injected into wastewater.

With either of these post-treatment methods, the researchers were able to remove the majority of the pharmaceuticals more or less completely from wastewater. However, elimination rates were low for contrast media, in particular. "As contrast media mainly enter water via urine, separate collection would be an effective solution in this case," McArdell believes. For example, she suggests, patients could be given so-called roadbags for urine disposal. This system would also cover excretion of contrast media outside hospitals.

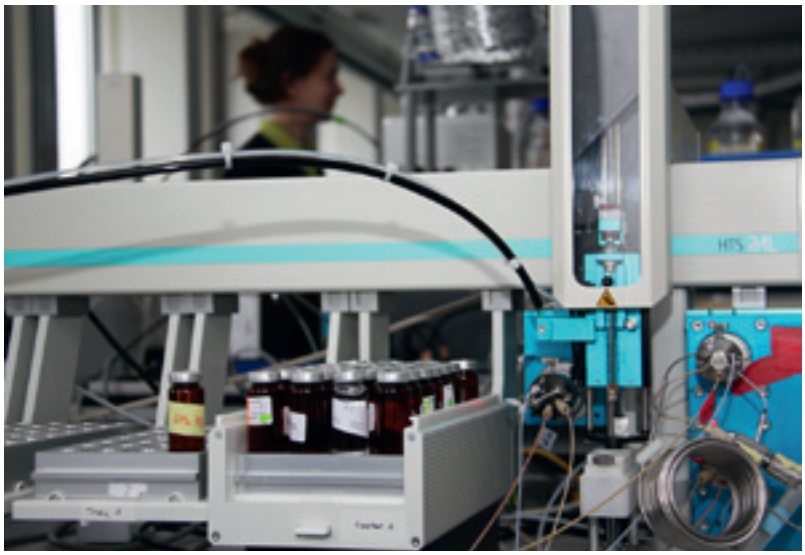
Complete elimination of pharmaceuticals from hospital wastewater could be achieved with reverse osmosis, a process also used in seawater desalination plants. Here, water is forced under pressure through a membrane with microscopic pores, which retains contaminants. However, as regards wastewater treatment, this method is still in its infancy and is relatively expensive.

Involving all relevant stakeholders

How society should ultimately deal with the problem of hospital wastewater is not a matter to be decided by researchers alone. However, as well as natural scientific and engineering methods, research can offer social scientific tools which permit a systematic, transparent and broadly based approach to complex decision-making processes involving a variety of stakeholders with divergent interests.

In the case of hospital wastewater at the KSB and the IPW, Judit Lienert and Nele Schuwirth of the Systems Analysis, Integrated Assessment and Modelling department applied a method of this kind – multi-criteria decision analysis. This method involves compiling an overview of the technical solutions available, ascertaining the preferences of the relevant stakeholders, and assessing the acceptability of the various approaches. "This means that any conflicting interests can be recognized rapidly," says Lienert.

On the basis of their colleagues' findings, Lienert and Schuwirth compiled a broad range of possible wastewater treatment options for the two hospitals and identified four main objectives: low costs, good wastewater quality, good feasibility (i. e. low effort for staff and patients) and good public perception. In order to determine and evaluate stakeholders' priorities regarding the objectives and effects of treatment options, they conducted structured interviews with ecotoxicologists, engineers, water protection agencies, health authorities, and hospital management and staff.



In the lab, wastewater samples are subjected to elaborate chemical analysis.

Summing up the results, Lienert says: "In the case of the cantonal hospital, with its relatively high pharmaceutical load, the decision analysis showed that comprehensive wastewater treatment would be the best solution." Here, the costs did not appear to be a priority concern. Reverse osmosis – the most effective, but also the most expensive method – best met the respondents' individually weighted objectives, followed by use of vacuum toilets with subsequent incineration of wastes. In the case of the psychiatric centre, which contributes a low proportion of the total pharmaceutical load at the wastewater treatment plant, costs were regarded as a more critical factor. Lienert comments: "Especially with complex problems, this kind of decision analysis is valuable, as the aim is to implement measures with the broadest possible acceptance. It's the only way to produce solutions which really work." ○○○

http://tinyurl.com/eawag-hospitalwastewater
http://tinyurl.com/eawag-mcda

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Tap water – a popular drink

Tap water from the mains or mineral water from the supermarket? The decisions made by Swiss consumers on this question have a lot to do with social habits – and especially with the family.

Tap water – which is cheaper and more environmentally friendly than bottled mineral water – is a popular drink in Switzerland. According to surveys conducted by the Swiss Gas and Water Industry Association (SVGW) in 2001 and 2006, the Swiss are very fond of tap water and drink it frequently. On the other hand, recent figures indicate that sales of bottled water are increasing in this country.

Convenient and readily available

Psychologists led by Hans-Joachim Mosler of the System Analysis, Integrated Assessment and Modelling (SIAM) department at Eawag wished to find out why Swiss consumers opt for bottled water even though tap water is so highly rated. The social scientists aimed to determine the key psychological factors involved in the choice between the two sources of water. To this end, they surveyed 731 German-speaking Swiss aged between 14 and 90. The questionnaire included questions on consumption patterns, socio-demographic background, and motives and emotional factors, such as perceived water quality, convenience, health-related aspects and price perception.

The results underlined the high value attached to tap water. At home, around 50 per cent of respondents drink tap water exclusively, a mere 10 per cent drink only bottled water, and the remainder are "mixed drinkers". In the workplace, more than 40 per cent still drink tap water exclusively, but the proportion drinking only bottled water rises to over 30 per cent.

The latter report that environmental aspects are less important to them at work, while sparkling water is more important to them than it is at home. In addition, they more frequently observe people drinking bottled water in the working environment, which appears to influence their preferences.

Purchases of bottled water were also quantified. Just over half of the respondents buy any bottled water at all and, if they do so, then in average quantities of around 9 litres a week (i.e. a standard six-pack). By contrast, those who drink only bottled water buy around 12.5 litres a week.

In line with the findings of the SVGW surveys, the researchers confirmed the public's high level of satisfaction with tap water in Switzerland. They found that 82 per cent are satisfied or very satisfied – and the degree of satisfaction ultimately also plays a role in decisions on consumption: those who are satisfied with tap water or not satisfied with bottled water will in most cases opt for tap water both at home and at work. Factors such as convenience and availability likewise have a positive influence on tap water consumption at home. Also important are water purity and confidence in water quality.

Family ties

A particularly important reason for the consumption of bottled mineral water is a preference for sparkling water. Rather than carbonating water themselves, those who like fizzy water tend to buy it in bottles. But sheer habit also seems to turn consumers into inveterate bottled water drinkers.

Interestingly, decisions on water consumption are not just an individual matter. Instead, preferences are guided by the social environment. It is true that a sense of obligation to order bottled water in restaurants does not influence home or workplace consumption, but the majority of Swiss consumers drink the same kind of water as their relatives, friends and acquaintances. In addition, when they are at home they tend to feel more obliged to offer guests bottled water than tap water.

Tap water thus still appears to be very popular among Swiss consumers. If their preferences change at some point and if they are to be induced to switch back to tap water, the habits of social groups would offer a more promising line of attack than pricing or quality considerations. ○○○

Stefan Kubli

Switzerland is a nation of tap water drinkers.

www.eawag.ch/forschung/siam

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Ecological engineering with fly larvae

In developing countries, the dumping of organic waste leads to sanitary problems and pollution. Using fly larvae for waste treatment could alleviate these problems – and even provide a source of income for local businesses.

Recent years have seen significant improvements in waste management in low- and middle-income countries. Resaleable materials, in particular, such as metals, plastics or glass, are increasingly ending up in recycling centres. Organic household and market waste, however, is frequently disposed of in open dumps, ditches or surface waters, where it may serve as a breeding ground for pathogens or decompose in an uncontrolled manner, releasing methane (a potent greenhouse gas). "If this type of waste had an economic value, it would also be collected to a greater extent," says Stefan Diener, a researcher in the Department of Water and Sanitation in Developing Countries (Sandec). He is convinced that, with appropriate incentives, health and environmental problems could be substantially reduced.

New product from waste

The solution proposed by Diener is an unconventional one – industrial-scale treatment of organic waste using larvae of the black soldier fly *(Hermetia illucens).* These larvae can devour large quantities of rotting material in the course of their development and, as they feed, they would effectively be turning themselves into a product that could generate income for local entrepreneurs. Diener explains:

The fly larvae are rich in protein and fat.

"Fully developed larvae, known as prepupae, consist of 40 per cent protein and 30 per cent fat, so they represent a valuable and sustainable alternative to fishmeal, which is currently used in the animal feed industry." Because fishmeal is generally a product of sea fishing rather than of fish-processing waste, it contributes to the problem of overfishing. In addition, the price of fishmeal has tripled over the last ten years, so there are also compelling economic reasons for seeking alternative sources of animal protein – particularly for the booming aquaculture sector in developing countries.

To demonstrate that organic waste degradation by soldier fly larvae actually works in practice, Diener set up a pilot treatment unit at the EARTH University in Guácimo (Costa Rica). The unit comprised several trays (2 metres long and 80 centimetres wide) to which regular supplies of fresh household waste were added, together with *Hermetia* larvae. These voracious feeders reduced the waste volume by up to 80 per cent (dry mass). In the pilot unit, over 2 tonnes of organic matter was processed in this way, with around 80 kilograms of prepupae being harvested. However, despite the success of this experiment, Diener stresses that the method is still at the trial stage and a unit of this kind cannot yet be operated on an industrial scale.

Soldier flies are ideally suited for the combined disposal and production process not just because of the high waste reduction efficiency. These insects – which are found in Canton Ticino as well as in the tropics and subtropics – do not transmit diseases, and they are easy to harvest: "As soon as they reach the prepupal stage," says Diener, "they stop feeding, crawl out of the waste and can be conveniently collected for further processing."

A student at the pilot waste treatment unit in Costa Rica monitors the performance of the larvae.

Faecal sludge treatment

According to Diener, the production of high-protein animal feed is only one potential application for the prepupae. Chitin, the main component of the insects' cuticle, could be used to produce collagen for wound healing, and the fat could be a source of biofuels. He adds: "The residual waste – essentially larval excrement – can be used as a fertilizer or converted to biogas in a digester."

In addition, the production of larvae is not restricted to household waste. Initial studies carried out by Eawag and the Asian Institute of Technology in Bangkok have shown that the method can also be applied successfully with dried faecal sludge. Processing appears to be particularly efficient if household and market waste is also added to the sludge. ○○○

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Life without arsenic

In many regions of Southeast Asia, groundwater is contaminated with arsenic. Regular consumption of contaminated water causes serious damage to human health. In Vietnam, planning of low-arsenic wells has been facilitated by the development of a three-dimensional risk map. But whether local communities actually opt for arsenic-safe water also depends on psychological factors.

High concentrations of arsenic in drinking water pose a health threat to more than 100 million people worldwide. Arsenic is a ubiquitous trace element, occurring naturally in rocks and especially in geologically young sediments. When it is dissolved, it can accumulate in groundwater. Long-term consumption of arsenic-laden drinking water leads to serious health problems, including cancer.

Contaminated groundwater is particularly widespread in the river deltas of Southeast Asia – where it is also an important source of drinking water for large numbers of people. In Vietnam's Red River Delta, for example, Eawag researchers discovered that around three million people are at risk from using arsenic-rich water as their only water resource.

Of the roughly 17 million people living in the Delta region, 11 million have no access to public water supplies and are largely dependent on tube wells.

Insidious development of symptoms

Over a five-year period, Michael Berg, Caroline Stengel and Lenny Winkel of the Water Resources and Drinking Water department at Eawag, together with colleagues from Hanoi University of Science, investigated contamination patterns for arsenic and other elements throughout the Red River Delta. This involved chemical analysis of groundwater samples from over 500 private tube wells across the 14,000 square kilometre region, including the capital Hanoi.

Berg says: "In 27 per cent of all wells, arsenic concentrations exceeded the guideline value specified by the World Health Organization." According to the WHO, concentrations of less than 10 micrograms per litre are safe. In an earlier study, the researchers had already observed concentrations which occasionally were 100 times higher than the WHO guideline value. Chronic intake of levels in excess of 50 micrograms per litre can cause arsenic poisoning (arsenicosis).

The construction of tube wells in the Red River Delta region began in the mid-1990s. Scientists from Eawag and the Hanoi University of Science first detected high groundwater arsenic concentrations in 1998, during a project sponsored by the Swiss Agency for Development and Cooperation. However, cases of arsenicosis in the population were not seen until 2004, as symptoms develop very slowly – over a period of ten years or more.

In addition to arsenic contamination, the researchers found unsafe levels of manganese in 44 per cent of wells. Excessive intake of manganese can impair brain development in children.

For many people in Southeast Asia, tube wells are the only source of drinking water.

Long-term impacts of overexploitation

With the aid of geological data, the researchers developed a mathematical model to generate a three-dimensional risk map for the entire region. With this map, arsenic concentrations in groundwater can be estimated up to a depth of 100 metres. "Risk modelling facilitates the planning of new, low-arsenic groundwater wells," says Berg.

The researchers were also able to explain why Hanoi's water supplies have relatively high concentrations of arsenic. To meet the needs of its growing population, the city has been pumping water for over 100 years from deep, uncontaminated aquifers lying below the arsenic-rich zones. As a result, arsenic-rich water has percolated from the shallow layers to the deeper aquifers. Berg points out: "These findings on long-term impacts could be valuable for other countries with arsenic problems – for example, in Bangladesh, which has only been extracting groundwater from deep aquifers since the 1970s."

As a proportion of the population in the Red River Delta will not have access to arsenic-free drinking water in the near future, simple treatment technologies are needed to make contaminated water safe to drink. One promising option is the sand filter, as shown by studies carried

out by the researchers in Vietnam. "Sand filters remove arsenic from water very efficiently and at low cost," says Berg.

Education is not enough

Accordingly, in regions with high levels of arsenic contamination, various NGOs are promoting the adoption of measures to ensure safe drinking water supplies – as well as the use of sand filters, these include, for example, switching to other wells, installation of piped water supplies or rainwater harvesting.

However, promotion and provision of appropriate technologies do not automatically guarantee that safe options will actually be (consistently) used by local communities. In an affected area of Bangladesh, for example, Jennifer Inauen and Hans-Joachim Mosler of the Systems Analysis, Integrated Assessment and Modelling department showed that around 40 per cent of residents continued to use arsenic-rich water despite the availability of safe alternatives.

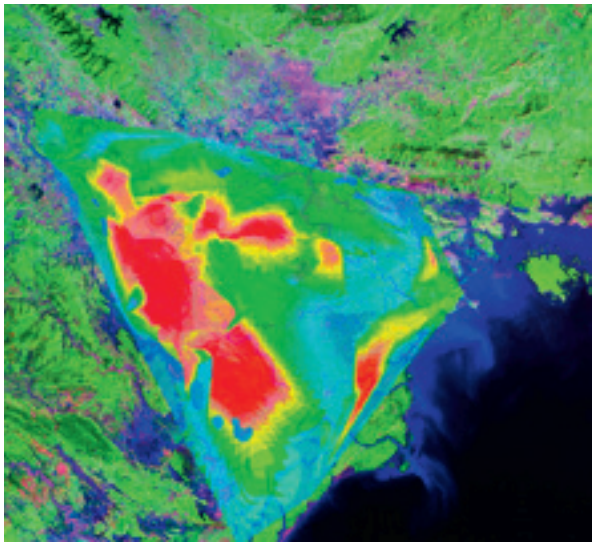
According to Jennifer Inauen, "The conventional wisdom is that this behaviour can be explained by a lack of risk awareness, and that it can be changed by education in the sense of imparting knowledge." But, she believes – as we have learned from social psychology – this in itself is generally not sufficient: "In many cases, the decisive factors are social norms and people's ideas about what others might expect of them."

To investigate the reasons for the use or non-use of arsenic-safe water sources in Bangladesh, and to find out how to bring about changes of behaviour, Mosler and Inauen conducted a social psychological study. Using a structured questionnaire, they interviewed around 750 families who had access to an arsenic mitigation option, so as to identify the factors influencing their choices.

The subsequent statistical analysis indicated, for example, that people are deterred from using an arsenic mitigation option if it is more complex and time-consuming. In addition, they feel that they lack the ability to cope with malfunctions and defects. The behaviour of other villagers also has a major influence.

Based on these findings, the researchers elaborated measures that could have a favourable influence on determinants of behaviour. A promising intervention, for example, could be to use opinion leaders to influence the behaviour of other villagers and to increase the popularity of arsenic mitigation options. Practical guidance on safe use of these options should enhance users' self-efficacy and thus increase acceptance. The researchers also see a need to improve attitudes towards the additional effort involved.

The researchers now plan to implement appropriate interventions in the field and investigate how these affect the behaviour of the people at risk. ○○○



Risk map for the Red River Delta: red indicates a high probability of occurrence of arsenic-rich groundwater.

Increasing the use of water filters

A problem similar to that of arsenic contamination affects certain parts of Ethiopia: excessive levels of fluoride in drinking water may cause growth disorders, dental fluorosis and bone deformities. Although fluoride can be effectively removed with a bone char filter, many people continue to consume unfiltered water.

Here again, therefore, Alexandra Huber and Hans-Joachim Mosler of Eawag developed a social psychological model in order to investigate the behavioural determinants of filter use and how these could be influenced by targeted interventions (compare the article opposite).

In the case of household filters, a perceived lack of storage capacity was found to be a decisive factor – even though 40–50 litres can be filtered per day. The aim of one intervention is thus, with users, to plan a daily routine for filling the filter, to ensure that sufficient safe water is available throughout the day. Initial results suggest that appropriate guidance was effective in changing behaviour in the desired way.

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Greenhouse gas emissions from reservoirs

Substantial amounts of the greenhouse gas methane are emitted not only from large tropical reservoirs but also from run-of-the-river reservoirs in Switzerland. Especially in the summer, gas bubbles rise to the surface – in Lake Wohlen, for example, a reservoir on the Aare. How significant are these emissions? Can hydropower still claim to be a climate-neutral source of energy?

Methane from the sediments at the bottom of a reservoir can reach the atmosphere via various pathways. As a dissolved gas, it slowly diffuses into the water column and is released into the air at the surface. It is also emitted as a result of turbulence when water passes through turbines. The higher the methane concentrations in the water, the higher the emissions to the atmosphere. The amount of methane produced in a reservoir can be estimated by measuring dissolved concentrations in the water.

Alpine reservoirs: not significant emitters

When methane production in sediments reaches a high level, bubbles are formed which rise through the water column, giving the lake the appearance of champagne or mineral water. This "ebullition" transports large amounts of gas to the atmosphere in a short time. It is, however, difficult to measure, owing to the high degree of spatial and temporal variability. The bubbles can be captured in funnels, but large numbers of measurements are required to obtain statistically sound results. Because some methane bubbles are dissolved as they ascend, methane concentrations increase towards the surface of the lake. Researchers from the Surface Waters department of Eawag used the extent of this increase as the basis for a more precise analysis of the measurement data.

Researchers deploying funnel-shaped gas traps to study methane bubbles rising to the surface of Lake Wohlen.

Keystone

Reservoirs in the Alps (pictured: the Grande Dixence Dam in Canton Valais) have little impact on the climate.

Torsten Diem compared greenhouse gas emissions from eleven Swiss reservoirs – Lakes Sihl, Lungern, Gruyère and Wohlen in the pre-Alps and Central Plateau, and Lakes Luzzone, Zeuzier, Santa Maria, Grimsel, Bianco, Oberaar and Dix at alpine elevations. The results show that carbon dioxide and methane (CH_4) are emitted by all the lakes. However, the emissions are very low: the average rates – excluding Lake Wohlen – are approx. 1 gram of CO_2 and 0.2 milligrams of CH_4 per square metre per day. Alpine reservoirs are thus not significant sources of greenhouse gas emissions.

Lake Wohlen: a special case

In contrast to the other reservoirs studied, environmental chemist Tonya Del Sontro observed high levels of methane transport by ebullition in Lake Wohlen on the Aare near Berne, especially on warm summer days. The emissions measured were up to 200 milligrams per square metre per day – i.e. 1,000 times higher than the average for the other reservoirs. In addition, small amounts of dissolved methane diffuse from the sediment during the winter months.

Overall, Lake Wohlen produces around 150 tonnes of methane emissions per year. Given the high global warm-

ing potential of methane, this is equivalent to roughly 3,700 tonnes of CO_2, or 25 million car kilometres. This is the highest methane emission rate recorded to date for a temperate reservoir. However, compared to a coal-fired power station, the Aare hydropower plant (annual output 160 gigawatt-hours) still produces relatively low emissions – expressed as CO_2 equivalents, they amount to 20 grams per kilowatt-hour. CO_2 emissions from a coal-fired plant are around 1 kilogram per kilowatt-hour – 50 times higher.

Methane bubble formation requires the presence of easily degradable carbon, warm temperatures and relatively shallow water. In alpine reservoirs, inputs of carbon from plants are minimal and temperatures are low, which explains why greenhouse gas emissions from these lakes are not significant. However, as Lake Wohlen lies below Lake Thun, algae are transported into the reservoir via the Aare. An additional factor is probably contamination in sediments, from the days when wastewater entered the Aare largely untreated.

Without the reservoir, these loads would enter Lake Biel, where they would mostly be deposited at greater depths. But because Lake Biel is stably stratified in the summer, possible methane emissions via gas bubbles would be confined to the Aare delta. Methane emissions were presumably also lower before the Jura Water Correction, when the Aare still flowed directly into the Rhine: marine deposits produce much less methane, because organic carbon in sediments is oxidized by sulphate in seawater.

Problem affecting the tropics

Previous studies have focused on tropical reservoirs as major sources of emissions. Here, flooded vegetation often contributes to the formation of greenhouse gases. In some documented cases, estimated emissions are more than ten times greater than in Lake Wohlen. At this level, methane and carbon dioxide emissions are no longer negligible. In fact, in many of these studies, the true extent of emissions is probably underestimated, as the effects of ebullition were not reliably calculated.

Taking a reading from the gas cylinder on a floating funnel is an acrobatic feat.

New hydropower plants on the Amazon, on the Mekong or in tropical Africa can therefore not be considered to be climate-neutral. In some cases, the "side effects" of their operations are comparable to those of modern coal-fired power plants.

Researchers are currently developing methods which allow bubbling gas to be quantified more precisely by sonar surveys. This makes it possible to determine more rapidly where and when methane is released in a lake or reservoir. Del Sontro says: "We hope that in future, with these improved methods, the acrobatic feats involved in observing ebullition with floating funnels will no longer be necessary."

The situation is summed up by Bernhard Wehrli, professor of Aquatic Chemistry: "Reservoirs below natural lakes and shallow estuaries may be hotspots for greenhouse gas emissions. That should not be overlooked in global methane budgets." He estimates that, worldwide, reservoirs could account for about 18 per cent of anthropogenic methane emissions, and adds: "What determines how climate-friendly a reservoir is, is not just the location but also water protection and wastewater treatment measures in the catchment." In order to provide a more objective basis for the political debate concerning greenhouse gas emissions from reservoirs, measurement guidelines have been developed by an expert group in a joint UNESCO/International Hydropower Association project. ○○○

Nitrous oxide released from WWTPs

Greenhouse gases are released into the atmosphere not only from reservoirs but also from wastewater treatment plants (WWTPs). Here, environmental engineers at Eawag are focusing in particular on nitrous oxide (N_2O). As a greenhouse gas, N_2O is 300 times more potent than CO_2, and it also contributes significantly to the depletion of the stratospheric ozone layer. To date, estimates of N_2O emissions from biological wastewater treatment have been extremely vague. Measurements carried out at the Eawag pilot treatment facility suggest that unfavourable operating conditions – e.g. insufficient oxygen or high ammonium concentrations – can lead to significantly higher N_2O emissions than previously assumed. In cooperation with Empa, Eawag is therefore currently developing a method using various nitrogen isotopes to identify the parameters affecting N_2O emissions. This should provide a basis for reduction strategies.

www.eawag.ch/forschung/surf/gruppen/methane/index

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Lake Constance: good-quality water

The quality of water obtained from Lake Constance – one of the most importance sources of drinking water in Central Europe – is excellent. In some tributaries, however, levels of micropollutants could be problematic for certain aquatic organisms.

Lake Constance is one of Central Europe's most important reservoirs, supplying drinking water for roughly 4.5 million people in Switzerland and Germany. Each year, 17 treatment facilities draw around 180 million cubic metres of water from the depths of the lake. According to Eawag studies, water quality in the deep layers is excellent.

Water samples are filled into glass bottles.

Low levels of contamination

In order to assess current contamination levels, Heinz Singer and colleagues from the Environmental Chemistry department prepared a comprehensive inventory of organic micropollutants on behalf of the International Commission for the Protection of Lake Constance (IGKB). Using state-of-the-art analytical methods, they screened for pesticides, biocides, pharmaceuticals, food additives and industrial chemicals, as well as transformation products. "Altogether," says Singer, "we found 47 substances." In all cases, concentrations were lower – sometimes considerably lower – than the maximum target value of 100 nanograms per litre (ng/l) specified for pesticides in water resources. Over 80 per cent of the substances occurred in concentrations of a few nanograms per litre. As Singer points out, "These quantities are so low that they can hardly be detected with existing technologies." Comparatively high concentrations of 50–100 ng/l were measured for various pharmaceuticals and for two corrosion inhibitors mainly used in dishwasher detergents.

Elevated concentrations in rivers

To find out which tributaries contributed the greatest contaminant loads, Singer evaluated mass fluxes for the entire catchment of Lake Constance, using a model developed at Eawag. Elevated concentrations of the substances analysed were found to occur in particular in the rivers Steinach (which rises in Canton St Gallen), Schussen (in Baden-Württemberg) and Dornbirner Ach (in Vorarlberg). Singer says: "This is due to the relatively high proportion of treated effluent in these three rivers." For example, under low-flow conditions, up to 80 per cent of the water in the Steinach originates from wastewater treatment plants.

Values in some cases exceeding 500 ng/l – problematic for certain aquatic organisms – were detected for the anti-inflammatory agent diclofenac. In almost half of the river stretches investigated, low-flow concentrations were high enough to be potentially harmful to aquatic organisms in the long term. Singer adds: "Using advanced treatment methods such as powdered activated carbon adsorption or ozonation, most of these active substances could be eliminated from wastewater."

On the basis of modelling calculations, Singer also estimated how concentrations of the substances of interest in Lake Constance will develop over the next 20 years. While inflows and outflows of certain compounds are balanced, levels of diclofenac, for example, can be expected to double if this product continues to be used to the same extent and the performance of wastewater treatment plants is not improved. "But even then," says Singer, "the concentration will be less than 10 ng/l – still well below the limit value for drinking water." ○○○

www.eawag.ch/forschung/uchem

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Higher salt levels in Lake Constance

Since the 1960s, the chloride content in Lake Constance has risen 2.5-fold. Concentrations are currently around six milligrams per litre. According to Eawag researchers, the rise is attributable to increased use of road salt and of salt in households and agriculture in the catchment area. In 2006, more than 100,000 tonnes of chloride was applied. However, only around two thirds of the total ends up in Lake Constance – the rest remains in the soil and groundwater. Levels are expected to continue to rise in the future. While no measures are required as yet, since the environment can cope with concentrations of this magnitude, the researchers say that Lake Constance provides an example of the massive scale of human interference with natural material cycles.

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Risk of transformation products

As well as parent compounds, transformation products of pesticides and pharmaceuticals may pose risks to the aquatic environment. The risk of transformation products can be assessed using a combined modelling and measurement approach.

It is becoming increasingly clear that not only active substances but also their transformation products may pose a risk to aquatic ecosystems. Transformation products are often more readily water-soluble and thus more likely to enter surface waters or groundwater. However, these findings have yet to be fully taken into account in the Swiss Water Protection Ordinance. As Kathrin Fenner of the Environmental Chemistry department at Eawag explains, "What has been lacking so far is a generally applicable method which could be used to systematically identify and assess potentially problematic transformation products."

Modelling degradation

In order to fill this gap, the environmental chemist and her team – as part of the Federal Office for the Environment's "MicroPoll strategy" project – developed a prioritization method based on a combination of modelling and measurement. They used this method to identify relevant transformation products for 62 pesticides, biocides and pharmaceutical active substances widely used in Switzerland, and to assess their ecotoxicological potential.

A researcher checks the automatic sampling process on the Petite Glâne river in the Lake Murten catchment.

Since transformation products are only known for a small number of compounds, the researchers carried out degradation studies with microorganisms themselves or used a computer model to simulate the formation of transformation products. To detect the presence of these (generated or postulated) products in water samples, they then used high-resolution mass spectrometry. With this technique, the exact mass of a chemical compound can be determined so accurately that the possible number of molecular formulae is extremely limited. With the aid of additional analyses, the compound and its structure can be reliably identified.

The researchers sought – and found – transformation products in various Swiss streams, rivers, wastewater treatment plant (WWTP) influents and effluents, and groundwaters. "51 compounds were present in the water samples in relevant concentrations," says Fenner. In the case of pesticides, for example, nine transformation products exceeded the drinking water quality standard of 0.1 micrograms per litre for pesticides and degradates in several samples. Three of these products were also found in high concentrations in various groundwater samples. In WWTP effluents, the researchers also detected seven pharmaceutical transformation products which likewise exceeded the limit specified for pesticides.

Fenner concludes: "Our investigations show that many transformation products occur in concentrations comparable to those of the parent compounds." A single compound may even give rise to several different transformation products. As Fenner points out: "Since the compounds are not immediately further degraded and persist in water for some time, they are not negligible for ecotoxicological risk assessments."

According to Fenner, the high degree of stability of certain transformation products of pesticides can even lead to chronic contamination of water resources: these products leach through the soil into groundwater and then successively enter surface waters, while the parent compounds themselves are generally less persistent, with peak exposures only arising during the application period.

Expansion of monitoring

But are transformation products actually problematic for the aquatic environment? To help answer this question, the researchers developed a method which can be used to assess the ecotoxicological risk potential of these substances.

Analysis of transformation products indicated that, in most cases, the toxicity range is similar to that for the parent compound. But in a few cases – e. g. with the analgesic metamizole – the transformation products were judged to be markedly more toxic than the parent compound. "For substances like that, a thorough ecotoxicological assessment is definitely worthwhile," says Fenner. In the longer term, she adds, it is important to include such priority transformation products in monitoring programmes and to specify limits for them.

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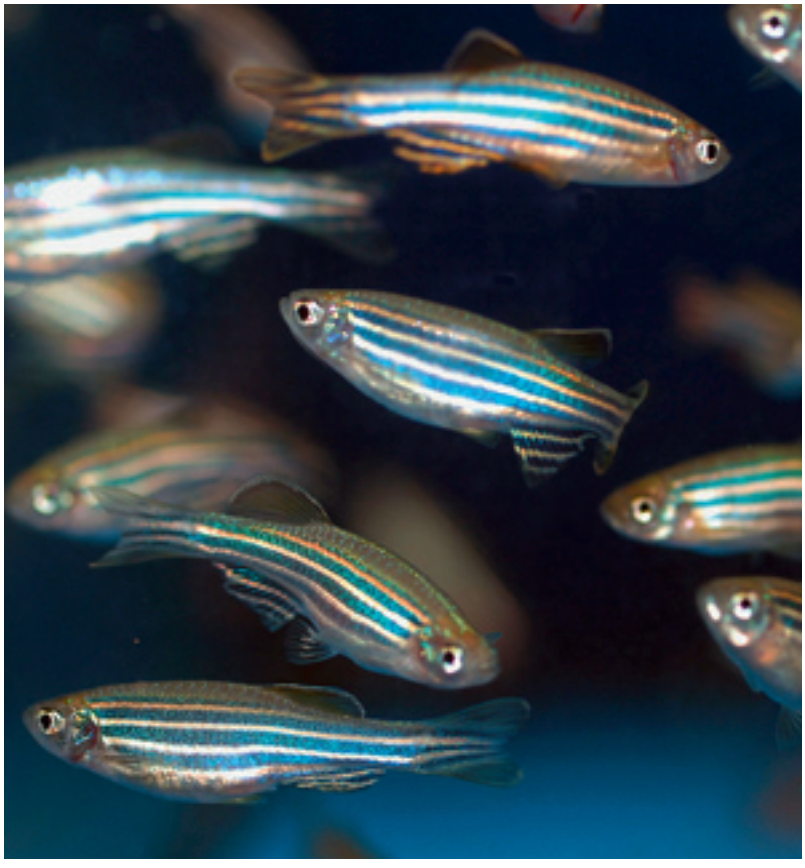
Surviving in a chemical cocktail

In their natural environment, aquatic organisms are permanently exposed to a wide variety of chemicals. In the course of their evolution, they have developed a sophisticated defence mechanism providing protection against harmful substances. But certain chemicals render this protective barrier permeable, making the organisms more sensitive to environmental toxicants.

Plant metabolites, algal toxins, and constituents or degradation products of artificial fertilizers, pesticides, pharmaceuticals, cosmetics, flame retardants and cleaning agents – our surface waters are complex mixtures of naturally occurring substances and chemicals introduced into the environment by humans. Although these contaminants are generally found in very low concentrations, aquatic organisms are exposed to them permanently, and in most cases almost nothing is known about their long-term effects.

However, organisms are not entirely helpless vis-à-vis environmental toxicants, as evolution has equipped them with certain defence mechanisms. Our knowledge of how organisms protect themselves against undesirable substances is mainly derived from studies of mammals. Mammalian cells have various detoxification and repair systems which, to a certain extent, can intercept and neutralize toxic chemicals or repair any damage caused. Now, Stephan Fischer of the Environmental Toxicology department at Eawag has identified a defence system of this type in fish – so-called multixenobiotic resistance transport proteins, or MXR transporters.



Kostas Margiludis, MPI-CBG

The cellular detoxification system is vitally important for zebrafish.

Expelling foreign substances from cells

These proteins, found in the cell membrane, serve as active efflux pumps, recognizing and expelling foreign substances which enter the cell. Transport proteins of this kind were first identified in human tumour cells, where they block the action of cytostatic drugs. In addition, experts believe that diseases such as cystic fibrosis and arteriosclerosis are caused by defective transporters. Fischer explains: "In humans, these proteins normally form an effective blood-tissue barrier – they're found especially in the intestine, kidney and liver, but also in the brain, testes or placenta."

Fischer identified a number of MXR transporters in rainbow trout cell lines and in zebrafish embryos: "They are present, for example, in the gills, where they act as an environment-tissue barrier." To demonstrate that they also function as cellular guards in fish, he exposed the cells and embryos to fluorescent dyes which are recognized and blocked by MXR transporters.

Under normal conditions the transporters functioned effectively, as shown by the fact that the dyes did not accumulate inside the cells – these appeared dark under a special light, while the surrounding area was fluorescent. The results were different when MXR transporters were chemically inhibited or when, in fish embryos, individual genes required for MXR protein synthesis were turned off ("knock-down"). The inside of the cell was then fluorescent, as the dyes had overcome the defence system.

Increased sensitivity to toxicants

The laboratory experiments also show how certain chemicals, by blocking transporters, can make the cell's protective barrier permeable to xenobiotics. Chemicals of this kind which inhibit MXR proteins are known as chemosensitizers. As Fischer points out, "These can defeat the cellular defence system and make an organism more sensitive to toxicants, without themselves being toxic."

To find out what this means in practice, the environmental toxicologist carried out another experiment, in which fish embryos were exposed to vinblastine for 48 hours. This cytotoxic alkaloid (derived from the Madagascar periwinkle) inhibits cell division and is used as a chemotherapeutic agent in cancer treatment. Under normal conditions and with moderate doses of vinblastine, the zebrafish cellular defence system worked well: on average, around 20 per cent of individuals died when

Limited detoxification in algae

To protect themselves against toxic metals such as lead, algae produce phytochelatins – polypeptides which bind and thus immobilize heavy metals. Studies carried out by Christian Scheidegger at Eawag showed that the unicellular green alga *Chlamydomonas reinhardtii* responds very rapidly to elevated lead concentrations in water, synthesizing protective phytochelatins within minutes. In addition, the higher the lead concentration, the more detoxification molecules are formed.

In Scheidegger's experiments, this cellular defence mechanism allowed the algae to cope effectively with short-term exposure (lasting a few hours). However, with longer-term lead exposure (over a period of several days), this mechanism was no longer sufficient and the vitality of the *Chlamydomonas* algae declined. Scheidegger explains: "Over time, not enough phytochelatins are present in the cells to bind accumulating lead." The algal response to chronic stress takes the form of reduced or arrested photosynthesis and growth. These effects were already observed at lead concentrations which can be expected to occur in heavily polluted waters. The study also shows that if ecotoxicological assessments are to be meaningful, consideration of long-term exposure is essential.

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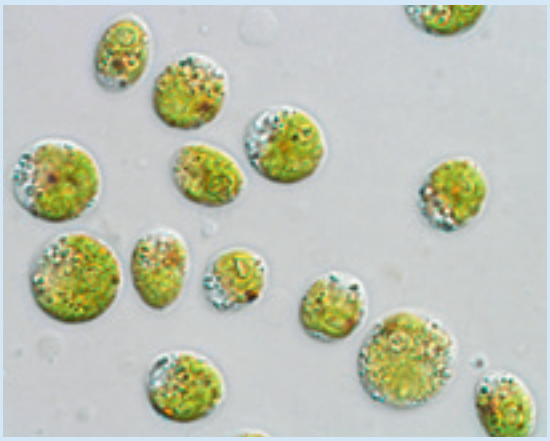


Unicellular freshwater algae.

exposed to a concentration of 1.6 milligrams of vinblastine per litre of water.

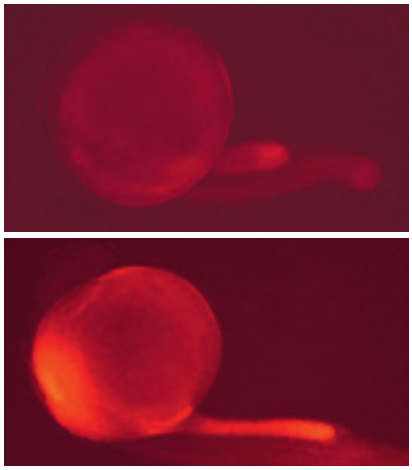
However, the situation was different when cyclosporin – an immunosuppressant obtained from a fungus – was added. Fischer comments: "Cyclosporin acts as a chemosensitizer, which is why the fish are much more sensitive to toxic substances." Accordingly, in combination with cyclosporin, the vinblastine concentration used in the first assay was now lethal in up to 80 per cent of embryos. When MXR transporters were not inhibited, at least twice this dose of vinblastine was needed to produce comparably high mortality rates.

Limited knowledge of chemosensitizers

Scientists only began to study chemosensitizers in detail a few years ago. As yet, therefore, only a small number of environmentally relevant substances have been identified which increase sensitivity to other chemicals via inhibition of MXR transporters. Known chemosensitizers include, for example, synthetic musks, which are widely used as fragrances in personal care and cleaning products, and polycyclic aromatic hydrocarbons, which occur in fossil fuels and are used in pesticides and dyes and as stabilizers or plasticizers.

The chemosensitizers identified to date belong to a wide variety of chemical groups, which suggests that these substances – not in themselves toxic to aquatic organisms – are quite widely distributed in surface waters. Fischer emphasizes that it is important to study the effects not just of individual substances in isolation, but also of mixtures of chemicals, such as are typically encountered in the environment. After all, the example of chemosensitizers demonstrates that a toxicant may cause much more damage in the presence of other substances.

As a next step, Fischer intends to use rainbow trout cell lines and zebrafish embryos to study the chemosensitizer potential of various environmental chemicals. He believes that this approach could even be developed into a standardized method for use in future ecotoxicological risk assessments of chemicals. ○ ○ ○



Uptake of dye into a fish embryo is prevented when its defence system is intact (top), but not when MXR transporters are inhibited (bottom).

www.eawag.ch/forschung/utox

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Successful adaptation in moor frogs

Evolution sometimes proceeds quite rapidly. Thanks to natural selection, moor frogs in Sweden have successfully adapted to acidified waters within a matter of decades – and altered their defences against predators.

In the 1970s, acid rain and forest dieback were major environmental concerns, particularly in Europe. Today, this type of pollution remains problematic in Scandinavia and in northeastern parts of North America. But acidification is not only a stressor for forests – soils and surface waters are also affected, together with many animal species. In Sweden, the impacts on water bodies may be severe, and in many cases species-rich ponds have been largely deprived of their biodiversity.

Evolution "while you watch"

In southwestern Sweden, however, moor frogs have exhibited a remarkable ability to cope with the adverse environmental conditions. These frogs live in ponds which, as a result of acid rain, have a pH as low as 4 (i.e. as acidic as a glass of wine). Sandra Hangartner and Katja Räsänen of the Aquatic Ecology department at Eawag showed that Swedish moor frog populations have adapted both to the low pH of water and to changes in the ecosystem. In their study, the researchers demonstrated that environmental stressors – in this case, acidity – can lead to evolutionary changes in organisms within a few decades.

In moor frogs, the production of vigorous offspring is due not just to good paternal genes but also to maternal effects.

Frogs are aquatic organisms, particularly during the breeding period and in the larval stage, which means that egg clutches are already adversely affected by acid conditions. Hangartner says: "The egg capsule is altered, embryos are generally less active, and tadpole hatching is reduced." However, the researchers showed experimentally that embryos from low-pH ponds are significantly more tolerant of acid conditions and have a higher survival rate than "neutral origin" populations.

After hatching, one of the main risks to tadpole survival is predation. While tadpoles in neutral ponds are prey to other amphibians, fish and insects, the diversity of predators in acidic ponds is mainly confined to insect species. This change in the ecosystem also has an influence on the defences of the moor frog larvae. Tadpoles from acidic and insect-rich waters developed more powerful tail fins, which improved their ability to flee, and in experiments they survived direct confrontation with dragonfly larvae more frequently than tadpoles from neutral ponds with lower predator density.

In addition, tadpoles from acidic water grew more rapidly. As Hangartner explains, "The high growth rate is also an adaptation to the specific environmental conditions – or a defence against insect predators, because many insects are unable to ingest larger tadpoles."

Need for genetic diversity

The operation of evolutionary adaptive mechanisms depends on the presence of large populations with a high degree of genetic variation. This increases the likelihood that the genetic endowment of certain individuals will enable them to cope more effectively with changing environmental conditions than other members of the same species. Such individuals will be more vigorous and produce more – likewise better adapted – offspring. Over time, this process of natural selection will favour the "superior" genes.

In adaptation processes of this kind, maternal effects also play an important role: mothers specifically pass on to their offspring certain genetic or environment-dependent adaptations, which influence early development in particular.

The ability of Swedish moor frogs to adapt to environmental changes raises the hope that amphibian species are not completely helpless in the face of (frequently anthropogenic) stressors, but can cope with them to a certain extent. However, a key requirement is sufficiently large and genetically diverse populations – and often these cannot be taken for granted. ○○○

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Legacy pollutants from a glacier

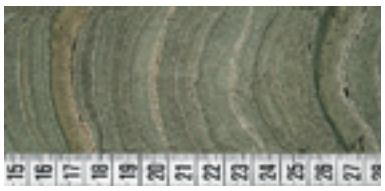
As a result of global warming, glaciers are receding worldwide. Toxic substances trapped in the ice for decades may be released in meltwater, making glaciers a significant secondary source of long-banned pollutants.

Chemicals such as DDT and polychlorinated biphenyls (PCBs), and toxic by-products such as dioxins, are popularly associated with (past) pollution incidents and accidents, (more recent) food safety scandals, and malformations or cancer. For some years now, the use of many of these substances has been heavily restricted worldwide. But it is almost impossible to eliminate them completely from the environment – even in Switzerland, where DDT and PCBs have been totally banned since 1986. This is because they belong to the group known as persistent organic pollutants (POPs), which break down very slowly, remaining in the environment for decades or centuries.

Pollutants in sediments

Because of their physical properties, POPs are transported over long distances via the atmosphere and can be detected globally, from tropical to polar regions. Working together with colleagues from Empa and the ETH Zurich, Eawag scientists have discovered that, in recent years, the amounts of such substances entering the sediments of various Swiss Alpine lakes have begun to increase again – and they have also found out why.

The researchers used sediment cores to study how pollutant levels have changed over the last 100 years in Lakes Oberaar, Stein and Engstlen in the Bernese Alps. Sediment samples were collected by driving long plastic tubes into the lake floors. The cores thus retrieved were then split longitudinally in the laboratory. The layers deposited over the years are similar to annual tree rings. Flavio Anselmetti, a geologist in the Surface Waters department at Eawag, says: "The various types of sediment provide a record of environmental changes in the past." Anselmetti was responsible for sampling and for the interpretation and dating of sediments, while chemical analyses were carried out by Empa.



Environmental archive: sediment layers are clearly visible in the split drill core.

The layers provided evidence that the use of POPs reached a peak in the 1960s and 1970. After the substances were banned, concentrations decreased sharply. Surprisingly, however, the sediment cores from Lakes Oberaar and Stein revealed a sudden increase in the levels of these chemicals from the 1990s onwards, with certain compounds even exceeding the previous peak values. How was this to be explained?

Glaciers: sources of pollutants

The researchers, literally, did not have to look far for an answer, as in each case it lay just above the lake. Both lakes are mainly fed by glacial meltwater – from the Oberaar and from the Stein Glacier respectively. The glaciers are "reservoirs" of substances formerly deposited in snow and incorporated into the ice – including pollutants such as dioxins, DDT and PCBs. Anselmetti and his colleagues suspected that, as the ice masses had been melting more rapidly due to global warming, increasing amounts of pollutants were once again being released into the lakes. They demonstrated, for example, that the annual decrease in the length of the Stein Glacier is correlated with the increase in pollutant levels in the lake.

Their hypothesis was confirmed with the aid of samples taken from Lake Engstlen. While these sediments also showed the characteristic decline in pollutants observed after the 1970s, there had been no recent increase. The reason was that Lake Engstlen is the only one of the three lakes not fed by glacial meltwater; instead, it is supplied by water from springs and precipitation.

To facilitate core retrieval, the drilling rig is set up on the frozen surface of Lake Stein.

The research team was thus able to demonstrate what some experts had long conjectured – that, in an era of climate change, glaciers are significant secondary sources for renewed releases of problematic chemicals into the environment. Over the past ten years alone, the Oberaar Glacier, for example, has retreated by more than 120 metres, releasing clearly detectable levels of toxic substances in its meltwater. ○○○

www.eawag.ch/forschung/surf

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Environmental history from a Turkish lake

What makes Lake Van in eastern Turkey such a special waterbody? Seven times as large as Lake Constance, but with no outlets, and having remained ice-free during the ice ages, its sediments provide a record not only of seasonal cycles, but of volcanic eruptions, earthquakes, prolonged warm and cold periods and other environmental data. Now, for the first time, these deposits are being retrieved by drilling right down to the bedrock. Researchers hope that the sediment cores recovered will shed light on 450,000 years of climate and environmental history.

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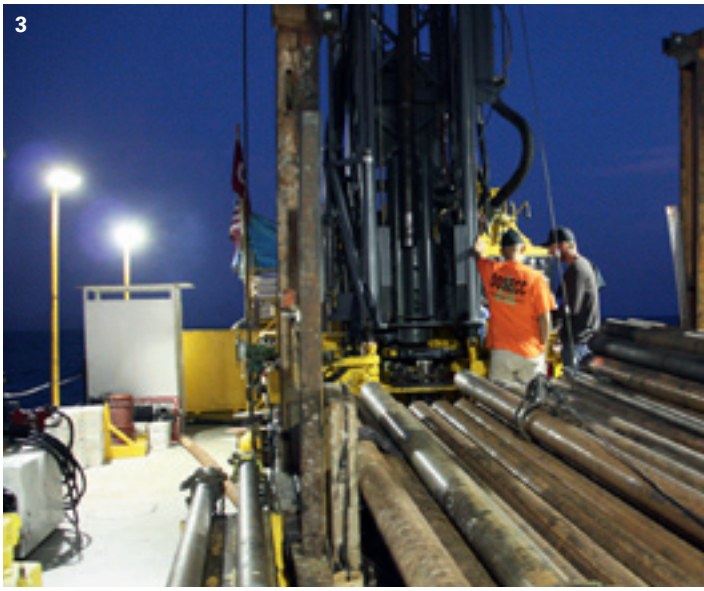

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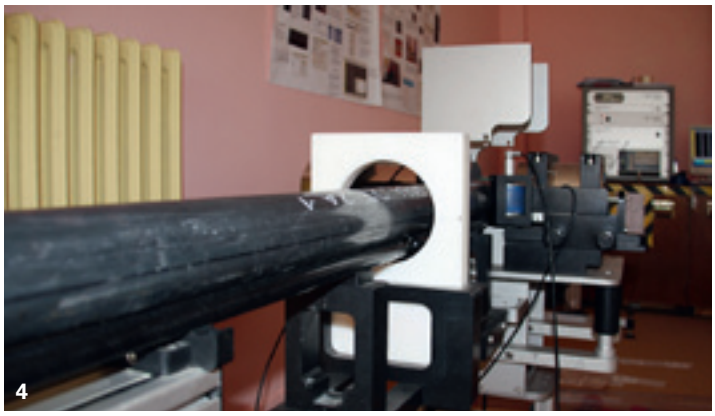
1) Summer 2010: The drilling platform on Lake Van, whose clear water – with a pH of 9.6 – is extremely alkaline. Visible in the background is Mount Süphan (4,058 metres), a dormant volcano.
2) On the rig, two geologists cut drilled cores into 1.5-metre sections and label them.
3) Weather and waves permitting, drilling is carried out around the clock; in the foreground, a stock of drill rods; in the background, the rotary drilling table, 375 metres above the start of the borehole on the lake bed.
4) In a makeshift laboratory at the Hotel Seldschuken in Ahlat, several sensors scan the newly drilled cores. Density, conductivity and magnetic/elastic properties provide initial clues as to the origin of the material and the deposition conditions.
5) Loose sediment originating from where one core is separated from the next is analysed continuously. The intact cores are left untouched.
6) At a pressure of up to 170 bar, pore water is extracted from samples and analysed e. g. for salinity and pH.
7) Minute specimens are examined under the microscope; this allows volcanic minerals, diatoms, pollen grains etc. to be identified.
8) February 2011: At Bremen University, the cores are carefully bisected using a special circular saw. Detailed analysis of the layers can now begin.
9) Artistic patterns in 20-centimetre sections of core material (each representing up to 400 years): Black layers are volcanic ashes mixed with pumice. The minor faults visible in the third and fourth sections and the fold in the fifth are evidence of earthquakes and volcanic activity. The fine brown-beige layers are typical lake sediments, marked by seasonal cycles.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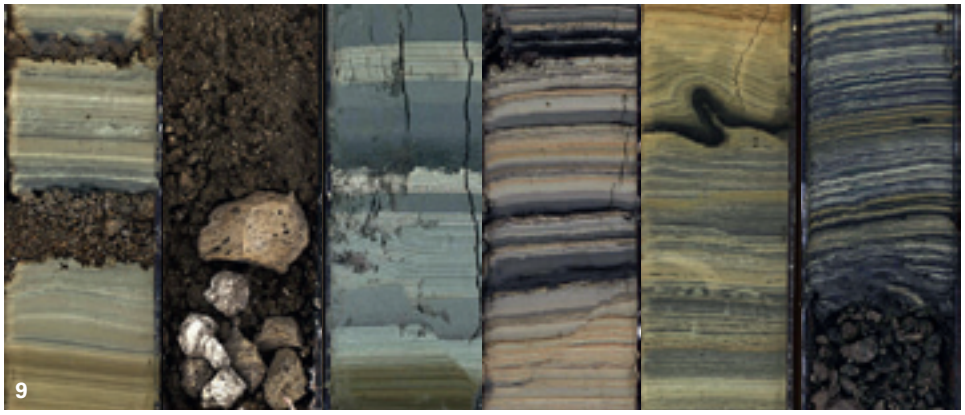
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An interdisciplinary adventure

Today, the five scientists on the floating rig have 12 cores – representing 18 metres of drilled sediment – to load onto the supply ship *Alikaptan*. After a brief exchange of information between palaeobotanist Thomas Litt of Bonn University and geologist Flavio Anselmetti of Eawag, the vessel takes three scientists and three drillers – who have just completed their 12-hour day shift – back to the small harbour of Ahlat.

The interdisciplinary team – comprising researchers from Switzerland, Germany and Turkey and a US drilling crew – spent three months in eastern Anatolia retrieving over 800 metres of sediment cores from the 400-metre-deep Lake Van. This large-scale project was a challenge for all concerned, given the choppy waters and the special chemical conditions of this terminal lake, as well as unexpected bureaucratic obstacles and a culture in the Kurdish region of eastern Anatolia which was alien to most of the participants. The project – which Eawag was instrumental in initiating – is supported by the Swiss National Science Foundation and the German Research Foundation (DFG) and forms part of the International Continental Scientific Drilling Program (ICDP). The successful recovery of the cores is only the first phase of the project. In February 2011, the cores were cut open at Bremen University and detailed analysis is now underway.

The readily countable annual layers, the possibility of determining absolute age by argon-argon dating of volcanic glass deposits and many other types of evidence make Lake Van sediment a unique archive – not just for reconstructing the history of the lake and the nearby volcanoes, but also for the climate and environmental history of Central Europe as a whole. Looking back in this way over several glacial interglacial cycles would not be possible with Swiss lakes, for example, as they were either modified during the ice ages or only formed when the ice receded.

▸ www.eawag.ch/lakevan, ▸ www.icdp-online.org

Research

Teaching

Consulting

Norbert Staub, ETH Zürich

By providing education and training for students, Eawag plays an important role in Switzerland: it helps to ensure that professionals at home and abroad take an integrated approach to emerging issues in water use and protection and can implement sustainable management of water resources. In 2010, Eawag's teaching activities were again maintained at a consistently high level. More than a fifth of the institute's scientific staff taught at universities, at the ETH Lausanne and ETH Zurich, or at universities of applied science. The number of Bachelor's and Master's students supervised has increased steadily in recent years. The number of doctoral dissertations supervised has risen even more sharply, from 111 in 2009 to 153 in 2010.

At Eawag, students learn within a solution-oriented research environment, competing also at international level. They have the opportunity to participate in international research – e. g. the Lake Van project in Turkey – and to help solve practical problems in projects involving external partners. The numerous awards received by students and young researchers at Eawag reflect the quality of their work.

Jukka Jokela

Promoting ecology

"There's more water than land there," says Jukka Jokela, referring to his home region – Finnish Lakeland. This is one of the reasons why aquatic ecosystems have become the biologist's main research interest. As well as carrying out research, he lectures regularly at the ETH Zurich. "Basically, I'm promoting ecology among my students." His aim is to make them think and point them in the right direction: "I explain the broad concepts to them – they have to elaborate the details themselves." Lecturing also gives him an opportunity to brush up or broaden his own knowledge. Wherever possible, he includes examples from his current research – e.g. on host-parasite interactions between freshwater snails and trematodes. "I'm investigating how the genetic diversity of host organisms changes in the course of evolution." Switzerland, Jokela adds, is a global leader in evolutionary ecology, which was what ultimately brought him to Eawag five years ago. An additional attraction is the variety of scientists from around the world who work together here: "The students benefit from this mixture of different cultures and backgrounds."

Armin Peter

Communicating a passion

"When the students can stand knee-deep in fast-flowing water and catch a fish, then they've understood what it's all about," says biologist Armin Peter, who lectures on fish ecology and river restoration. Whether he's teaching students at the ETH or professionals attending practice-oriented Eawag courses (PEAK), Peter is keen not just to impart knowledge but to communicate his passion for the subject. "Near-natural watercourses are extremely dynamic, both ecologically and physically," he says. To his mind, fish – difficult to detect as they dart about – even have an air of mystery. "It's only our research methods that allow us to make them visible for a moment." In his research, Peter studies how environmental changes affect fish habitats and how engineered rivers can be restored to a near-natural state. "In recent years, a lot of surface waters have been rehabilitated in Switzerland, but because of the dense settlement patterns there's still a major need for action." Peter supports this process by advising federal and cantonal authorities. He tries to show his students not only the beauty of natural waters but also the problems they face: "Maybe they'll one day be in a position to make planning decisions affecting rivers and streams, so it's important to raise awareness early on."

Max Reutlinger

Training and nurturing young people

They arrive as children and leave as young adults: 26 apprentices are currently employed at Eawag in Dübendorf and Kastanienbaum. More than half of them are chemical lab technicians, and the remainder are biology lab technicians, administrators/secretaries or IT systems engineers. Max Reutlinger has been responsible for vocational training for almost 40 years. He joined Eawag as a chemistry graduate in 1972; at that time, just two people were being trained as chemistry lab technicians. "Originally," Reutlinger recalls, "I intended to stay for three years to set up a new training programme." But he found his work so enjoyable that he spent the rest of his career at Eawag. Over the last several decades, he has continuously developed the vocational training programme – the first of his many charges are now in their fifties. "Every year brings new people and new challenges – and that's what motivates me," he says. Supervising young people in this crucial stage of their development, opening doors and enhancing their prospects – for Reutlinger this was more than a mere job. He will be retiring in the summer of 2011: "Then I'll have more time for my second passion." He plans to map and cultivate orchids and to undertake conservation work in the Eigental protected area.

Complementary collaboration

Eawag has a strong commitment to the training of students and maintains close links with numerous Swiss higher education institutions. This gives rise to synergies and helps to promote interdisciplinarity. Teaching activities are largely based on the institute's own research.

Although Eawag operates primarily as a federal research institute within the ETH domain, it is also strongly committed to the training of students. In 2010, more than 20 per cent of Eawag's scientific staff had teaching responsibilities at universities, the Federal Institutes of Technology in Zurich (ETH) and Lausanne (EPFL), and universities of applied sciences.

Last year, a total of eight full professors worked at Eawag, including seven teaching at the ETH and EPFL. Eawag and the EPFL intensified their collaboration, with two new full professorships – the chair in Environmental Chemistry held by Eawag Director Janet Hering (who is also professor of Environmental Biogeochemistry at the ETH) and Urs von Gunten's chair in Drinking Water Treatment. Also in 2010, Kristin Schirmer, head of the Environmental Toxicology department, was appointed as an adjunct professor at the EPFL.

Variety of professorships

In addition, a number of Eawag staff hold professorships at cantonal universities: Mario Schirmer of the Water Resources and Drinking Water department is associate professor of Hydrogeology at the University of Neuchâtel. At the University of Berne, Eawag maintains a chair in partnership with the Institute of Ecology and Evolution; here, Ole Seehausen, head of the Fish Ecology and Evolution department, is a professor in the Aquatic Ecology division.

In recognition of his teaching services, Bernhard Truffer, head of the Innovation Research in Utility Sectors (Cirus) department, was recently appointed titular professor at the University of Berne. Another Cirus scientist with teaching responsibilities is Heiko Gebauer, who lectures in Technology Management at the University of St Gallen. At the University of Zurich, Hans-Joachim Mosler of the System Analysis, Integrated Assessment and Modelling (SIAM) department is professor of Social and Environmental Psychology.

Specialization

Characteristic of Eawag's teaching is the fact that it is largely based on the institute's own research, with a strong focus on interdisciplinarity and an integrated systems approach. This means that lecturers can communicate the latest scientific knowledge, while students learn within an environment of solution-oriented research carried out in Switzerland and abroad, competing at the global level.

In 2010, the total number of doctoral dissertations and Bachelor's and Master's theses supervised at Eawag rose by about a third compared with the previous year (153 dissertations, 142 Bachelor's and Master's theses). Most of these studies are carried out at Eawag, but the students are supervised in close partnership with their home institution. This type of collaboration permits complementary offerings: while the education institutions ensure that students receive basic training, Eawag provides opportunities to specialize.

Transfer to practice

One indication of the high quality of Eawag students' work – and training – is the fact that they regularly receive national and international awards. In 2010, for example, Linda Roberts and Natacha Pasche were both honoured for their doctoral dissertations, respectively receiving the Otto Jaag Water Protection Prize and the Hydrobiology-Limnology Award.

While PhD students at Eawag increasingly also come from universities abroad – about a fifth of the dissertations completed in 2010 involved cooperation with a non-Swiss institution – teaching is mainly carried out in partnership with Swiss institutions, some of which are based in French-speaking cantons. This broad network creates substantial synergies and helps to promote interdisciplinarity.

It also makes it possible for part of students' training, e. g. block courses or practicals, to be carried out at Eawag, strengthening the young scientists' ties with the institute. At the same time, Eawag's training activities are designed to encourage practitioners to adopt an integrated and problem-oriented approach. ○ ○ ○

Susi Lindig, ETH Zurich

Extensive network: Eawag collaborates closely with other higher education institutions.

www.eawag.ch/lehre

Analytical and communication skills

In the "Aquatic systems" practical, students learn the methodological and analytical tools of the scientific trade. In 2010, they investigated the effects of river restoration on the River Thur – and in the process even managed to attract the interest of the media.

How does science work, how do researchers proceed? For Bachelor's students of environmental sciences at the ETH Zurich, the "Aquatic systems" practical provides a hands-on lesson. As course organizer Bernhard Wehrli says, "The idea is that students should experience and learn the whole spectrum of scientific work in a real-life research project." Wehrli is professor of Aquatic Chemistry at the ETH and a group leader in the Surface Waters department at Eawag.

Public relations: an excursion organized by the students attracted considerable local interest.

Integrated approach

Last year's practical was conducted on a rehabilitated stretch of the River Thur at Frauenfeld as part of the Eawag "Restored corridor dynamics" (Record) project. Assisting Wehrli in supervising the students were scientists from three different Eawag departments – Water Resources and Drinking Water, Environmental Chemistry and Aquatic Ecology – as well as the ETH Zurich Institute of Biogeochemistry and Pollutant Dynamics. Wehrli explains: "We want to demonstrate to students the interdisciplinarity and integrated-systems approach which are the hallmarks of Eawag research."

The practical was designed to familiarize the 20-odd students with modern methods of sampling and of physical, chemical and biological analysis of an aquatic system. The aim was also, not least, to allow the participants to gain experience of teamwork.

For a total of around 30 days during the spring semester, the young scientists investigated the effects of the restoration measures on ground- and river water quality, ecological habitat improvements, or the impacts on the ecosystem of chemical pollutants from nearby wastewater treatment plants. Different working groups were each assigned one topic from the areas of environmental chemistry, microbiology, ecology or environmental physics.

The participants progressed through every step of a scientific research project: from the definition of a specific question, through sampling in the field, analysis in the laboratory, processing and evaluation of data, to the documentation, presentation and discussion of results. The various process steps were to be documented both individually, in field and lab journals, and as a group in the form of records and photographs. In an integration module at the end of the course, each group presented its work and findings to the other groups.

Press coverage

Lastly, Eawag Media Officer Andri Bryner explained to the young researchers how scientific subjects and findings can best be communicated to the public. Under his direction, the participants organized a public excursion and wrote two articles, which were in fact picked up by certain media outlets – for example, they were featured in a piece published by the NZZ newspaper.

The aspiring environmental scientists collecting samples on the River Thur.

Remarkably effective restoration

Compared to a channelized section, the roughly 700-metre-long rehabilitated stretch of the River Thur below Frauenfeld accommodates an above-average diversity of diatoms and insects. This was one of the findings of last year's "Aquatic systems" practical. In the restored stretch, for example, the students found 23 groups of insect larvae species – 50 per cent more than in the straightened section. These included a strikingly large number of stone flies, which are demanding in their habitat requirements. Even experienced researchers were surprised by these positive results.

www.ibp.ethz.ch/research/aquaticchemistry/teaching/Systempraktikum

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Practice-oriented training

Practice-oriented Eawag courses (PEAK) provide up-to-date knowledge based on aquatic research and promote a dialogue between theory and practice. In 2010, key topics covered at these training events included the behaviour of nanomaterials in the environment, drinking water quality in developing countries and methods for the analysis of groundwater.

Nanoparticles – frequently combined with metals – are found increasingly often in consumer products such as cleaning agents, clothes and medicines, or as a constituent of facade paints. However, knowledge of how these minute particles (measuring just a few millionths of a millimetre) behave in the environment, and of the associated risks, remains patchy and limited, even among specialists. For some years now, Eawag has collaborated with Empa and other partners in investigating a variety of questions relating to environmental issues raised by nanoparticles. In this research, Eawag can build on many years of experience in studying the chemistry and ecotoxicology of metals.

Exchanges among professionals

The aim of the advanced course on "Metals and synthetic metal nanoparticles in the aquatic environment" – held as part of the PEAK programme (see box) in 2010 – was to outline the current state of knowledge concerning the chemistry, ecotoxicology and analysis of metals and metal nanoparticles in aquatic systems. The latest findings of research carried out by Eawag and Empa were presented to – and discussed with – participants by Laura Sigg and Renata Behra of the Environmental Toxicology department and Ralf Kägi of the Process Engineering department.

Summing up what he had learned at the two-day event, one of the roughly 30 participants said: "Sound analytical methods provide the basis for risk assessment." The course was attended in particular by professionals from cantonal water protection agencies and laboratories, and from private analytical laboratories and environmental consultancies. One of the points to emerge from the course was how little is as yet known about nanoparticles. For example, as another participant noted, no analytical methods are currently available for use in a typical environmental laboratory.

The participants particularly appreciated the lively exchanges with fellow professionals, the presentation of specific case studies and data, and the way in which the event combined theoretical knowledge and practical application. They identified a general need for knowledge and further training especially with regard to analytical methods, risk assessment/management and the regulatory framework.

Course participants listen attentively to Ralf Kägi's explanations.

Identifying practical solutions

An advanced course with an international focus addressed the topic of "Improvement of drinking water quality in developing countries". This course was led by Annette Johnson of Water Resources and Drinking Water department and Rick Johnston of Sandec (Water and Sanitation in Developing Countries). Both of these Eawag research departments have studied the problem of microbial and geogenic contamination of groundwater wells. In addition to poor sanitation, contamination of drinking water with arsenic or fluoride is a significant cause of disease in various regions of Southeast Asia.

Improving the quality of drinking water from contaminated sources requires expertise and modern technologies which are available at Eawag – but not necessarily in the developing countries concerned. Accordingly, Eawag has teamed up with local partners to carry out research designed to investigate the extent of the problems and to develop solutions adapted to local needs and capabilities.

The course was designed for water and sanitation professionals who are active in these areas in developing and emerging countries. Issues and possible solutions were described and discussed in presentations and group work. In their feedback on the event, participants highlighted in particular the integrated approach adopted, as well as the motivated and expert course leadership.

Learning about effective methods

Another course organized by Eawag in 2010 dealt with "Modern analytical methods for groundwater management". In many parts of the world, groundwater is the main source of drinking water. Depending on climatic and

Practice-oriented Eawag courses (PEAK)

Practice-oriented Eawag courses (PEAK) are designed for specialists from industry, government and engineering or environmental consultancies. They provide up-to-date knowledge and promote exchanges among participants and between theory and practice. Each year, five to ten courses are held.

The PEAK programme was established in 1993 in order to make new insights and findings from Eawag research directly accessible to professionals, and at the same time to facilitate the sharing of experience. After the training and continuing education courses on "Chemical water analysis, interpretation of water quality" run by Eawag in the 1970s, PEAK – along with the postgraduate study programme and the postgraduate course on "Urban water management and water protection" – was the first systematic training programme offered by Eawag. The courses were also integrated as optional modules into the postgraduate study programme/postgraduate course.

Introductory courses provide the basic knowledge required to understand environmental problems and an up-to-date overview of the topic concerned. Advanced courses provide an overview of environmental problems with reference to specific examples and case studies. Applied courses teach practical methods for the detection, prevention and mitigation of specific environmental problems. The courses generally run for two to three days and comprise lectures, exercises and group work.

By the end of 2010, Eawag had organized 31 different advanced, 16 introductory and 28 applied courses, some of which had been held several times. Over the same period, in partnership with the Federal Institute of Technology Lausanne (EPFL) and the Institut de recherche en sciences et technologies pour l'environnement (Cemagref) in Lyon, it organized one or two ecotoxicology courses a year for water professionals – a programme which in 2008 was taken over by the newly established Ecotox Centre (see p. 44).

other local conditions, aquifer recharge may take anything from a few weeks to thousands of years. Contamination can thus have more or less rapid effects on water supplies, and remediation can be a difficult and lengthy process.

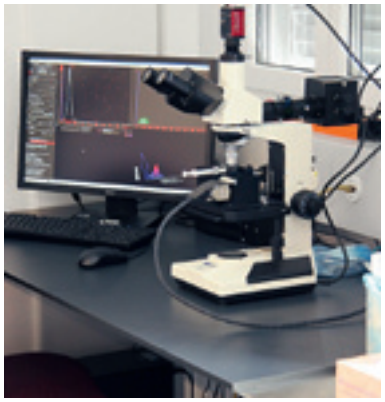
Effective analytical methods are therefore of great practical importance, particularly in assessing contamination of groundwater layers. Use of these methods is an important cost factor and requires careful planning. In their presentation, Eduard Hoehn and Mario Schirmer of the Water Resources and Drinking Water department cited the River Thur restoration project at Niederneunforn (Canton Thurgau) to illustrate the potential of time series analysis and the "direct push" method. The latter involves the use of rods driven into the ground to enable rapid and cost-effective deployment of sampling tools or monitoring probes.

The participants learned how groundwater characteristics can be inferred from time series for temperature and electrical conductivity. In addition, they were shown how water and contaminant pathways can be traced by means of isotope analysis.

Well-attended event: the course on nanoparticles in the aquatic environment attracted a lot of interest.

Well-established courses

As well as the three events described above, the PEAK programme in 2010 once again included courses on "Electrofishing for trainers" and "Environmental chemical analysis". Eawag is the only institution in Switzerland with the relevant expertise in the electrofishing area, while environmental chemical analysis is a dynamic field with a considerable demand for knowledge transfer. Another well-established – and extremely popular – course organized by Eawag again last year is "Fish in Swiss waters", which provides an introduction to the biology and ecology of indigenous fish fauna. ○ ○ ○



Analytical methods for nanoparticles are presented.

www.eawag.ch/lehre/peak

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Broadening horizons

At Eawag Summer Schools, young scientists have an opportunity to interact with leading researchers. Peter Reichert, a member of the Eawag Directorate, emphasizes the international flavour and specialist training function of these events.

How does a Summer School differ from normal teaching activities at universities?

In many ways, a Summer School is comparable to a block course at a higher education institution, comprising lectures, workshops, exercises and practicals. The main differences are that a Summer School generally involves a broad range of lecturers with an international profile, and that it is also open to participants from abroad. These international exchanges are an essential additional element of Summer Schools. Also, they take place during lecture-free vacation periods.

What is the idea behind the Eawag Summer Schools?

Extensive dialogue between the invited scientists and the international group of participants during a Summer School should help to broaden horizons and can even contribute specifically to new research ideas. In addition, there are opportunities for Eawag staff to have contacts and intensive exchanges with invited researchers. In particular, the guest instructors can combine their visit with a longer stay for research collaboration. Another benefit for Eawag is the training provided for doctoral students. Lastly, Summer Schools also help to enhance Eawag's visibility in the fields concerned.

Who are these events designed for?

Eawag Summer Schools are primarily targeted at doctoral students. In fact, because one of last year's two events at Kastanienbaum was co-funded by a Swiss National Science Foundation PhD programme, participation was essentially restricted to doctoral students. However, the other Summer School at Kastanienbaum and the one held at Dübendorf were open to anyone who was interested. The selection process was based on the applicants' CV and references, and on the personal benefit to be expected, according to the letter of motivation. For the Summer School at Dübendorf, attention was also paid to balancing internal and external participants. This means that the internal participants can undergo training in an international environment.

What framework is specified for Summer Schools at Eawag?

Eawag doesn't have any rigid specifications – the organizers can largely define the framework themselves. Key criteria include the availability of faculty and the scope of the topic chosen. In 2010, for example, given the importance of the practical component, one of the Summer Schools at Kastanienbaum ran for two weeks, while the others were limited to five to seven days.

Invited lecturer Katie Peichel of the Fred Hutchinson Cancer Research Center (Seattle) observing sticklebacks during the speciation course.

A PhD student from the Universidad de Granada (Spain) presenting a poster on speciation in plants.

Are the same courses held on a regular basis?

The Summer School on "Environmental systems analysis" at Dübendorf has already been held twice and will be taking place again in 2011. As these Summer Schools have less to do with Eawag's mandate as such and more with the training of specialists in Switzerland, the organizers have greater freedom. Certainly, one major criterion for organizing a Summer School is the additional benefits expected for Eawag, which I mentioned earlier. Depending on the specific topic, the external faculty available and internal training requirements, these additional benefits may vary over time. For this reason, it's not a good idea to make a long-term commitment to offer courses on a regular basis.

How are Eawag Summer Schools funded?

In 2010, the direct costs of the Kastanienbaum Summer Schools were largely funded through the Swiss National Science Foundation PhD programme and the "Frontiers of Speciation Research" networking programme of the European Science Foundation. The Dübendorf event was covered by the participants' fees. In all cases, remuneration for faculty was provided by Eawag and the external lecturers' home institutions.

Peter Reichert is head of the Systems Analysis, Integrated Assessment and Modelling department of Eawag and Titular Professor in the Department of Environmental Sciences at the ETH Zurich. As a member of the Directorate, he is responsible for training at Eawag.

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Course participants collecting samples on Lake Lucerne during the Summer School on pollutant dynamics and biogeochemistry in lakes.

Varied programme

In 2010, three Summer Schools were held at Eawag. The "Environmental systems analysis" event run by Peter Reichert, head of Systems Analysis, Integrated Assessment and Modelling, was concerned with model-based data analysis in the environmental sciences. In research, mathematical models are of major importance in testing hypotheses, summarizing and communicating knowledge and making predictions. This course provided an overview of systems analysis techniques relevant for model-based data analysis and allowed participants to gain initial experience in applying these techniques in practice. In addition, participants received advice on analysing their own data sets. Most of the roughly 35 participants were PhD students, with a few more experienced researchers and practitioners.

The "Methods of empirical speciation research" event run by Ole Seehausen, head of the Fish Ecology and Evolution department, dealt with the development of new species. The participants were introduced to major classical and new concepts in speciation research, and given an overview of modern methods, especially the integration of population genomics. In addition, interdisciplinary approaches were discussed. The event also provided opportunities to interact with leading researchers in the field. The course was addressed to PhD students, postdocs and exceptionally well-qualified and motivated Master's students. Altogether, 25 applicants were selected.

The Summer School on "Understanding and modelling pollutant dynamics and biogeochemistry in lakes" was run by Bernhard Wehrli of the Surface Waters department. The 20-odd participants were introduced to quantitative approaches for analysing and predicting the fate and behaviour of organic chemicals and key biogeochemical components in lake systems. During the course, participants were also able to discuss their own data analysis and modelling needs. This event was likewise primarily intended for PhD students and outstanding Master's students. ○ ○ ○

www.eawag.ch/lehre/schools

Learning life and work skills in the forest

As well as job-related capabilities, vocational training at Eawag aims to foster apprentices' social and personal skills. For young people entering today's job market, good communication skills and the ability to reflect on one's behaviour are key assets.

In Switzerland, around two thirds of all school leavers undergo basic vocational education and training (VET) in what is known as the dual system. Apprenticeship is thus the most important form of initial training. The training of apprentices has been formally included in Eawag's mission since 1997. This means that the institute is committed to playing an active part within the Swiss education and training system.

First and foremost, Eawag trains laboratory technicians in the fields of biology and chemistry. In addition, as far as possible, the institute offers apprenticeships in the secretarial/administration area and in IT. The places are generally filled by young people from the Zurich region. In 2010/2011, Eawag is hosting a total of 27 apprentices (see the table opposite).

In-house teaching laboratory

With the introduction of various new training ordinances over the last few years, VET in Switzerland has been placed on a new footing. The aim of modern VET is to enhance the employability of young people who have completed an apprenticeship. For this reason, VET is no longer rigidly regulated. Instead, the new training ordinances and plans merely set the framework within which individual trade and industry associations can elaborate the relevant content in line with the needs of today's job market. The cantons are responsible for planning and implementation, and organize the qualification procedures leading to the award of Federal Certificates of Proficiency (EFZ).

A typical apprenticeship in this country involves both training at a host company and education at a vocational school; apprentices may also attend cantonal industry courses to learn additional practical skills. Because Eawag provides high-quality basic training for chemistry lab technicians at its own teaching laboratory in Dübendorf – where apprentices from the Federal Materials Science and Technology Research Institute (Empa) are also trained – its apprentices are not required to attend the cantonal industry courses.

As well as ensuring that apprentices learn the usual practical skills and capabilities and theoretical (subject-specific and general) knowledge, Eawag's vocational training focuses in particular on developing the key competencies required for working life. This means that Eawag apprenticeships offer young people a training ground where they can acquire and apply the necessary skills in real-life, workplace-type situations.

Vocational training starts with a forest project week in Bergün designed to build team and social skills.

Formative influence of trainers

In contrast to earlier practice, vocational training now places greater emphasis on the development of social and personal skills. The ability to reflect on one's own behaviour and to draw conclusions accordingly enables apprentices to act appropriately in new situations. A key role in this process is played by the trainers, who walk apprentices through the various aspects of everyday working life. The extent to which apprentices' development is influenced by trainers' values and attitudes should not be underestimated. In today's globalized working environment, team skills are another fundamental requirement, calling for an ability to communicate as well as the capacity to deal with job pressures and conflicts.

In order to foster social skills and personal development, Eawag organizes a variety of camps for its apprentices. The young people begin this new phase of their life and education by taking part in a project week in Bergün, run by the Bildungswerkstatt Bergwald (mountain forest workshop). Here, the unusual conditions in which they find themselves encourage them to integrate into the

Apprentices at Eawag (2010/2011)

Occupation	1st year	2nd year	3rd year
Biology laboratory technician (EFZ)	1	1	1
Chemistry laboratory technician (EFZ)	6	6	7
IT systems engineer	1	–	1
Administrator/secretary	1	1	1
Total	9	8	10

group and to learn how to achieve various goals through teamwork. In addition to outdoor activities, they tackle the subject of learning itself under the guidance of a professional learning coach.

Subsequent camps are mainly organized and designed by the apprentices themselves. In general, a week is set aside for a selected topic, which the participants explore in detail, individually or in groups – giving presentations, taking part in discussions and learning how to develop an argument.

Training ground for working life: acquiring new knowledge and developing solutions as a group.

Insight into various areas

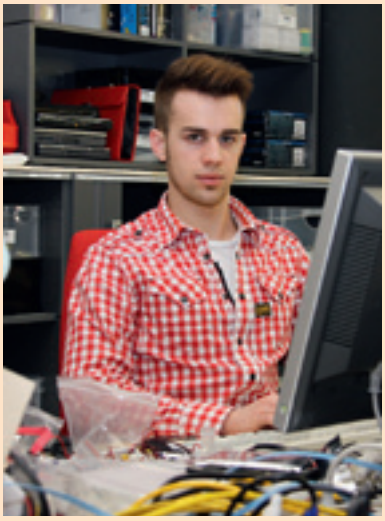
What form does on-the-job training take at Eawag? Apprentices spend three to six months in one placement before moving on to a different working group or department. Training is thus broad in scope, offering an insight into a wide variety of areas. The practical activities and schooling are supplemented and reinforced by more theoretical internal courses.

In the case of laboratory technicians, Eawag also works with a number of external training partners. Here, apprentices can acquire practical knowledge and skills in an everyday commercial environment.

As Eawag actively supports lifelong learning, apprentices are encouraged by their trainers to also take the vocational baccalaureate – a qualification which allows them to pursue their studies at a university of applied sciences.

Accolade for dissertation

In 2010, a dissertation written by Raphael Rietmann at Eawag was selected by the Swiss ICT Vocational Training Association as one of the top ten papers in the systems engineering field. The aim of the project – entitled "Implementation and integration of an Edge Transport Server in an Exchange 2007 organization" – was, using various anti-spam filters and transport rules, to separate junk mail from legitimate messages and ensure that the latter are correctly delivered.



"We're proud that our apprentices are so committed and eager to learn," says Bouziane Outiti, who is responsible for vocational training in IT at Eawag. "This level of commitment means that the apprenticeship provides major benefits for the employer as well as the apprentice."

Having successfully completed his training, Raphael Rietmann was employed by Eawag as an IT specialist (responsible for network-based software distribution) until he began his military service. When he has served his time in the army, he plans to study at a higher vocational education college (HF).

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Research
Teaching
Consulting

Sound consulting is based on research excellence. To facilitate the transfer of expertise to the practical sphere, Eawag establishes points of contact within the institute for professionals from the public and private sector. In September 2010, the Competence Centre for Drinking Water commenced operations at Eawag. The CCDW, offering a platform for research in the field of drinking water, will provide support for authorities, water suppliers and other partners.

One example is the provision of scientific advice for the two Basel cantons on drinking water treatment in the Hardwald area. However, Eawag also seeks to cooperate with authorities at the national level. In the Integrated River Management project, the findings of research carried out for the federal and cantonal authorities were presented to stakeholders at a conference organized jointly with the Federal Office for the Environment. In the “KoMet” project, combined modelling and measurement methods were developed to identify transformation products of pesticides, biocides and pharmaceuticals which are of relevance for water resources on account of their concentrations and effects. With projects of this kind, Eawag makes a significant contribution to the implementation of water protection in Switzerland.

Hansruedi Siegrist

Research and consulting go hand in hand

"After a while," says Hansruedi Siegrist, "you don't find it disgusting any more." He is talking about municipal wastewater – his main research interest. "But my friends do sometimes look askance when I tell them about my work over dinner." Siegrist, a chemist and engineer by training, is interested in the processes which occur during wastewater treatment. When he joined Eawag 30 years ago, the main concern was to remove nutrients from wastewater. Anthropogenic micropollutants came later. In addition to his research activities, Siegrist is frequently engaged as an expert to assess systems and processes for wastewater treatment plants, engineering firms and authorities. Conversely, consulting projects have also opened up new research areas. Recently, for example, a treatment plant operator enquired whether it would be possible for nitrogen in wastewater to be processed into a fertilizer, rather than being degraded by microorganisms. "We're working on that at the moment," says Siegrist. In particular, he appreciates the contacts with a variety of actors which his work involves: "Wastewater research is interdisciplinary – that's always fascinated me."

Inge Werner

Protecting the environment

When is a chemical substance toxic? "That's not a trivial question," says biologist Inge Werner. "How can I tell whether a fish is being poisoned?" As head of the Ecotox Centre, she develops methods for measuring, assessing and reducing the toxicity of chemicals. "It's too easy," she says, "if you only take into account the death of an organism." You can also judge how toxic a substance is by looking at whether an animal's internal organs are damaged or how successfully the species reproduces. Together with her 14 employees, she is therefore developing methods of determining the environmental effects of pollutants. They range from analyses of algae or midges to tests at the cellular level. These services are used in particular by federal and cantonal authorities. Also in demand are expert reports on specific questions, such as the treatment of wastewater and landfill leachate. In addition, the centre organizes ecotoxicology courses for water professionals. Werner's interest in ecotoxicology and water pollution control goes back a long way: as a bilingual secretary, she decided to take a second degree in this field "because the environment needs to be protected from humans."

Alfred Wüest

Science isn't an end in itself

"I feel a certain obligation to make my knowledge available to society," says Alfred Wüest. Rather than pursuing science for its own sake, he wants to help preserve natural waters: "My work deals with the balance between protection and use of water resources." A particle physicist by training, Wüest now produces expert reports for cantonal environment agencies, hydropower plant operators or organizations abroad. His biggest project to date was concerned with Lake Brienz: "Around ten years ago, fishermen noticed that the fish in the lake were hardly growing at all." On investigation, it rapidly became clear that nutrient concentrations in the lake are now much lower than in the past, and that water fleas – the favourite food source for fish – have almost died out as a result. Wüest and his colleagues discovered that wastewater treatment plants are no longer discharging more phosphates into the lake than are retained by the Grimsel dams. "The lake thus returned, as it were, to its natural state." Lake Brienz had in fact originally been oligotrophic – nutrient levels only rose as a result of human activities in the 20th century. "But most people didn't know what the lake had been like 100 years earlier," says Wüest. He therefore also sees a need to promote the cause of natural waters. "However, we don't tell our partners what to do – we provide a basis for decision-making."

Safe drinking water for all

With scientific findings, training and advocacy, Eawag is seeking to persuade even more people in developing countries to use the Sodis method – a simple way of purifying drinking water. It is also developing a special bag for use in disaster areas.

About 20 years ago, Eawag developed a method of preparing safe drinking water known as Sodis (solar water disinfection). This simple, low-cost method allows people, especially in developing countries, to treat their own water and thus protect themselves from diseases: if contaminated water is exposed to the sun for six hours in transparent PET or glass bottles, pathogens which can cause diarrhoea are killed by the sun's ultraviolet radiation.

Advocacy campaigns

For over ten years, Eawag has been involved in efforts to disseminate the method in Africa, Asia and Latin America. The Sodis Reference Centre (part of Sandec) collaborates with local partners in promoting the method in areas where people suffer as a result of poor water quality. Worldwide, it is already being used by more than five million people. But given that 900 million people still lack access to safe drinking water, much work remains to be done.

Water purified on a roof: the Sodis method is used in a slum area of Yaoundé (Cameroon).

"Our children are healthier"

Nalishebo Kwibisa (39) lives with her husband and four children in the village of Kaeya in western Zambia. The village lacks a water supply system, and the water in the unprotected waterhole is contaminated. The nearest well supplying safe drinking water is more than an hour away. "It's too far to go to collect water," says Kwibisa. "But our children often used to suffer from diarrhoea because of the unsafe water."

She first heard about the Sodis method from the community health advisor. Last April, she and her neighbours took a course on how to apply the method and improve hygiene. "At first," Kwibisa admits, "I was sceptical. But when I saw that the health advisor also uses Sodis to treat her own water, that convinced me." She started using this method to disinfect her drinking water every day. "Since then, our children have been healthier, which is a great relief for us."

As well as the provision of practical training for families at household level, activities are focused on advocacy at government level. Additional training can be provided via state-run institutions, such as schools or health centres. According to Regula Meierhofer, head of Sodis, "These channels are inexpensive and can reach large numbers of people over the long term." But, she adds, if governments are to be persuaded of the effectiveness of the method, scientific studies are needed as well as pilot projects.

Bags instead of bottles

In laboratory experiments and field tests, Eawag microbiologists have demonstrated that the method reliably inactivates pathogenic microorganisms. Several health studies have investigated whether it can also in fact prevent diarrhoeal diseases. In slum areas of Yaoundé (Cameroon), Eawag researchers compared the incidence of diarrhoea among children from families using Sodis to treat their drinking water and among children drinking untreated water. They found that diarrhoea occurred approximately 40 per cent less frequently in children from Sodis-using families.

The study findings are supported by reports of personal experience: children of Sodis users more rarely suffer from diarrhoea and can attend school more regularly (see box). In addition, families spend less on medicines used to treat diarrhoea.

Social psychologists are currently investigating whether, and if so why, people continue to use the method consistently after the end of a project. The findings of this research will be fed directly into other projects.

For use in disaster areas or in regions where PET bottles are in short supply, Eawag scientists are also developing a Sodis bag, which is to be handled in the same way as the bottles. This could be transported rapidly and cheaply. In designing the plastic bag, consideration has to be given not only to technical aspects but also to local needs and circumstances.

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Fish and anglers under pressure

Efforts to promote renewable energy should not be detrimental to natural waters or fish – this was the conclusion of a conference organized by the Fishery Advice Centre (Fiber). Another issue hotly debated at this event was the new Animal Protection Ordinance.

Since January 2009, small hydropower plants in Switzerland have benefited from "cost-covering remuneration for feed-in to the grid", a system designed to provide federal financial support for renewable energy sources. With the introduction of this scheme, less weight has been attached to impacts on ecosystems and the species within them – especially fish – than to climate protection goals.

Moderate use

This was one of the issues discussed at a seminar entitled "Fish and anglers under pressure", held at Olten in 2010 by the Fishery Advice Centre (Fiber) and the Swiss Fishing Federation (SFV). In a series of talks, various aspects of small-scale hydropower generation were highlighted by plant operators, fish ecologists, conservationists and government officials.

As a result of the new financing regulations, more than 700 planning applications for new plants have already been submitted to cantonal authorities. Of the rivers concerned, around 190 are as-yet unharnessed. At the seminar, Sabine Zeller of the Federal Office for the Environment (FOEN) presented an aid to enforcement designed to support cantonal decision-making. She recommended that cantonal authorities develop a strategy for the management of hydropower generation which weighs up competing use and protection interests, identifying where reasonable and moderate use is possible and where priority should be accorded to protection.

In the subsequent discussion, numerous critical views were expressed – particularly with regard to applications for plants on intact rivers and in areas worthy of protection. It once again became apparent that constructive cooperation between plant builders, environmental and fishing associations is essential for sustainable projects.

Appropriate protection?

The second controversial issue explored at the seminar was the new Animal Protection Ordinance (which came into force in 2008) and its effects on angling. From the perspective of most anglers, the new legislation is not fit for practical application – but animal protection activists take a different view. Rolf Frischknecht of the Federal Veterinary Office explained the background to the development of the new legislation.

In Frischknecht's view, the angling sector will continue to face pressure from animal welfare organizations. He argued that, by introducing appropriate controls, cantons and fishing associations could take the wind out of the sails of extreme groups. He emphasized that, in most cases, animal protection problems would be associated with non-club anglers who do not have a fishing licence.

In the discussion, critics pointed out the inconsistent approach taken by cantons to the ban on barbed hooks: while some cantons exercise their power to permit the use of barbed hooks for angling in certain cases, others do not, which gives rise to uncertainties. ○○○

Full house: around 100 people attended the Fiber seminar in Olten.

Fiber – the Fishery Advice Centre

Established in mid-2004, the Swiss Fishery Advice Centre at Kastanienbaum (Canton Lucerne) is jointly run by Eawag, the Federal Office for the Environment (FOEN) and the Swiss Fishing Federation (SFV). Its main task is to keep the fishing sector informed about the latest scientific findings on aquatic ecology, fish biology and fishery management. Since the end of 2009, Fiber has been led by fish biologist Jean-Martin Fierz (30), who is a keen angler.

Fiber was a product of the "Fischnetz" research project, which investigated the causes of declining fish yields in Switzerland and proposed various remedial measures.

The centre – which regularly answers queries from fishermen, cantonal and communal agencies, and environmental consultancies – offers expert advice in the field or in project work. In 2010, for example, Fiber was responsible for the tagging of 10,000 salmon as part of the Salmon 2020 recolonization programme. Fiber also provides information materials, issues a newsletter, and organizes seminars and presentations for fishery associations and other interested parties.

www.fischereiberatung.ch

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Reducing wastewater treatment costs and energy consumption

While Switzerland's wastewater treatment plants are of a high technical standard, the elimination of nutrients remains costly and energy-intensive. A refined biological process can now simplify the removal of nitrogen from sludge digester liquor, reducing costs by 50 per cent for this treatment step.

Wastewater treatment plants (WWTPs) must be capable of converting toxic ammonium (NH_4^+) to harmless nitrogen gas. The conventional method involves two steps – nitrification and denitrification. The first step requires large amounts of oxygen and the second requires the addition of organic carbon from the wastewater. In the absence of sufficient (or any) organic carbon – as in the case of anaerobic sludge digester liquor – an artificial carbon source, such as methanol, is needed.

Harnessing bacterial colonies

Around 15 years ago, two teams of Eawag and Dutch scientists discovered a process known as anaerobic ammonium oxidation, or anammox. Anammox bacteria can convert ammonium to nitrogen gas without the need for carbon. To initiate the process, part of the ammonium first has to be oxidized with oxygen to nitrite (NO_2) (partial nitritation). With this nitrite, the bacteria then oxidize the remaining ammonium, under anaerobic conditions, to molecular nitrogen.

Previously, the two phases of this process have been segregated. However, two-step systems require more space, and process regulation is more complex. The breakthrough came when it was realized that the conversion process can also be implemented in a single step: aerobic ammonium oxidation takes place on the outer layer of sludge flocs (barely a millimetre in diameter), consisting of bacterial colonies, while the anaerobic anammox reaction takes place in the anoxic inner part of the flocs.

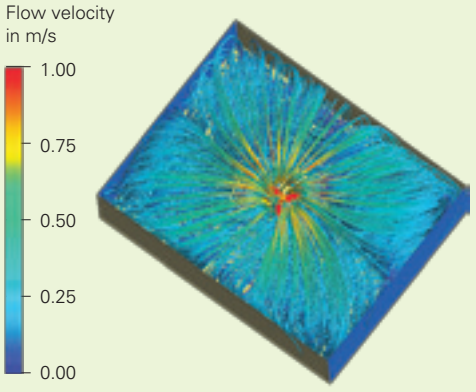
Compared to conventional nitrification/denitrification, nitrogen removal from digester liquor with anammox bacteria offers significant advantages: in particular, the oxygen requirement is more than halved (i. e. less aeration is required), and an external carbon source is no longer needed (see figure). This reduces energy consumption and operating expenses, leading to costs of around CHF 2 instead of CHF 4 per kilogram of nitrogen removed. In the case of the Zurich Werdhölzli plant, this amounts to annual

Anammox pilot reactor at the Eawag testing facility.

Process optimization with computational fluid dynamics

WWTPs represent a substantial investment, and existing plants cannot readily be converted without major expenditures. But in many cases, improvements can be achieved through operational adjustments, without any need for new installations. For example, Eawag engineers, together with private-sector partners, were able to improve flow and mixing conditions in reactors used in the biological treatment step with the aid of computer models.

At the Zurich Werdhölzli plant, support was to be provided for the switchover from a conventional to an intermittent-feed, intermittent-discharge sequencing batch reactor system. What was to be defined in particular was how an opening between two tanks could best be arranged, and whether mixing could be improved by a modified set-up or new operating modes for the aeration and stirring systems. The simulation ultimately identified the optimal position and size for the opening, but it also showed that even the optimized reactor is not completely mixed in any phase of operation. Based on these results, it was then possible to determine the best sites for the oxygen sensors and the addition of precipitants for phosphorus elimination, and to draw conclusions for future control concepts.



Modelled flow velocities in an aeration tank.

savings of approximately CHF 500,000. In addition, the process is highly efficient: more than 90 per cent of the ammonium in the process water is converted to nitrogen, relieving pressure on the plant.

Consequently, more organic substances – depending on the plant, possibly even additional material – can be added to the digestion mixture, so that the WWTP produces more biogas. This moves us closer towards one of the long-term objectives of all wastewater professionals – that WWTPs should become net producers rather than consumers of energy, or at least operate without an external power supply.

Switzerland: a leader

Because the anammox process is superior to conventional nitrification/denitrification in terms of space and costs, it may offer an alternative to the expansion of a WWTP, or allow planned expansions to be deferred. The process has already been adopted by six Swiss WWTPs, including major plants like those at Zurich Werdhölzli or St Gallen. Additional systems are planned. Switzerland is regarded as a leader in this field – thanks not least to the support and consulting services provided by Eawag.

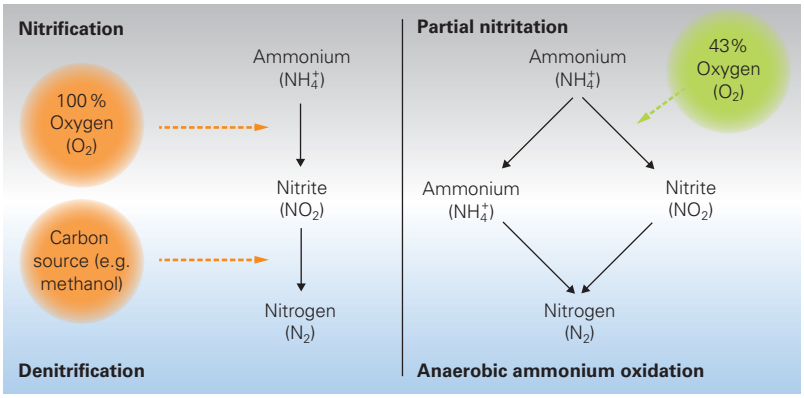
Experience with the development of wastewater treatment has shown that it often takes years to achieve stable operation of new processes in practice. Even in the case of the activated sludge process, developed before 1920, there still seems to be some room for optimization. Not surprisingly, therefore, the anammox process for nitrogen removal – which has only been operating on a large scale for five years – is still capable of improvement. For example, Eawag studies at the Werdhölzli plant showed that performance sometimes decreases by up to 50 per cent. The researchers suspect that ammonium oxidation is impaired by toxic substances in the liquor, so that too much oxygen remains for the anaerobic anammox bacteria in the second step of the process.

At present, the anammox method is mainly used for the treatment of process water at municipal WWTPs and in certain industrial processes. However, this does not exhaust the potential applications. But it remains doubtful whether anammox-based processes will in future be widely used to remove nitrogen from municipal wastewater. Here – in contrast to sludge digester liquor – the establishment of stable colonies of anammox bacteria is hampered by lower temperatures, lower ammonium concentrations and considerably higher organic loads.

Nitrite electrode under development

Process stability could be enhanced if – through improved control strategies – aeration could be more effectively coupled to fluctuating oxygen demand. To this end, private-sector partners of Eawag are currently developing a nitrite ion-selective electrode which can detect when ammonium oxidation exceeds the anammox rate. However, such an electrode would have to meet exacting demands: as little as a milligram of nitrite nitrogen per litre has to be detected in sludge – with loads of up to 100 milligrams of nitrate nitrogen. As well as using sensor technology, process control is also to be improved through a better understanding of sludge floc structure and of competition between the microorganisms concerned.

In all the Swiss anammox systems, biomass is present in the reactor in the form of suspended flocs, and the sludge looks very similar to activated sludge. By contrast, scientists at Delft University of Technology (Netherlands) and Ghent University (Belgium) are testing the same process in reactors with higher turbulence and lower hydraulic retention times. This leads to much more compact and coarser sludge particles or granules. The improved sedimentation properties and higher density of this granular sludge are advantageous, as they permit higher conversion rates. ○○○



Conventional conversion of ammonium to nitrogen gas (left) requires more oxygen and the addition of carbon. By contrast, conversion via the anammox process (right) reduces the oxygen requirement by more than half and does not require carbon.

www.eawag.ch/forschung/eng

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Replenishing oxygen supplies

To counteract excessive phosphorus levels, various Swiss lakes are aerated, i. e. artificially supplied with oxygen. According to an Eawag evaluation of two lakes in Canton Zurich, additional reductions in phosphorus levels, rather than aeration, are needed to further improve the condition of Lake Türler and Lake Pfäffikon.

From the 1950s onwards, excessive inputs of phosphorus from municipal wastewater and agricultural runoff led to eutrophication of many lakes in Switzerland. Inputs only started to decline again in the 1980s, with the construction of wastewater treatment plants and the introduction of a ban on phosphates in detergents. In many cases, there was a need to counteract the deep-water oxygen depletion which resulted from the eutrophication of lakes. Certain waterbodies therefore began to receive artificial supplies of oxygen. In Canton Zurich, for example, winter aeration has been successfully applied in Lake Türler since 1987, and in Lake Pfäffikon since 1992. An evaluation conducted by Eawag suggests that the condition of these two lakes could now be improved in particular by further reducing phosphorus levels, rather than by aeration.

Oxygen exhausted in the summer

Artificial mixing systems were originally installed to permit regular deep mixing of the two lakes in the winter and to increase oxygen uptake in the deep layers. Each year, from November to April, these systems release air bubbles above the lake bed, thus maintaining water convection down to the deepest layers. "As a result of this complete mixing, deep-water oxygen concentrations in both lakes rise in the winter to over 10 grams per cubic metre," says Alfred Wüest of the Surface Waters department, who carried out the study together with Eawag colleagues on behalf of the Canton Zurich Office for Waste, Water, Energy and Air (AWEL). Artificial mixing in the winter increases the habitat available for fish.

However, the artificial mixing system is not operated in the summer, so that the naturally occurring thermal stratification is not affected. With thermal stratification, lighter surface water heated by sunlight overlies the colder, heavier deep water layer. Mixing only occurs in water layers close to the surface. In the late summer, oxygen in the deep waters is exhausted and they are no longer accessible to fish.

High nutrient concentrations, e. g. due to runoff of agricultural fertilizers, lead to strong algal growth in lakes. When the algae subsequently die, a large proportion sink to the lake bed, where the biomass is degraded by microorganisms. Because the decomposition process requires large amounts of oxygen, severe oxygen depletion is common in the deep waters of eutrophic lakes with algal blooms.

Nonetheless, according to Wüest, oxygen levels have recovered dramatically in Lakes Türler and Pfäffikon – although this is due not only to artificial mixing measures but also to marked reductions in phosphorus pollution. In both lakes, phosphorus concentrations have fallen sharply since the mid-1970s: Lake Türler now has concentrations of 16 milligrams per cubic metre (mg/m^3), compared to more than 200 mg/m^3 previously, while Lake Pfäffikon has concentrations of 20 mg/m^3, compared to more than 100 mg/m^3 in the past. When phosphorus levels are so high, lakes are "hypertrophic" – inhospitable environments, almost devoid of life in the deep waters.

Nutrient-rich Lake Zug

With mean phosphorus concentrations of 85 mg/m^3, Lake Zug is one of Switzerland's most eutrophic waterbodies. In addition, as the hydrological residence time is around 15 years, nutrient removal is very slow. As part of a phosphorus reduction project, Alfred Wüest and Beat Müller of the Surface Waters department have reviewed earlier predictions concerning the time frame for reductions. In 1994, an Eawag study concluded that the target phosphorus concentration of 40 mg/m^3 specified by the Scientific Steering Committee for the Remediation of Lake Zug could be achieved by 2040. According to Wüest's latest calculations, if current trends continue, Lake Zug will still contain around 160 tonnes of phosphorus in 30 years' time, which is equivalent to a concentration of approx. 50 mg/m^3 – i. e. the goal for a mesotrophic lake will not be met. However, as Wüest emphasizes, phosphorus inputs could be markedly reduced as a result of new developments in agriculture. He recommends that a re-evaluation should be carried out in 15 years' time.

The artificial mixing system in Lake Türler leads to complete mixing and increases deep-water oxygen levels.

Aeration system not to be replaced

As Wüest emphasizes, "If inputs of phosphorus were further reduced in both lakes, oxic deep water could be maintained throughout the year without artificial mixing." In addition, the occurrence of complete mixing every winter does not, in fact, reflect natural conditions in either of the lakes. In Lake Pfäffikon, for example, a complete "overturn" only used to occur on average about every two years. Lake Türler probably only underwent complete mixing in the winter every few decades.

However, according to Wüest, phosphorus concentrations in Lake Türler would need to be reduced by another 50 per cent in order to achieve a positive oxygen level throughout the year. But in Lake Pfäffikon, Wüest believes, the target level has almost been reached.

Because artificial mixing is no longer essential for these two lakes, AWEL does not plan to replace the ageing aeration system in Lake Pfäffikon. It was used for the last time in the winter of 2010. In both lakes, however, artificial mixing measures have helped to control nutrient accumulation in the deep waters, leading to a lower nutrient (mesotrophic) status.

Restricted whitefish habitat

To avoid fish kills, Canton Zurich has also aerated part of Lake Greifen since 2009. Here, during the warm summer months, the habitat of whitefish in particular is often restricted to a layer of water less than a metre in depth. Above this layer, the water is too warm (over 21 °C), while the cooler deep waters below are anoxic due to algal growth from the midsummer. Although phosphorus concentrations have decreased over the last 20 years from around 120 mg/m^3 to 40 mg/m^3, the lake remains nutrient-rich (eutrophic).

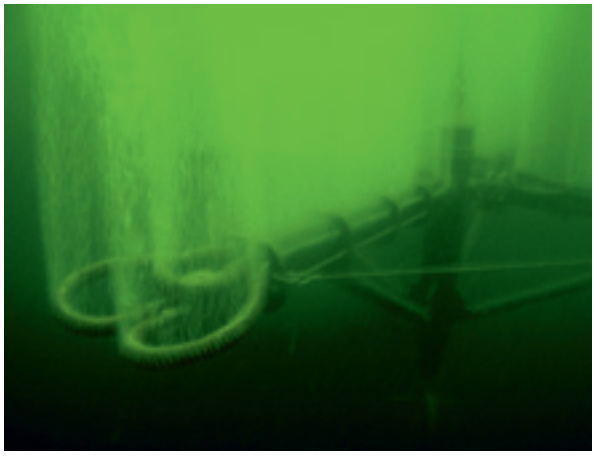
During the summer, a diffusor system was used to oxygenate the critical transition zone (metaliminion) between the warm surface layer and the anoxic deep waters at a depth of five to ten metres, over an area of about a square kilometre. With this system, around 26 tonnes of oxygen were released into Lake Greifen from the end of May to the beginning of October.

AWEL

Assembly of the diffusion system which is to supply Lake Greifen with oxygen.

Alfred Wüest was requested by AWEL to assess the effectiveness of the system after one year. His conclusions are mixed: the amount of oxygen injected did not satisfactorily offset oxygen consumption. "The oxygen supplied was only effective in August and largely ineffective before mid-July and after the beginning of September," says Wüest. In addition, operation of the diffusors warms up the metalimnion. He recommends that, if the system is to remain in use, it should only be operated from mid-July to the beginning of September, and with a higher oxygen input. The system did, however, offer one advantage: in the midsummer, as observations showed, the diffusors were used by whitefish as a refuge. ○ ○ ○

AWEL



In 2009, diffusors released around 26 tonnes of oxygen into Lake Greifen.

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Bioassays: a promising approach

Toxicity tests involving cell lines or whole organisms are suitable for assessing the efficiency of a wastewater treatment plant in eliminating micropollutants. According to studies carried out by the Ecotox Centre, the ecotoxicity of both individual substances and mixtures can be evaluated with routine application of bioassays.

Effective wastewater treatment should produce effluent of high quality. To monitor the removal of harmful substances, chemical analysis is normally used, although the use of cell lines or test organisms to detect substances and evaluate their ecotoxicity offers numerous advantages. For example, bioassays make it possible to assess the toxic effects of mixtures and not merely of individual substances, as with chemical analysis. Indeed, bioassays involving whole organisms capture the effects of all the substances present in a water sample – i. e. chemicals and nutrients. In addition, a single specific bioassay can be used to test a wide variety of individual substances with the same mode of action.

As part of the FOEN "Micropoll strategy" project, the Eawag/EPF Lausanne Ecotox Centre studied the suitability of numerous bioassays for monitoring the elimination of micropollutants in wastewater treatment plants (WWTPs).

Performance of advanced treatment steps

Micropollutants are trace organic contaminants found, for example, in pesticides, pharmaceuticals, biocides, fragrances, impregnating agents, cleaning products and paints. Some of these substances are only partially removed by conventional wastewater treatment processes. As a result, certain micropollutants are present in effluent in concentrations which have adverse effects on aquatic ecosystems and organisms. Inputs of these substances to receiving waters can be reduced by the use of additional treatment steps at WWTPs.

Peter Schönenberger

Cornelia Kienle and Petra Kunz discuss the results of a yeast estrogen screen assay.

The Ecotox Centre

oekotoxzentrum centre ecotox

The Swiss Centre for Applied Ecotoxicology (Ecotox Centre) investigates and assesses the effects of chemicals on the environment, with the aim of reducing risks to a minimum. Based at Eawag and at the EPF Lausanne, the Ecotox Centre seeks to bridge the gap between research and practice. Its activities include consulting, training, applied research projects and the maintenance of national and international contacts in the ecotoxicology field. Since September 2010, the centre has been led by aquatic ecotoxicologist Inge Werner.

Two of these advanced technologies – implemented in a pilot plant at the Vidy WWTP in Lausanne – were evaluated by Cornelia Kienle of the Ecotox Centre, in collaboration with various project partners. Here, micropollutants were to be removed by (i) ozonation followed by sand filtration or (ii) addition of powdered activated carbon followed by ultrafiltration (a process in which wastewater is passed through membranes with ultrafine pores).

Using bioassays, the researchers aimed to determine whether the removal of micropollutants is improved by the advanced treatments – and to evaluate the suitability of such assays for assessing wastewater treatment performance. The bioassays were also to be used to detect any toxic transformation products formed as by-products of ozonation.

The ecotoxicologists used two different types of bioassays (see table). *In vitro* bioassays, which focus on specific biochemical processes in cell lines or in single-celled organisms, can detect classes of chemicals such as estrogens or herbicides with a high degree of sensitivity. However, as Kienle points out, "*In vitro* bioassays only reveal to a very limited extent how substances affect whole organisms." Accordingly, *in vivo* bioassays involving whole organisms are used to study biological parameters such as growth, reproduction or mortality. They capture the effects of all the substances in a wastewater sample, but yield little information on the substance classes responsible.

Up to 100 per cent elimination

At the pilot plant, WWTP staff collected samples of raw influent and of treated wastewater at various stages – after biological treatment, after addition of powdered activated carbon with ultrafiltration, after ozonation, and after ozonation with sand filtration. The samples were then investigated using the various bioassays and by chemical analysis.

As shown by the *in vitro* bioassays, the biological treatment step reduced the toxic effects of wastewater. However, the substances of interest were not fully eliminated: for example, treated wastewater still contained substances with herbicidal and endocrine-disrupting effects.

However, the specific *in vitro* bioassays showed that both ozonation and activated carbon treatment removed most of the micropollutants remaining in the wastewater. Kienle explains: "Overall, when biological treatment was combined with advanced treatment, 84 to 100 per cent of the micropollutants were eliminated." This result was confirmed by chemical analysis of 58 typical organic micropollutants.

After ozonation, toxic effects were reduced in virtually all *in vitro* bioassays, which suggests that no harmful transformation products were formed as by-products. No genotoxicity or mutagenicity was observed.

In *in vivo* bioassays with blackworms, the test organisms showed reduced biomass after ozonation, but not after sand filtration. According to the ecotoxicologists, the reduction in biomass could be attributable to unstable transformation products formed during ozonation which have adverse effects on worm growth. However, these are removed from the wastewater by the sand filter. Kienle concludes: "To reduce the risk of such transformation products, ozonation should always be followed by a final filtration step with biological activity."

In *in vivo* bioassays with rainbow trout, toxicity was reduced by ozonation and by treatment with activated carbon and ultrafiltration. This was demonstrated by lower mortality, higher hatching rates or higher embryo weight compared with fish kept in wastewater that had only undergone biological treatment.

In vitro bioassays: suitable for performance assessment

The results of the other *in vivo* bioassays were not uniform. In most cases, toxicity was reduced after biological treatment. However, the (generally low) residual toxicity was not further reduced by any of the additional treatment steps. In general, after ozonation, the *in vivo* bioassays provided no evidence of a consistent rise in toxicity that would indicate the formation of stable toxic transformation products.

Comparison of the bioassays evaluated shows that there is no single test which could be used for overall assessment of the toxicity of a wastewater sample. Instead, a set of bioassays would always be needed. In the pilot study at the Vidy WWTP, *in vitro* bioassays based on cellular mechanisms proved to be highly promising and more suitable than integrative *in vivo* bioassays for assessing the elimination of micropollutants and the performance of advanced wastewater treatment technologies. According to the researchers, this approach is worth pursuing. They see a need, in particular, for standardization and certification of the test methods, so as to ensure the comparability of results. *In vivo* bioassays are generally more difficult to interpret, given the complexity of the biological processes; the costs of these tests are also much higher. "Even so," says Kienle, "chronic *in vivo* bioassays are desirable for effect assessment for whole organisms." There remains a need to develop suitable tests with sensitive organisms which could be carried out routinely at a reasonable cost. ○ ○ ○

Bioassays evaluated

Assay	Organism	Effects detectable
In vitro		
Yeast estrogen screen (YES)	Baker's yeast *(Saccharomyces cerevisiae*	Estrogenic effects due to receptor binding
Various CALUX assays (ER, AR, GR, PR)	Human cell lines	Effects on various hormone receptors (estrogen, androgen, glucocorticoid, progesterone receptors)
PPARg1 CALUX assay	Human cell line	Effects on substances which affect lipid metabolism
H295R steroidogenesis assay	Human cell line	Effects on synthesis of steroid hormones
Micronucleus assay	Chinese hamster cell line	Genotoxicity
UmuC assay	Salmonella *(Salmonella typhimurium)*	Genotoxicity
Ames test	Salmonella *(Salmonella typhimurium)*	Mutagenicity
Algal growth inhibition test	Green algae *(Pseudokirchneriella subcapitata)*	Herbicidal effects due to inhibition of photosynthesis and growth
In vivo		
Bioluminescence inhibition assay	Bacteria *(Vibrio fischeri)*	Bioluminescence inhibition
Growth assays	Green algae *(Pseudokirchneriella subcapitata)* Duckweed *(Lemna minor)*	Growth inhibition
Chronic daphnia toxicity test	Water flea *(Ceriodaphnia dubia)*	Reproduction inhibition, increased mortality
Amphipod test	Freshwater shrimp *(Gammarus fossarum)*	Reduced feeding activity, increased mortality
Blackworm reproduction test	Blackworm *(Lumbriculus variegatus)*	Reproduction inhibition, biomass reduction
Snail reproduction test	New Zealand mud snail *(Potamopyrgus antipodarum)*	Reproduction inhibition, increased mortality, endocrine disruption
Fish embryo test	Zebrafish *(Danio rerio)*	Increased mortality
Fish early life-stage toxicity test (FELST)	Rainbow trout *(Oncorhynchus mykiss)*	Reduced hatching rate, increased mortality, deformed larvae, abnormal behaviour, growth inhibition, vitellogenin concentration (endocrine disruption endpoint)

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The secret life of groundwater

Using a flow cytometry-based method developed at Eawag, scientists can now for the first time determine how much microbial life is actually present in groundwater. The new method provides much more realistic results than – and could ultimately replace – existing techniques for the analysis of water.

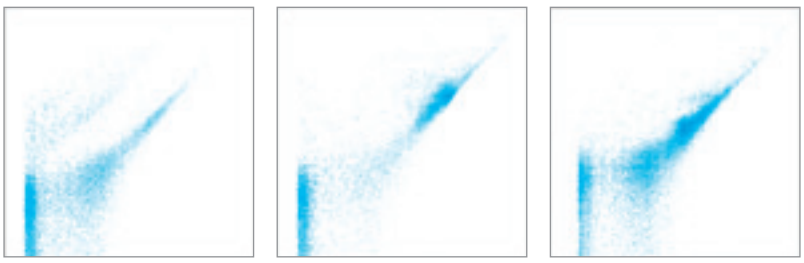
"Good-quality groundwater was long assumed to be practically 'sterile'," says Thomas Egli, head of the Environmental Microbiology department at Eawag. Partly thanks to a flow cytometric method developed by his group, he has now demonstrated for the first time that this assumption is mistaken – and that Swiss groundwaters are teeming with microbial life.

More rapid and accurate

On behalf of the Federal Office for the Environment, Stefan Kötzsch and Thomas Egli analysed groundwater samples from 50 NAQUA monitoring stations (see box) as part of a survey of the microbiological state of Swiss groundwater. "Using our method," says Kötzsch, "we were able to detect around 1,000 to 1,000,000 microorganisms per millilitre in the water samples."

Flow cytometry thus delivered far more realistic results than the heterotrophic plate count (HPC) method which is legally prescribed for assessment of the microbiological quality and safety of drinking water. This method can only detect bacterial cells which grow into colonies on solid nutrient media (agar plates). Egli points out: "With HPC, it's only been possible to detect a mere 0.1 to 1 per cent of all the microorganisms present in a natural water sample." Another advantage of flow cytometry is that it is much less time-consuming. While HPC analysis, depending on the method used, can take several days, results with flow cytometry are available after a quarter of an hour.

In medicine, flow cytometry has already been used for over 20 years, e.g. for counting blood cells. But because bacteria are much smaller than human cells and thus more difficult to detect, the method has not been widely used in microbiology. Recently, however, technically refined and less expensive devices have started to be used for microbiological monitoring of biotechnological processes and in the food industry.



Microbiological fingerprints: visualization of flow cytometry data reveals characteristic patterns for different types of water: groundwater (left), drinking water (middle) and river water (right).

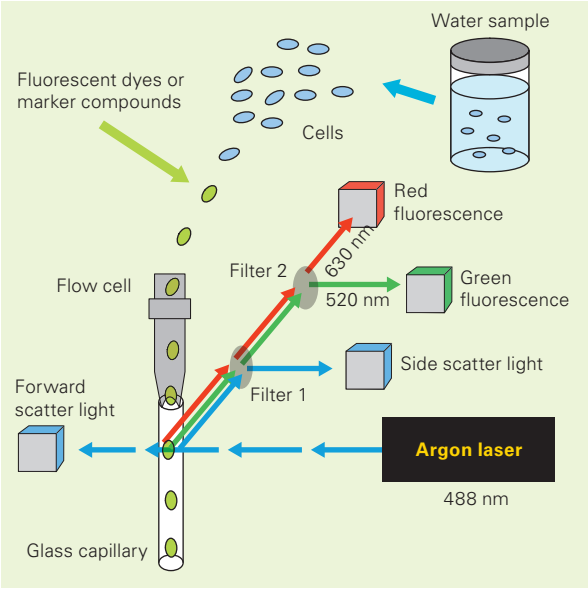
Eawag technician Hans-Ueli Weilenmann at the flow cytometer.

Active cells: more numerous than supposed

The principle of flow cytometry is relatively simple: a beam of light from a laser is passed through a stream of microorganisms flowing in single file through a glass capillary. When the light beam strikes a cell, part of the radiation is scattered and – redirected by lens, mirror and filter systems – is picked up by a light detector. Up to 1,000 particles per second can thus be counted. The cells can also be stained with fluorescent dyes, which bind to DNA, proteins or cell surface structures.

Using this technique, environmental microbiologists can distinguish (green-labelled) living from (red-labelled) dead or inactive microorganisms. Kötzsch says: "Our investigations consistently show that – irrespective of sampling time and location – around 90 per cent of cells in groundwater are active and viable." This is a significantly greater proportion than is detected by existing methods.

The Eawag researchers not only showed that Swiss groundwaters contain considerably more microbial life than was previously supposed to exist, they also – using



Schematic view of the flow cytometry process.

additional methods – confirmed the good quality of these waters.

According to Egli, "Flow cytometry also reveals that ground, spring and drinking water and water from streams, rivers, or lakes differ significantly from each other in terms of microorganisms and can be characterized by a kind of microbiological fingerprint." Changes over time can also be detected with this method: for example, in some of the groundwaters analysed, the number of microorganisms varied from season to season and was lower during the autumn than in the spring. Kötzsch adds: "The influence of rainy periods or flood events on groundwater can also be analysed rapidly and in detail."

Already in use in Zurich

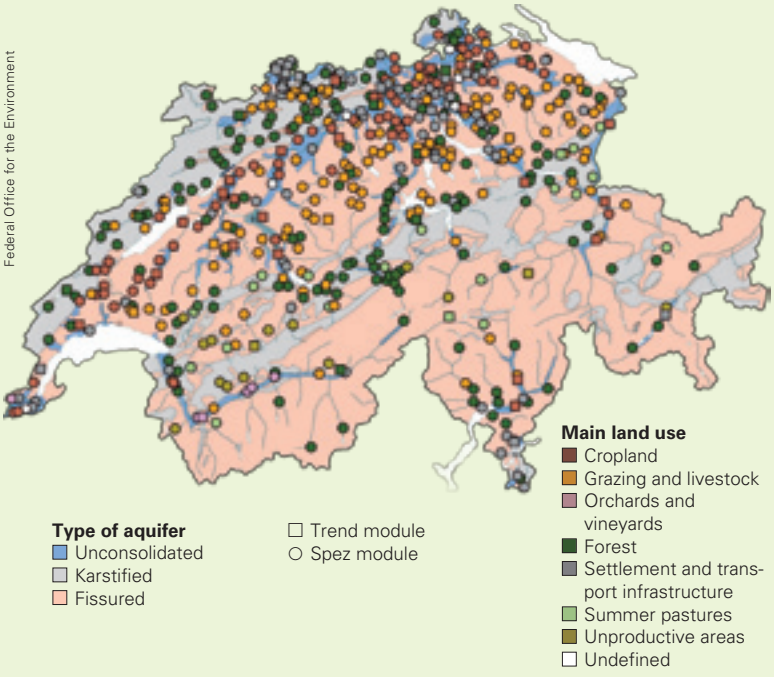
Since groundwater in Switzerland is by far the most important source of drinking water, monitoring of groundwater quality by cantonal and federal agencies is a legal requirement, as well as drinking water controls. Egli says: "With flow cytometry, we now have available for the first time a sound method which permits reliable microbiological assessment of groundwaters and would be suitable for efficient monitoring." The new method is already being used (alongside the legally required HPC method) for routine analysis of drinking water by Zurich Water Works, which had collaborated with Eawag researcher Frederik Hammes in the development of the technique.

For their development of flow cytometry-based microbiological analysis of drinking water, the Eawag researchers and their colleagues at Zurich Water Works received the Muelheim Water Award in 2010. This international award recognizes outstanding projects in applied research and the implementation of innovative concepts that contribute to an improvement of water management in Europe. The award is sponsored by RWE Aqua GmbH in Muelheim an der Ruhr and the Rhineland-Westphalian Waterworks Company (RWW).

NAQUA and NADUF

As part of a national groundwater monitoring programme (NAQUA), the Federal Office for the Environment (FOEN) maintains a network of over 500 monitoring sites. The programme, in which Eawag also participates, is designed to document the state and development of groundwater resources. NAQUA aims to characterize and classify the most important groundwater resources in Switzerland, to detect the occurrence of problematic substances or undesirable developments at an early stage, and to identify and check the effectiveness of any protection measures which may be required.

In addition, the FOEN, together with Eawag and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), runs the National River Monitoring and Survey programme (NADUF). Complementing NAQUA, this network of measuring stations is designed to provide a basis for assessing the current state of Swiss watercourses, as well as changes over the medium to long term.



The National Groundwater Quality Monitoring Network NAQUA (Trend and Spez modules) comprises a total of 545 monitoring sites.

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Eawag in 2010

Close links with Asia: a delegation from China visiting Eawag.

Eawag engages in a dialogue with society – both in Switzerland and abroad – so as to draw attention to emerging water-related problems and seek viable solutions. The success of these efforts depends on highly motivated, expert and enterprising staff, an excellent infrastructure and a productive working environment. Accordingly, 2010 was another year marked not only by research, teaching and consulting activities but also by contacts with the public, promotion of equal opportunities, support for young scientists, renovation of facilities and expansion of infrastructure.

Broad dialogue

Numerous visitors

Eawag maintains contacts with a wide range of stakeholders. Last year brought a variety of opportunities for exchanges with water professionals, policymakers, industry and members of the public. At the Dübendorf and Kastanienbaum sites alone, Eawag welcomed more than 1,200 visitors.

The work of researchers at Kastanienbaum attracts the interest of visitors of all ages.

These people were interested not only in aquatic research issues but also in the innovative headquarter building (Forum Chriesbach) and the institute itself.

Close links with Asia

Eawag's international contacts primarily involve day-to-day scientific exchanges among researchers. Also interested in Eawag are officials from neighbouring European countries and from Asia, especially China. Infrastructure management and local planning specialists often consult Eawag experts. In August, Ambassador Fadah Hsieh from the Taiwanese Embassy in Berne visited Eawag and met Eawag Director Janet Hering.

In September, Rik Eggen, Deputy Director of Eawag, gave a presentation entitled "Future Cities – Water Challenges" at a conference organized by the ETH Zurich at the Shanghai World Expo. On this occasion, he also met the Chinese Minister of Water Resources, Chen Lei.

Joining the dots in Glatt Valley

As well as international contacts, Eawag attaches importance to relations with the communities where the institute is based – Horw in Canton Lucerne and Dübendorf in Canton Zurich. It therefore maintains close contacts with representatives of local authorities in both Lucerne and Zurich and supports site-related projects. In December 2010, for example, Eawag hosted an event to mark the opening of the new Glatt

Opening ceremony for the Glatt Valley line at Forum Chriesbach.

Valley railway line, coinciding with the change of the SBB timetables.

The new line connects Eawag with Zurich Airport and other transport hubs. The opening ceremony – attended by over 300 guests from business, official and political cir-

cles – was held at Eawag headquarters in Dübendorf, in the immediate vicinity of the new stop. This was followed by a public celebration, where water experiments for children were among the attractions at an Eawag booth.

Artists in Labs

2010 also saw international exchanges of an artistic nature. Since 2003, Eawag has been participating in the "Artists in Labs" project, coordinated by Zurich University of the Arts (ZHdK). Last year, under the Sino-Swiss Residency Exchange Programme, artists from Switzerland/China spent five months collaborating with researchers at Chinese/Swiss research institutes, transforming their impressions into works of art.

Aniu presenting his work.

Artist-in-residence at Eawag's Aquatic Ecology department was Aniu (Qing Jun Chen), a Shenzhen-based photographer and visual artist. Focusing in particular on the importance of water for Eawag scientists and other staff, he carried out experiments with water under the microscope. His photographs and installations were exhibited at Eawag in Dübendorf, in Shanghai and in Berne.

Eawag at the "2 Degrees" exhibition

Eawag participated in an exhibition which opened last year in Basel entitled "2 Degrees – Weather, Humans and Their Climate". The Eawag exhibit demonstrated a new method of measuring rainfall using mobile phone antennas, which offers greater spatial resolution than traditional point measurements from rain gauges. The six-month exhibition, running at the Kunstfreilager Dreispitz until Spring 2011, provided a forum for discussions on weather and climate issues. It attracted over 31,000 visitors, including 650 school classes.

Awards

Successful young scientists

Eawag research has an excellent reputation and attracts many talented young scientists. In 2010, several of them received awards for outstanding performance: in March, the Berne Prize for Environmental Research went to Eawag scientist David Bittner and his colleague Daniel Bernet of Berne University for their study of gonadal deformities in Lake Thun whitefish. In June, Eawag researcher Martine Maan received the Dutch Zoology Prize of the Royal Dutch Zoological Society. This prize recognizes the best research in the field of integrative zoology.

Linda Roberts conducting field work in Bangladesh.

In November, two young Eawag scientists received awards for their doctoral dissertations: at the ETH Zurich, the Otto Jaag Water Protection Prize went to Linda Roberts for her work on arsenic contamination of rice paddies in Bangladesh, while the Hydrobiology-Limnology Award went to Natacha Pasche for her research on nutrient cycles and methane production in Lake Kivu in central Africa.

Honours for long-standing researchers

As well as young scientists, Eawag researchers with many years of experience received prestigious awards last year. In February, former Eawag Director Alexander Zehnder was awarded the Order of the Federal Republic of Germany for his outstanding services to German science, which have helped to strengthen Germany as a research location.

Also particularly gratifying was the granting of the international Muelheim Water Award to an Eawag research team led by Frederik Hammes and Thomas Egli, together with Zurich Water Works. They received the award, worth CHF 20,000, for the development of a new, practical method for the analysis of drinking water (see p. 46).

Infrastructure

Modern buildings for cutting-edge research

If research is to be pursued at a consistently high level, modern workplaces and infrastructure are essential. In 2010, Eawag celebrated the reopening of its fully modernized

No ivory tower: the renovated laboratory building at Dübendorf.

laboratory building at Dübendorf. The building, with around 3,600 square metres of floor space, was originally opened in 1970. Over the last two years, refurbishment work was carried out, with the labs remaining in operation throughout.

The overhaul also involved optimizing energy efficiency: consumption of fossil-based energy has been almost halved thanks to increased heat recovery and other measures.

At the Kastanienbaum site, Eawag also opened a new building to replace the old temporary office facilities. The wooden construction conforms to the "Minergie-P" standard, and staff were closely involved in decisions on the interior design and fittings.

New risk management

In 2010, Eawag restructured its risk management organization and appointed a Risk Manager, who chairs the Risk Committee. This is made up of two safety officers from each of five areas – Fire & Building Safety, Chemical Safety, Biosafety, IT Security and Radiological Safety. Also members of the Risk Committee are the three officers responsible for the internal control system. In addition, risks at Eawag were reassessed last year and appropriate management measures implemented. A risk report, issued annually, provides information on safety-related incidents.

Merger of research libraries

Last year, the new head of the Eawag library, Lothar Nunnenmacher, made preparations for the merger of the libraries of the four research institutes Eawag, Empa, PSI and WSL, intensifying existing cooperation. The newly merged library, known as Lib4RI (Library for the Research Institutes within the ETH domain), opened in January 2011, following a brief planning period of just a few months. Lib4RI is organizationally and administratively part of Eawag, where it has the status of an internal department.

Lib4RI is connected to the Nebis lending network operated by the ETH library, ensuring continued cooperation within the ETH domain. In addition to the physical holdings, which remain available at the existing locations, an improved electronic library has been established, as non-location- and non-time-dependent access to resources is particularly important for the four research institutes spread across 11 different sites in Switzerland.

The Eawag, Empa, PSI and WSL libraries have now been merged.

Eco-management

Cycling to Eawag

Eawag has already received two awards from Pro Velo Switzerland (the umbrella organization representing cyclists' interests) as a cycle-friendly workplace. Last year, Eawag continued its efforts to encourage staff to cycle to work. Since the beginning of May 2010, a new, separate bike shelter has been available for Eawag and Empa staff at the Stettbach railway station on the Zurich city boundary. The new shelter is ideally situated, well lit and well equipped, with room for 100 bikes and spaces for trailers. Secure bicycle storage is free of charge for staff from the two research institutes.

Eawag is covering the investment, rental and maintenance costs through CO_2 offset fees levied on business flights. This is the first bike shelter at a Swiss railway station which is exclusively accessible to employees of particular institutions.

The lockable bike shelter at Stettbach station.

Further information on resource and environmental management at Eawag and on Eco Team projects is available at: *www.eawag.ch/about/nachhaltig/umweltteam*

It is a result of successful cooperation between Eawag, Empa and IG Velo, the Dübendorf authorities and the Glatt Valley transport company.

In addition, since the end of October, a new cycleway and footpath has been in operation between Eawag headquarters and the Stettbach station, offering greater safety and a considerable time-saving for pedestrians and cyclists. This path was built by Canton Zurich on the initiative of Eawag. At the same time, a section of the River Chriesbach running along the new route was restored, with support from the green electricity fund of the Zurich power utility (EWZ).

Equal opportunities

More women in research

In 2010, the Eawag Committee on Gender Equity and Equal Opportunity focused on the advancement of women in scientific careers. Eawag has launched a mentoring project for female postdocs, which provides career-planning support for women employed at the institute and aims to increase the proportion of women working in research.

A mentoring programme supports young women pursuing scientific careers.

Also ongoing is the "Fix the leaky pipeline" career-building programme, pursued in cooperation with the other institutes within the ETH domain.

More women in management

Eawag has a high proportion of women in management functions. To further increase this proportion, talented female candidates are not only identified but actively encouraged to apply for faculty and tenure-track positions in particular. The committees responsible for filling these positions are required to comply with the "Guidelines for Search Committees: Increasing Diversity". In addition, Eawag and Empa support the shared childcare centre.

Greater respect for languages

At an institution like Eawag with an internationally diverse staff, it is important that different cultures should be valued and respected. Last year, a team was appointed by the Gender Equity and Equal Opportunity Committee to develop recommendations for the management of languages and language barriers, based on a staff survey. The team suggests, for example, that initial announcements of events should include details of the language in which they will be conducted, and recommends mixed-type presentations (e.g. a lecture delivered in German with slides in English).

In addition, Eawag has taken measures to support the integration of staff with diseases or disabilities and developed individual solutions to integrate the people concerned into working life.

Personnel

New appointments and professorships

In the year under review, the ETH Board appointed four Eawag scientists as professors. Eawag Director Janet Hering and Urs von Gunten became full professors at the Federal Institute of Technology Lausanne (EPFL). Environmental chemist Juliane Hollender and ecotoxicologist Kristin Schirmer became adjunct professors at the ETH Zurich and the EPFL respectively.

Other key positions were filled by experienced specialists. In April, for example, Lothar Nunnenmacher became head of the Eawag-Empa library. Bringing a wealth of experience in library management (most recently at the ETH Zurich), he has already successfully implemented the (previously planned) merger of the libraries of all four research institutes within the ETH domain.

In September, Inge Werner took up her position as new head of the Ecotox Centre. She previously served as associate adjunct professor and Director of the Aquatic Toxicology Laboratory (ATL) at the UC Davis School of Veterinary Medicine. The ATL is a State-certified lab which investigates surface water quality and aquatic ecosystem health throughout California. Here, Werner – who has a PhD in zoology – carried out numerous applied projects in aquatic ecotoxicology, in cooperation with State and local authorities.

In January 2010, Jukka Jokela became a member of the Eawag Directorate. Jokela, a Finnish citizen, has

carried out research in the Aquatic Ecology group at the ETH Zurich since 1996. Since 2005, he has been a full professor at the ETH Zurich. From 2005 to 2009, he also served as head of the Aquatic Ecology department at Eawag.

Stable headcount

Compared to the previous year, headcount grew in line with long-term planning, particularly in scientific and technical functions. Overall, the headcount rose by 24 (up 5.6 per cent). The increase in scientific staff was roughly equally balanced between men and women. In technical and administrative functions, more male staff were recruited. In management functions, the proportion of women remains relatively high (23 per cent) and is increasing particularly at high functional levels.

Eawag remains committed to the training of apprentices. It offers 26 apprenticeship places in clerical, IT and laboratory positions (see p. 34).

48 per cent of staff at Eawag are women.

Research integrity

The reputation of scientists and scientific institutions rests on research integrity. Accordingly, in 2010, the four research institutes of the ETH domain (Eawag, Empa, PSI and WSL) jointly underlined their commitment to research integrity by introducing "Guidelines for Good Scientific Practice". Under these guidelines, for example, scientific results must be reproducible and it must be possible for experimental steps to be reconstructed. Fabrication or theft of primary data and plagiarism are strictly prohibited, as are publication of the same content in various scientific journals or subdivision into a number of small, incomplete publications ("salami tactics"). Each person involved in a research project bears the responsibility for the part which is under his or her direct control. Overall responsibility for the content of a publication lies with the corresponding author. In the event of problems relating to integrity, staff can contact specially appointed ombudspersons.

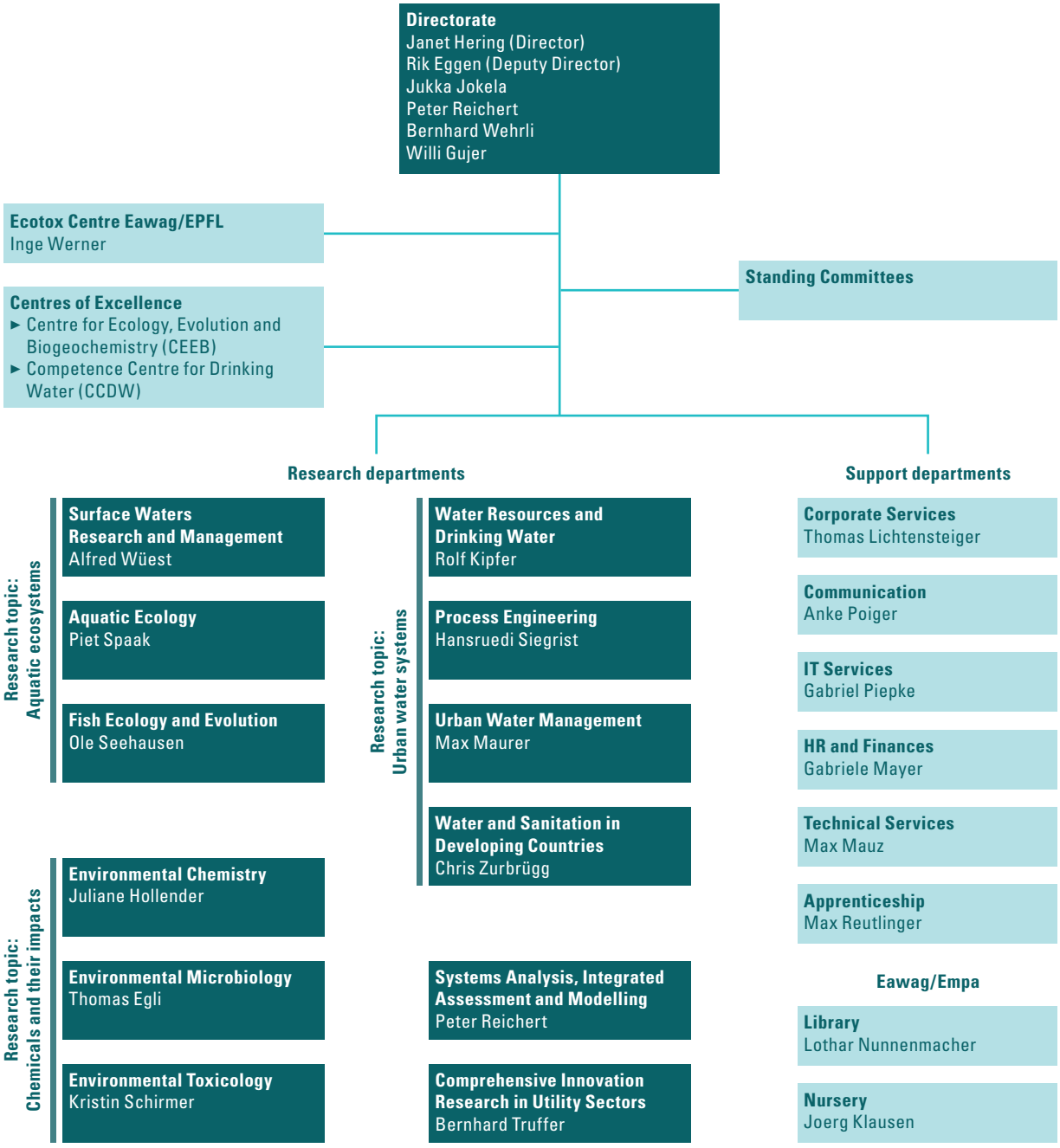
Integrity: Eawag has adopted guidelines for good scientific practice.

Changes in Advisory Committee membership

The Stakeholder Advisory Committee serves an important function for Eawag. Bringing together key actors in the Swiss water sector, it advises the Directorate on major strategic decisions. Last year saw a number of changes in the membership of the Committee. New members include representatives of federal and cantonal authorities – Stephan R. Müller, head of the Water Division at the FOEN, and Heinz Habegger, head of the Canton Berne Office of Water and Waste Management – and representatives of industry – Claus Conzelmann, global head of Safety, Health and Environmental Sustainability at Nestlé, and Reto Schneider, head of Emerging Risk Management at Swiss Re. Since May 2010, the Committee has been chaired by Ursula Brunner of the Zurich law firm Ettler Suter, who took over from André Bachmann, Director of BMG Engineering, Schlieren. ○○○

Ursula Brunner, the new President of the Stakeholder Advisory Committee.

Organisation



Advisory Board

Ursula Brunner (President, from May 2010), Lawyer, Ettler Suter Lawyer, Zurich
André Bachmann (President, until May 2010), Executive Director BMG Engineering, Schlieren
Peter Arbenz, President Helvetas
Claus Conzelmann (Vice President, from May 2010), Head of Safety, Health & Environmental Sustainability Nestlé Group
Erika Forster-Vannini (until December 2010), State Councillor, St Gallen
Günter Fritz, Head of Environment Health and Safety, BASF Schweiz AG
Urs Gantner, Leader of department Research and Extension FOAG – Federal Office for Agriculture, Berne
Heinz Habegger (from May 2010), Head Awa – Office of Water and Waste Management Canton Berne
Jürg Meyer, Director, Division ISS Infrastructure Services, ISS Schweiz AG, Zurich
Stephan R. Müller (from November 2010), Division Head Water, FEON – Federal Office for the Environment, Berne
Reto Schneider (from May 2010), Director, Head Emerging Risk Management, SwissRe, Zurich

People

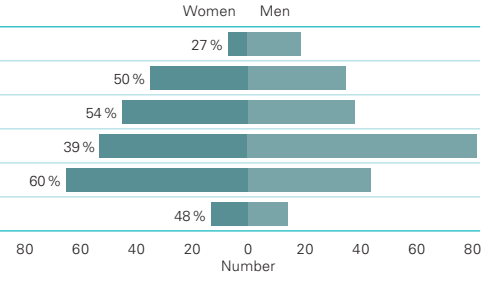
Personnel	People	Wehreof women	Wehreof non-swiss	Full-time equivalents
Full professors [1]	9	1	3	9
Titular professors	15	3	5	14
Scientific staff (academic staff)	161	58	82	149
PhD students	97	52	62	97
Technical staff	90	43	12	75
Administrative staff	60	50	11	43
Apprentices	26	11	4	26
Total	**458**	**218**	**179**	**413**
Affiliated staff (nursery)	19	18	2	17
Trainees [2]	38	20	26	38

[1] 8 of them are not or not directly employed by Eawag
[2] Variable employment periods, total number in 2010

Percentage employment	Women	Men	Total
1–49 %	13	8	21
50–79 %	39	7	46
80–99 %	38	24	62
100 %	128	193	321
Total	**218**	**232**	**450**

Origin	Women	Men	Total
Switzerland	130	143	273
EU	68	71	139
Other	20	18	38
Total	**218**	**232**	**450**

Age structure	Women	Men	Total
60–65	7	19	26
50–59	35	35	70
40–49	45	38	83
30–39	53	82	135
20–29	65	44	109
15–19	13	14	27
Total	**218**	**232**	**450**
	(48,4 %)		



Apprentices	Women	Men	Total
Biology lab technician	1	2	3
Chemistry lab technician	8	10	18
IT systems engineer	0	2	38
Administrator	2	1	3
Total	**11**	**15**	**26**

Activities

	2008	2009	2010
Supervised dissertations	119	111	153
Supervised Bachelor's and Master's theses	97	109	142
Publications in refereed journals	253	232	259
Publications in non-refereed journals	55	114	72
Spin-offs	1	–	–
Patents, licence agreements	–	–	–
Service contracts	31	24	35
Prizes	12	19	26
Teaching programmes at ETHZ, EPFL	81	82	95
Teaching programmes at other universities	52	41	24
Teaching programmes at universities of applied sciences	2	6	0
PEAK-Courses (further education)	4	5	6
Conferences	39	53	54
Committee memberships	178	184	190

Further details are available at *www.eawag.ch/annualreport*

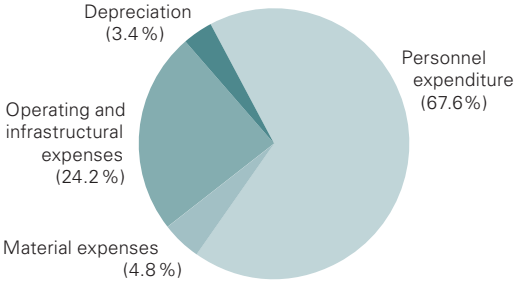
Finances

Financial statement	2008	2009	2010
Personnel	39 498 230	39 278 708	41 923 339
Materials	3 693 473	11 426 136	2 990 640
Operating and infrastructural expenses	13 049 526	14 011 009	14 920 290
Depreciation	1 315 815	1 896 647	2 109 090
Provisions	5 780 247	1 001 944	–210 058
Expenditure	**63 337 291**	**67 614 444**	**61 733 302**
Federal government funding	54 429 850	47 596 574	54 239 254
Third-party resources (incl. changes in inventories)	11 237 615	11 068 789	14 246 016
Miscellaneous revenue	935 584	1 238 918	1 717 018
Income	**66 603 049**	**59 904 281**	**70 202 289**
Result	**3 265 758**	**–7 710 163**	**8 468 987**

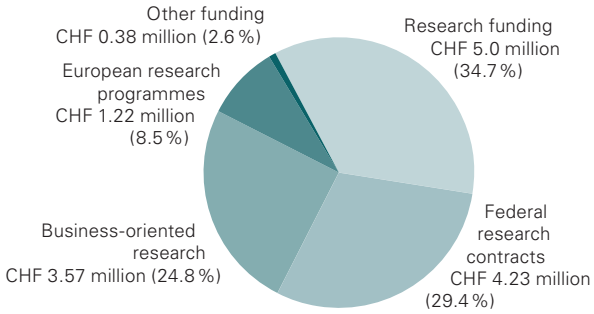
Investments	**15 823 645**	**3 849 680**	**6 774 457**
Real estate	13 890 051	1 484 507	3 713 999
Movables	1 663 563	2 047 665	3 006 300
IT	270 031	317 508	54 158

all figures in CHF

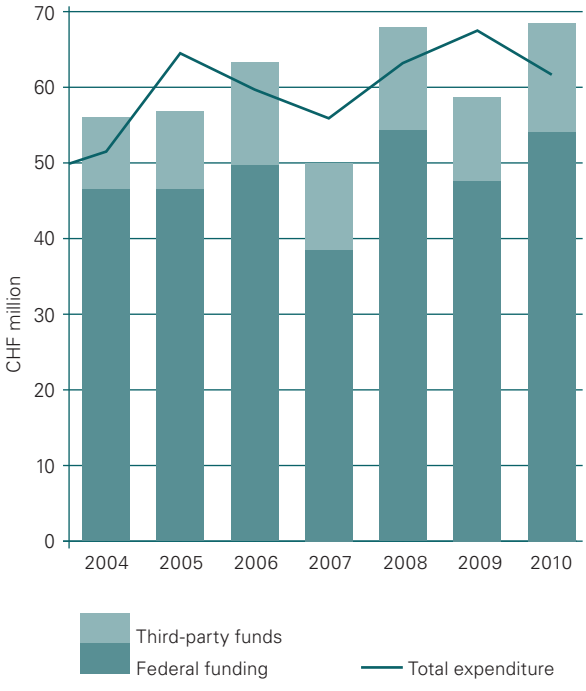
Breakdown of expenditure 2010



Third-party resources 2010



Development 2004–2010



The Annual Report 2010 presents only a small selection of Eawag's research, teaching and consulting activities. A database of all publications by Eawag researchers (including article summaries) is available online at: www.lib4ri.ch/institutional-bibliography/eawag.html Open access publications can be downloaded free of charge. If you have any queries, please contact: info@lib4ri.ch

The Annual Report is also available in German.

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