eawag
aquatic research

Annual Report 2011

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. In total 467 staff are employed in research, teaching and consulting at the Dübendorf (Zurich) and Kastanienbaum (Lucerne) sites.

Cover photo
A flow cytometric method developed by Eawag could revolutionize drinking water monitoring. This method delivers results – within a matter of minutes – which provide a much more realistic picture than is possible with the conventional plating method. Hans-Ulrich Weilenmann (right) of the Environmental Microbiology department discusses the practical application of this system with a Zurich Water Works (WVZ) technician at the Lengg drinking water treatment plant (see p. 42).

Content

Study the past if you would divine the future

Confucius

Eawag's focus for 2012–2016 on three overarching topics – water for human welfare, water for ecosystem function, and strategies for trade-offs and competing demands – builds strongly on past activities and accomplishments. Yet it also calls for a strengthening of Eawag's capacities in modelling and an expansion of current activities in the social sciences.

In 2011, Eawag celebrated its 75th anniversary. This was an occasion to review past accomplishments and assess future directions. We asked which of our past activities are relevant today. What emerging issues must we address?

Throughout its history, Eawag has focused on water quality as it affects human health and aquatic ecosystems. Robust observation has been a cornerstone of this work, and it becomes increasingly important with climate change and other new challenges.

Observations for better understanding

Since the 1970s, Eawag has participated in the water-quality monitoring programme NADUF, which has focused on nutrients and heavy metals. The extension of this programme to include organic micropollutants has now been assessed (p. 36). Novel methods, particularly for high-frequency sampling, are needed to identify the complex effects of environment change, as shown by a study of algae in Lake Zurich (p. 10). A reliable baseline, against which future change can be assessed, is being established for lake fish through the ongoing "Projet Lac" (p. 24). Records in corals and sediments provide information on past conditions (p. 12). In present-day observations, new genetic information helps to assess hidden diversity (p. 11) and to interpret the evolutionary effects of environmental factors (p. 39).

Interpreting observational data requires consideration of multiple factors and integration of their effects. Comparative laboratory experiments are a valuable basis for the interpretation of field observations. Ecotoxicological studies that use molecular techniques to assess responses at the whole-organism level (p. 22) are an important step in making the link to field observations. In addition, alternatives to routine testing on animals are needed to reduce the burden of complying with environmental regulations (p. 23).

Integration for greater effectiveness

Eawag emphasizes problem-solving and addresses the critical needs of society in industrialized, emerging and developing countries. With the growing pressures on the water environment, problem-solving becomes increasingly multidimensional and calls for greater integration with a sound scientific basis.

Designing solutions to multifaceted environmental problems calls for an integrated perspective. For example, the ecological effects of hydropower are well known but are increasingly of concern. The growing demand for renewable and less carbon-intensive energy production poses a conflict with the interest in the preservation and restoration of aquatic ecosystems (p. 40). Eawag developed a feasible concept for assessing micropollutants from municipal wastewater (p. 36). From the Cleantech perspective, the value of wastewater as a resource can partially offset treatment costs; nitrogen recovered from wastewater as ammonium sulphate can be used as fertilizer (p. 20).

Integration and cooperation with practitioners and stakeholders are crucial to solving environmental problems. In the Restored Corridor Dynamics (RECORD) project, such cooperation has facilitated access to field sites for long-term observations (p. 14). For the Swiss Centre for Applied Ecotoxicology, addressing stakeholder concerns and integration across sectoral boundaries are also a main concern (p. 38).

Effective problem-solving requires that knowledge, technologies and tools are made accessible to stakeholders, for example through reports on community-led urban environmental sanitation for developing countries (p. 16). Prior experience with local communities in developing countries facilitated the field testing of a novel technology for drinking water treatment in Kenya (p. 16). In the emerging economy of China, the social science aspects of decentralized water treatment are being investigated in a collaborative project with local researchers (p. 18). In Switzerland, tools for decision support have been applied to integrated river management (p. 15). These and other research results have been shared with stakeholders through the practice-oriented Eawag courses (PEAK).

New initiatives for 2012

Eawag's Development Plan 2012–2016, which was approved in 2011, identifies three focus areas: water for human welfare, water for ecosystem function, and strategies for trade-offs and competing demands. This requires a strengthening of Eawag's capacity in modelling, which will be a target for hiring in 2012. An expansion of current activities in the social sciences is also needed and will build on the base of Eawag's current research on innovation. This activity, together with the joint appointment (with Bern University) of Karin Ingold as an assistant professor for policy analysis and the planned expansion in environmental economics, will be the core of a new department of environmental social science.

Janet Hering, Director

1

Highlights 2011

1 The Info Day marking Eawag's 75th anniversary was held at Forum Chriesbach, the Institute's headquarters in Dübendorf. A wide range of presentations highlighting current research activities promoted dialogue among the scientists and water professionals present. A central theme of the anniversary celebrations was the successful collaboration which has existed for many years between Eawag researchers and practitioners.

2 At an anniversary reception, guests from industry, as well as political, administrative and scientific circles, offered Eawag their congratulations.

3 At the reception, Director Janet Hering presented the Eawag Award to veteran Eawag researcher and ETH Emeritus Professor Jürg Hoigné, in recognition of the chemist's dedication to and achievements in research, teaching and consulting in the field of water and wastewater treatment.

4 Together with guests, retirees and former doctoral students from Switzerland and abroad, Eawag staff celebrated the anniversary in style at a colourful event held in Dübendorf, featuring drama, speeches and live music.

5 Announcing the anniversary: visitors arriving at Forum Chriesbach are greeted by flags in three languages.

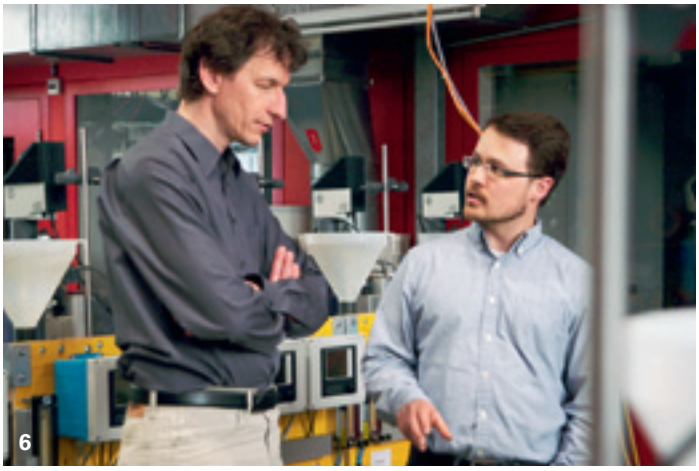
6 To mark the anniversary, Eawag established a postdoctoral fellowship, to be awarded in a competitive procedure to a young researcher with an excellent academic record and new ideas for research. The first successful candidate was US engineer George Wells, who took up his position in the Process Engineering department in 2011. He is pictured here in conversation with Professor Eberhard Morgenroth.


2


3


4


5


6

7

7 In 2011, the Department of Water and Sanitation in Developing Countries (Sandec) won an International Water Association (IWA) Development Solutions Award. This award recognizes outstanding innovations or contributions to science and practice which have had a demonstrable impact in low- or middle-income countries. Sandec Head Christian Zurbrügg (left) received the award from IWA President Glen Daigger at the 2nd IWA Development Congress, held in Kuala Lumpur in November 2011.

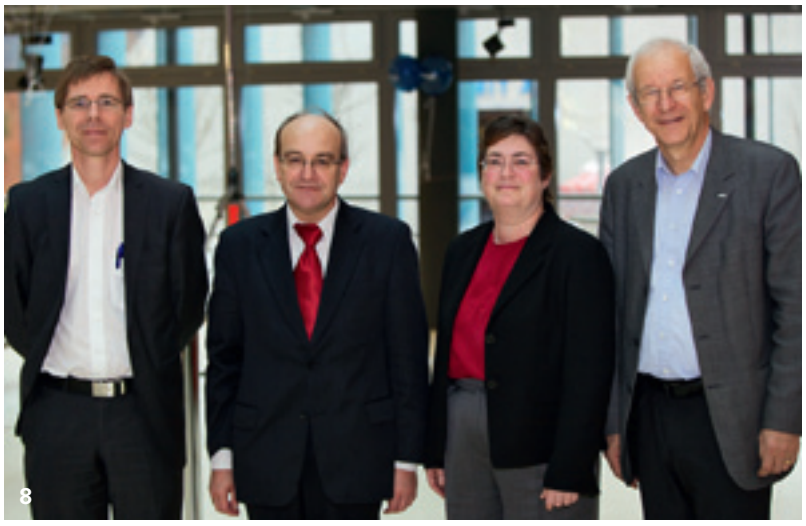
8 Janet Hering began her 2nd term as Director of Eawag in 2011. At a reception held to mark her reappointment by the Federal Council, she was congratulated by ETH Board President Fritz Schiesser (2nd from left) and by two representatives of the ETH Domain – PSI Director Joël Mesot (left) and ETH Zurich President Ralph Eichler (right).

9 Young scientists at Eawag are frequent recipients of awards for outstanding work. For example, Saskia Zimmermann's dissertation on wastewater treatment earned her the 2011 Otto Jaag Water Protection Prize, which was presented by ETH Rector Heidi Wunderli (left). For details of other awards see p. 45.

10 Existing collaboration between Eawag and Bern University was further strengthened in 2011. Bernhard Truffer – head of Innovation Research in Utility Sectors (Cirus) at Eawag – was appointed Titular Professor at Bern University. Social scientific research activities were also expanded, with the appointment of Karin Ingold (pictured) as Assistant Professor of Policy Analysis at the Bern University Institute of Political Science, a new position co-funded by Eawag.

11 A group of Eawag researchers were among the winners of the ES&T awards for the Best Papers of 2010, announced in March 2011. The publication by Damian Helbling, Hans-Peter Kohler, Kathrin Fenner, Juliane Hollender and Heinz Singer entitled "High-Throughput Identification of Microbial Transformation Products of Organic Micropollutants" was named Top Paper in Environmental Science.

12 In both research and teaching, Eawag collaborates closely with the ETH Zurich, so it was a key contributor to the "Treffpunkt Science City" popular science programme on the topic of water. Eawag scientists took part in a series of short lectures, and a guided tour offered insights into laboratory research at Dübendorf. Photo: Eawag researcher Michael Wächter (centre) discusses with a visitor the principle of nutrient recovery from source-separated urine.


8


9


10


11


12

Research
Teaching
Consulting

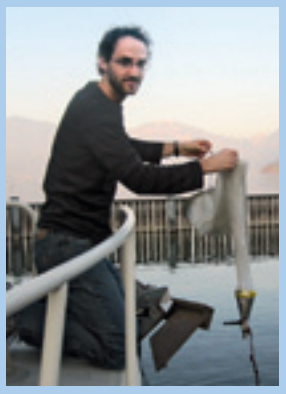
In 2011, Eawag strengthened its national and international connections, reaffirming its position as a world-leading aquatic research institute. Eawag scientists served on committees responsible for the organization of more than 15 conferences in Switzerland and abroad, and gave presentations at numerous scientific gatherings. The number of scientific publications produced was slightly higher than in the previous year, and there was an increase in publications with a higher impact factor. Last year, Eawag experts also participated in 127 scientific networks and served on 34 scientific committees, thus further expanding national and international cooperation.

In its 75th anniversary year, Eawag defined the strategic direction of its research, which is to focus on three overarching topics over the next few years: water for human welfare, water for ecosystem function, and the development of strategies for trade-offs and competing demands. Particular attention will be paid to resource-use conflicts and opportunities arising in the area of water and energy.

Blake Matthews

Integrating ecology and evolution

"Evolution is a continuous process – and the results are already apparent after a short time," says Canadian environmental scientist Blake Matthews. He is interested in how aquatic ecosystems respond to environmental – e. g. climatic – changes, but also in the influence of evolution. To investigate this, Matthews compared two stickleback species kept in experimental tanks (mesocosms) around 1,000 litres in volume. The two species are descended from the same ancestor but differ in their feeding habits (planktonic versus benthic prey). Matthews showed that both species can modify their habitat – e. g. ecosystem productivity – and do so in different ways: "Thus, not only do environmental changes drive evolution but, conversely, evolutionary processes also shape the environment." Accordingly, the researcher aims to integrate more closely the fields of ecology and evolutionary biology. "We don't yet know much about how they're related – for instance, how evolution affects ecosystem functions such as drinking water quality."



Nele Schuwirth

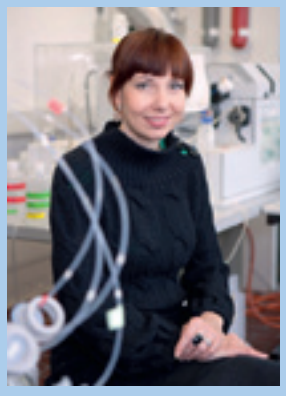
Using models for surface water management

"What I find fascinating," says geologist Nele Schuwirth, "is the idea of modelling natural processes mathematically." But she is aware that a computer model can never reflect all the complexity and chance elements found in nature: "So I always try to create a model which is both realistic but at the same time as simple as possible." Her models are employed, for example, in ecological assessment of rivers. Parameters such as temperature, discharge or light can be used to predict the occurrence of macroinvertebrates in particular river sections. In future, this should facilitate prediction of the ecological impacts of river restoration measures. Schuwirth is also developing decision support techniques for complex situations which may involve competing demands. For example, the goals of water quality, biodiversity or power generation call for different measures. "For each model, I need data from a variety of fields," she says. Often, she can obtain the necessary information from colleagues at Eawag: "It's very convenient – I can find an in-house expert for virtually every field of aquatic research."

Lenny Winkel

Tracking trace elements

"China is ideal for investigating selenium," says geochemist Lenny Winkel. Parts of China are among the world's most selenium-rich regions, while others are extremely deficient in this element. "How are these differences possible within one country?" Winkel wonders. She is interested in the selenium cycle because this trace mineral is important to human health: "The more abundant it is in a given region, the higher the dietary intake will be." According to the hypothesis she has proposed to explain its uneven global distribution, dissolved selenium is released into the atmosphere by marine phytoplankton and transported over long distances by wind currents before eventually being washed out by rainfall. Funding for Winkel's study of the selenium cycle was granted under the SNSF professorship scheme, partly thanks to her work on another trace element – arsenic. This element, which occurs naturally in soils in Southeast Asia, can contaminate groundwater, posing a health risk to the local population. Winkel explains: "By integrating data on geology and soil properties into a computer model, we were able to predict arsenic concentrations in groundwater." While this research is being continued by local partners, Winkel has now moved on to the selenium project.



Plankton rebounding in Lake Zurich

The interaction between rising temperatures and successful efforts to combat eutrophication is promoting plankton biodiversity in Lake Zurich. The new species are being carefully monitored by the local water supplier, as they include organisms which can release toxic substances.

In the 1970s, Lake Zurich harboured around 40 species of phytoplankton and only 7 species of zooplankton, on average; by 2008, the figures had risen to more than 100 and 15 respectively. This increase in the diversity of these free-floating microscopic life forms was accompanied by an increase in their total biomass. These findings come from a study carried out by Eawag researchers in cooperation with experts from Zurich Water Works (WVZ).

Long-time series

The study was made possible by an unusually long series of chemical, physical and biological data, deriving from measurements performed in the lake by WVZ since 1977. Parameters including temperature, pH, light intensity and phosphorus and nitrogen concentrations are monitored at 14 points in the water column, from the surface to a depth of 135 metres. In addition, phytoplankton and zooplankton samples are analysed, enumerated and classified; fortunately, the same methods have been used throughout, and for much of the time the same experts have been involved. Using statistical analyses, the researchers have now identified the drivers underlying this data set.

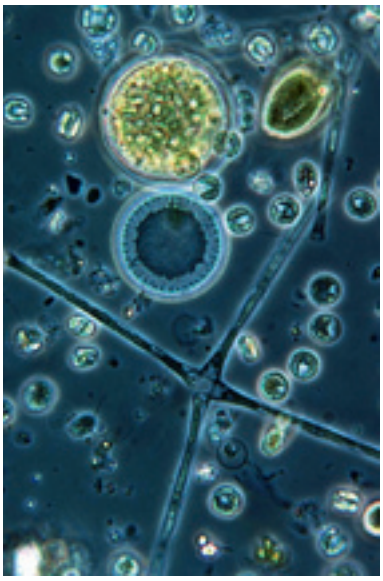
More niches, more species

The most notable trends observed since 1977 are a slight but steady rise in water temperature (by about 0.2 degrees) and a marked decrease in phosphorus concentrations (from approx. 90 to 20 micrograms per litre). In addition, phosphorus concentrations now show less seasonal variation than in the past, but a broader range across different lake depths. All these factors have promoted an increase in the diversity of phytoplankton species and led to more stable populations than those of 30 years ago. According to project leader Francesco Pomati of the Aquatic Ecology department, the lake now accommodates more ecological niches, enabling more organisms to find the habitat, light and nutrients they need to survive. In the past, algal growth was confined to the uppermost water layers.

The greater biodiversity of phytoplankton – which serves as a food source – goes in tandem with an increase in the number of zooplankton species, even though rising water temperatures tend to be associated with a decline in zooplankton biodiversity. Pomati believes that the findings from Lake Zurich are also applicable to other lakes of similar history and characteristics. "And no doubt," he adds, "our work will enrich the debate on the impacts of anthropogenic environmental change."

Under observation

Among the species benefiting from the changes in environmental conditions are some which are not universally welcome – e.g. *Planktothrix rubescens,* which can produce toxic microcystins. Growth of this cyanobacterium is encouraged by the more stable thermal stratification of the lake and the availability of phosphate in deeper water layers. The spread of this species is being closely monitored, as WVZ microbiologist Oliver Köster emphasizes: "We're observing these developments carefully, especially at the depths where lake water is taken for water supplies." However, consumers should not be alarmed, as water treatment with filters and oxidants (e.g. ozone) already ensures that these organisms and their toxic products do not enter Zurich's water pipes. ○○○



The term "plankton" refers to microscopic forms of plant and animal life found in natural waters. Swiss lakes are rich in plankton.

Contact:
Dr Francesco Pomati,
francesco.pomati@eawag.ch

Algal blooms in Lake Greifen

The floating automated monitoring platform developed in the Aquaprobe project sheds new light on the emergence and disappearance of algal populations. With this system, researchers no longer have to rely on spot checks, as data can be obtained automatically from any depth at almost any time and transmitted to an onshore centre for analysis. Certain species can proliferate on the surface of a lake within a matter of days. In 2011, growth of the cyanobacterium *Microcystis aeruginosa* was monitored by the platform on Lake Greifen (Canton Zurich). Francesco Pomati and his team recorded a sharp increase in cyanobacteria at a depth of 10–20 metres in July, before surface blooms of *M. aeruginosa* appeared at the beginning of August. For two weeks, a layer of scum formed on the lake surface and the water became cloudy. In contact with the cantonal authorities and the Zurich University Limnological Station, Eawag helped to assess the situation. As no production of toxins by this algal strain was observed, the Cantonal Laboratory issued a warning for people susceptible to allergic reactions, but a ban on swimming was not required.

www.ae.ethz.ch/research/aquaprob

Same species, different types

Conservation measures aim to protect species. Sometimes, however, a single species comprises a number of distinct types which – though morphologically very similar – differ in their ecological requirements. These so-called cryptic species need to be taken into consideration in conservation efforts.

For conservationists, the biological species is the key unit of currency: measures are designed to preserve species diversity, to protect and support endangered species, or to control invasive species. In general, a species is recognized as such because its members resemble each other very closely in terms of morphology (i.e. physical structure and appearance). But thanks to modern methods of genetic and molecular biological analysis, it is increasingly becoming clear that a "morphospecies" often consists of a complex of genetically distinct groups. The individuals in each group do not interbreed with individuals of the other types. These distinct groups are known as cryptic species.

Reconstructing distribution patterns

A case in point is the common freshwater amphipod *Gammarus fossarum*, which comprises three cryptic species, prosaically designated as types A, B and C. *Gammarus fossarum*, which lives in small rivers and streams across Central Europe, plays a key role in aquatic ecosystems – both as a fish food source and as a shredder of organic matter.

Anja Westram, a doctoral student in the Aquatic Ecology department, investigated the differences between these hidden species of *Gammarus fossarum* in Switzerland. Using genetic analysis, she studied the geographical distribution of the various types. "For the most part, the three types have different distribution ranges," says Westram. "Type A is found in the east, while type B mainly occurs in the west. In between, there's a contact zone, in the Rhine drainage basin, where both of these types are present." Type C was only found at three sites in the westernmost part of Switzerland. Westram assumes that the current distribution of the various cryptic species is the result of recolonization processes which took place at the end of the last glacial period (around 10,000 years ago). Thus, type A could have survived in an ice-free refugium in the Danube basin before spreading once again as the ice sheets retreated, while the recolonization of type B's habitats could have proceeded from a refugium in southwestern Europe.

As Westram emphasizes, a detailed knowledge of cryptic species is not only helpful for reconstructing historical distribution patterns. It is also extremely important for effective and appropriate management measures. "Cryptic species can differ markedly in their ecological requirements, their physiology or their behaviour," she says. "This has to be taken into account in the development and implementation of conservation measures, especially where keystone or endangered species are concerned."

Differences in vulnerability

Ecological differences are observable in the case of *Gammarus fossarum*. For example, type A has been shown to prefer stony habitats, while type B prefers plants and muddy substrate. In addition, Westram demonstrated that the degree of genetic differentiation between populations is much higher for type A than for type B. This suggests that type A populations are more isolated from each other, with limited gene flow occurring between them. According to Westram, this is only partly attributable to geographical barriers impeding such exchanges. Rather, the results suggest that type A is less mobile, and that mating of individuals from different populations is therefore rarer. Consequently, these populations show a higher degree of adaptation to local conditions, as their gene pool is not continually exposed to novel variants.

A, B or C? It's not possible to say which cryptic species this freshwater amphipod belongs to on the basis of appearance alone.

However, this differentiation probably makes type A more vulnerable to environmental changes and more susceptible to local extinction. With the loss of a local population, unique gene variants (not found in other populations) could also be lost. An event of this kind would therefore be more serious for type A – and the entire food web of which it is a component – than for type B, in which genetic diversity is more evenly distributed across populations. Westram concludes: "The example of *Gammarus fossarum* makes it clear that conservation measures are not always uniformly applicable for one species – you have to consider the different requirements and circumstances of each cryptic species." ○○○

Contact:
Professor Jukka Jokela, jukka.jokela@eawag.ch

Divining the future from the past

A violent volcanic eruption in eastern Anatolia 200,000 years ago, a high frequency of floods in the Swiss Alps 2,500 years ago, and a sudden change in ocean currents in the North Atlantic since the 1970s – with modern analytical methods, lake sediments or deep-sea corals can provide precise insights into environmental history. Research on climate archives can deepen our understanding of ongoing developments and sharpen predictions.

From Lake Baldegg on the Central Plateau to Lake Fälen at the foot of Mount Säntis or Lake Grimsel in the Bernese Oberland, from Lake Lauerz in the north to the Italian Lago di Garlate in the south – since 2008, the two doctoral students Stefanie Wirth and Lukas Glur have retrieved and analysed sediment cores from a total of 20 alpine and prealpine lakes. These layered deposits serve as a geological archive, extending 12,000 years back in time. As part of a project funded by the Swiss National Science Foundation, the researchers have focused their attention on those sample layers which provide evidence of flood events. These consist of turbidites, coarse material deposited between finer lake mud layers; put simply, they are chaotic layers punctuating a quiet sedimentary sequence. During floods, large amounts of freshly eroded material are rapidly washed away, transported by turbidity currents and deposited on the lake bottom. More than 4,000 layers of this kind were detected by the research team.

Agreement with measurement data

Hydrological measurements have been carried out for around 150 years, while (e.g. monastic) records of historical flood disasters go back at least 500 years. In terms of the period under study and the time scale of natural climate variability, this is a relatively short span. But it was sufficient to check the results of Glur and Wirth's analyses: the data obtained from the 20 lakes on the frequency and intensity of floods over this period are in close agreement with existing records and measurements. So now, for the first time, a data set is available which – thanks to this "calibration" – provides reliable information on extreme precipitation events and floods which occurred in the Alps over the rest of the period since the last ice age (i.e. 9,500 years). This is not merely of interest to actuaries concerned with flood risks.

Sediment core drilling on Lake Trüb at the foot of Mount Titlis and analysis of a bisected core.

Uneventful warm period

Recent climate models suggest that the projected warming will be accompanied by an increase in the frequency and intensity of rainfall events. So it seems appropriate to examine more closely the postglacial warm period which is known to have occurred 5,000 – 8,000 years ago. Mean annual temperatures in the Alps at that time were up to one degree higher than the average for the 20th century, so this period could be useful for comparison with current scenarios for the future. After being carbon-dated, these sediment layers were therefore analysed. Surprisingly, the data from both the southern and northern Alps for precisely this period show a rather low flood frequency. The highest flood frequency was observed for the Little Ice Age (1550 – 1850) and for various periods – e.g. 1,200, 2,500 or 9,500 years ago – which all tended to have cooler temperatures. "But," says Glur, "it would be wrong to conclude that floods will not increase in association with global warming." Rather, the background to these findings now needs to be studied in more depth, with the aid of pollen analysis. It is possible, for example, that erosion was inhibited by the higher treeline existing at that time, leading to lower turbidite deposition in sediments.

On another point, however, the findings are more conclusive: the idea that there could have been inverse correlations between the two sides of the Alps was not confirmed. Glur explains: "There is some regional variation, but thanks to the large number of lakes studied we've been able to show that there's generally a good agreement between the southern and northern Alps in the frequency and intensity of flood events."

Ocean currents documented by corals

Biogeochemist Carsten Schubert has used, not sediment cores, but deep-sea corals to investigate global warming. In close collaboration with the University of Basel, he showed that the influence of the cold Labrador Current in the North Atlantic has been decreasing continuously since the 1970s. The North Atlantic Oscillation (NAO) is the fluctuation in the atmospheric pressure difference between

the Icelandic Low and the Azores High. This weather system not only dictates whether winters in Europe will be cold and dry or warm and wet, but also influences ocean currents in the North Atlantic. On the continental shelf off Nova Scotia, the NAO seems to control the interaction between different water masses. During positive phases, the oceanography of the Northeast US continental shelf is dictated by a relatively warm (10 °C), saline, nutrient-rich water mass, originating from the Gulf Stream. If the NAO is in a negative phase, the Labrador Current – a relatively cold (6 °C), nutrient-poor water mass of subpolar origin – is dominant.

Drastic shift to warmer waters

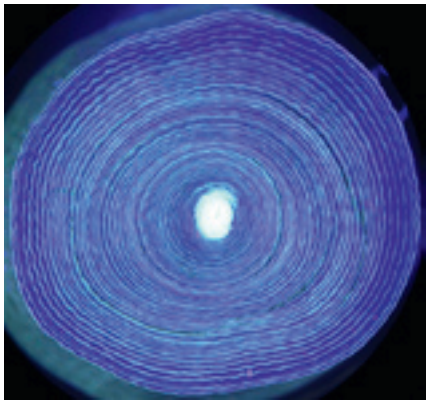
The researchers demonstrated that a drastic shift to a "warm water mode" occurred in the Northwest Atlantic in the early 1970s. They made use of the fact that, depending on their origins, water masses carry different nitrogen stable isotope signatures ($^{15}N/^{14}N$ ratios). The isotope signals are recorded in deep-sea corals, hundreds of metres below the surface, which feed on sinking organic particles. The corals thus permit reconstruction of the ocean current conditions prevailing over the last few decades. Precise dating is possible thanks to the corals' readily identifiable annual growth rings.

Isotope analysis of much older (fossil) deep-sea corals from the same area confirmed that, formerly, nitrogen isotope ratios had remained practically unchanged. This indicates that the change in ocean currents observed since the 1970s is a unique occurrence, at least over the past 1,800 years. The researchers suspect that there is a direct connection between this change in ocean currents and anthropogenic global warming.

Lake Van: answers and mysteries

The relevance of another Eawag project was grimly highlighted by two severe earthquakes which struck the Van region of Eastern Anatolia in October and November 2011, causing hundreds of deaths and injuries. In the summer of 2010, an international drilling team retrieved more than 800 metres of sediment cores from Lake Van. By analysing these cores, the researchers hope to be able not only to reconstruct the environmental and climatic history of the region, but also to answer questions about the frequency and severity of earthquakes. Deformations in the sediment and deposition from seismically triggered turbidity currents make it possible to compile an unprecedented time series of such events. Laboratory studies are ongoing at Eawag and at Bonn University. But it is already clear that no chronology of seismic activity to date has extended so far back in time. Provisional datings of volcanic ash from the deepest layers indicate ages of up to 500,000 years. While sediment cores from Swiss lakes go back no further than the last ice age (i. e. about 12,000 years), Lake Van harbours deposits from three or four interglacial periods. Oak pollen provides evidence of warmer periods, while steppe vegetation pollen was deposited in sediments during colder periods. Remains of freshwater mussels recovered from the deepest sediment layers bolster hopes that the drillings will shed light on the earliest origins of the lake. At that time, it must have had an outlet, but when and how this was closed off is one of the unresolved mysteries of Lake Van. Today, it is a terminal lake, which is both saline (21 per mille) and highly alkaline (pH 9.8).

The sediment core drilling platform on Lake Van in Eastern Anatolia.



The annual growth rings of a deep-sea coral under ultraviolet light.

Contacts:
Flood history: Lukas Glur, lukas.glur@eawag.ch
Corals: Dr Carsten Schubert, carsten.schubert@eawag.ch
Lake Van project: Professor Rolf Kipfer, rolf.kipfer@eawag.ch; www.eawag.ch/vansee

Taking the river's pulse

On the Thur, researchers investigated how river restoration affects hydrological processes. Using groundwater sensors which measure electrical conductivity, they were able to calculate the travel time of infiltrating river water.

As the name suggests, the RECORD project (Restored Corridor Dynamics) is designed to collect a whole host of observations and measurements on the restored stretch of the Thur between Niederneunforn (Canton Thurgau) and Altikon (Canton Zurich). Cameras are used to document vegetation and river morphology, weather stations to record meteorological conditions, data loggers for hydraulic head, temperature and electrical conductivity, and soil sensors for hydrological, geophysical and biogeochemical parameters. "We want to understand the interactions between river, river corridor and groundwater processes," says project leader Mario Schirmer, a hydrogeologist in the Water Resources and Drinking Water department. For four years, the Thur's "pulse" was taken by researchers from Eawag, the Federal Institutes of Technology in Zurich (ETH) and Lausanne (EPFL), and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL).

More rapid infiltration

Although numerous river reaches have been restored in Switzerland, little is known about the effects of these interventions. Is biodiversity increased? Is water quality improved? How are exchanges between river water and groundwater affected? Are pollutants effectively degraded? According to Schirmer, "Only with a mechanistic understanding of all the processes involved can we assess the outcome of measures, make reliable predictions and improve future projects." To study the differences between a restored and a non-restored stretch, the researchers set up a second field observatory on a channelized section of the Thur near Felben-Wellhausen (Canton Thurgau).

In the RECORD project, Eawag focused in particular on water transport between the riverbed and groundwater, and on the behaviour of nutrients and pollutants within this system. The researchers used data on electrical conductivity – collected by means of groundwater sensors deployed in a number of observation wells – to determine how rapidly river water travels through the subsurface. The measurements indicated that, in the restored stretch, river water enters the aquifer in about a third of the time it takes in the channelized stretch. According to the experts, this is due to differences in riverbed morphology and bank structure.

Restoration of stretches close to groundwater wells may therefore be problematic: river water contains not only treated but also untreated wastewater – from overloaded sewers – contaminated with faecal bacteria and other pathogens. An adequate residence time in the soil ensures that such pathogens are broken down by microorganisms, so the water is then safe to drink. Schirmer says: "In the case of the restored river stretch, it takes the water an average of eleven days to reach the nearby pumping station." Under Swiss law, a residence time of at least ten days is specified, and restoration measures are prohibited in groundwater protection zones. Accordingly, the researchers recommend that such measures should be avoided in close proximity to pumping stations; alternatively, it may be possible for a groundwater well to be relocated.

Need for long-term monitoring

The fact that groundwater and drinking water quality may be adversely affected by more rapid infiltration is also shown by measurements of micropollutants. In the restored stretch of the Thur, groundwater near the riparian zone contains higher levels of pesticides and pharmaceutical residues, as these are degraded to a lesser extent than in the channelized stretch on account of the shorter residence time. However, restoration measures were shown to have favourable effects on nitrate levels. Schirmer suggests that the relevant biogeochemical processes may be facilitated by greater subsurface heterogeneity, leading to more efficient breakdown of nitrate.

Schirmer concludes: "RECORD shows how complex the interactions in a river system are – and that successes do not become visible overnight. In fact, certain developments take years or decades." In his view, long-term monitoring should increasingly be carried out on restored rivers. The Thur is a case in point: the field site is to be maintained and preparations are underway for a follow-up project.

How does restoration affect the river system as a whole? Answers are to be provided by a panoply of instruments deployed on the Thur.

www.eawag.ch/ar11/record

Contact:
Professor Mario Schirmer,
mario.schirmer@eawag.ch

Reconciling ecology and river engineering

Restoration projects should focus on habitat diversity and connectivity, which are key requirements for intact, species-rich surface waters. But ecology and flood protection can still go hand in hand.

Dynamic, near-natural watercourses and flood protection are not mutually exclusive. This view underlies the "Integrated river basin management" project pursued by Eawag in partnership with the Federal Institutes of Technology (EPFL and ETH) and the Swiss Federal Institute for Forest, Snow and Landscape Research, with support from the Federal Office for the Environment. In this project, ecologists investigated the conditions required for near-natural, species-rich streams and rivers, while river engineers studied how these ecological requirements can be taken into account in the construction of flood protection infrastructure or in restoration efforts.

Diverse habitats

"The diversity, size and connectivity of habitats are crucial factors determining how intact a watercourse is," says Armin Peter, leader of the sub-projects carried out by Eawag. However, as the investigations showed, river rehabilitation involves more than merely restoring a heterogeneous, near-natural morphology. On the Bünz (Canton Aargau) and the Sense (on the border between Cantons Bern and Fribourg), the researchers studied how the diversity of aquatic macroinvertebrates was affected by the morphology of near-natural and engineered river reaches. They found only limited differences in this respect. Peter explains: "As well as morphological diversity, other factors play an important role in promoting the occurrence of characteristic species in rivers." He cites in particular the need for sufficiently dynamic flow regimes and temperatures. In the case of the Bünz, a more intact ecosystem is probably prevented by artificial fluctuations in flow rates, as well as poor water quality.

Another point to be considered, according to the researchers, is that many species require different habitats in the course of their development. For example, amphibians or aquatic insects spend part of their life cycle in water and part on land. If the quality of the habitat required for a particular stage of development is inadequate, the species concerned cannot become established. The ecologists found that mayflies and caddisflies have difficulty reproducing on numerous reaches of the Bünz. One of the reasons is that, because of the flow regime, there are too few stones protruding from the water where the flies can lay their eggs.

Population networks

Ecosystem functioning is also dependent on the genetic diversity of populations. Such diversity is essential if species are to be able to adapt to changing environmental conditions and survive over the long term. Populations which have sufficient numbers of individuals and are interconnected with other populations will tend to have the requisite genetic diversity. How closely connected a population network needs to be to ensure genetic exchanges depends in turn on the species – and in particular on its mobility.

On the Sense, Peter's team showed that the mayfly *Baetis rhodani* has a similar level of genetic diversity throughout the study area. This species can easily overcome barriers, dispersing by air. In contrast, the freshwater amphipod *Gammarus fossarum* is mainly spread by passive downstream drift. Accordingly, *Gammarus* populations exhibit much greater genetic diversity at river mouths than in upstream reaches.

Channelized confluences often pose significant barriers to connectivity. River engineers involved in the project developed a model which showed that tributary mouth widening could considerably enhance both morphological heterogeneity and habitat diversity – without adversely affecting flood safety. ○ ○ ○

In the Bünz, researchers used bricks to create artificial egg-laying surfaces for insects and other invertebrates.

Sound decision-making

If a wide range of interests and needs – from conservation to flood protection – are to be taken into account, restoration projects can soon become highly complex. In such cases, integrated planning tools can promote transparent decision-making. An approach of this kind, based on decision theory, has been developed by researchers at the Systems Analysis, Integrated Assessment and Modelling department of Eawag. The method can be used to describe the state of a river section, identify deficiencies, define possible options and predict the outcomes of various measures. It is designed to make trade-offs between competing interests and goals more transparent, thus making it easier to find consensus-oriented solutions.

Contact: Professor Peter Reichert, peter.reichert@eawag.ch

www.rivermanagement.ch

Contact:
Dr Armin Peter, armin.peter@eawag.ch

Making murky water safe to drink

Many people in developing countries have to do without safe drinking water. Relief could be provided by a simple, low-maintenance water filter which is capable of clarifying and disinfecting even the murkiest water. Initial field tests in Kenya indicate that this treatment method is effective under everyday conditions. The system is now to be optimized for wider use.

Worldwide, hundreds of millions of people lack access to safe water. Worst affected are poor communities in developing countries who frequently lack not only safe drinking water but also any means of simply and reliably purifying available supplies. To make matters worse, widespread ignorance of basic hygiene often leads to the contamination of clean water with pathogens. What is needed is a simple, low-cost and effective method of treating water for household use. Over the past few years, a system of this kind has been developed by researchers in the departments of Process Engineering and Water and Sanitation in Developing Countries (Sandec). In this household treatment system, water is purified using so-called ultrafiltration membranes. The method is currently being field-tested in Kenya.

The local community in Esokota (Kenya) was initially sceptical about the effectiveness of the water filter.

Flow rate maintained for years

The membrane filters used consist of a thin, permeable plastic sheet, with a pore size of just 20 nanometres (millionths of a millimetre). This means that not only minute particles such as suspended matter, but also bacteria, parasites and even viruses can be effectively removed; raw water is thus both mechanically purified and disinfected. Because of their high purification efficiency, membrane filters are already widely used in industrial applications. However, these filters have one major disadvantage: they require frequent cleaning, as their permeability is reduced by the formation of a fouling layer on the membrane surface after a short period of operation.

For this reason, it used to be thought that such filters were not suitable for water treatment purposes in developing countries – the efforts and costs involved in regular cleaning of clogged membranes would be prohibitive. However, while working on her dissertation, environmental engineer Maryna Peter-Varbanets (now a postdoc at Sandec) made an interesting observation: although membrane filter permeability always declines fairly rapidly after cleaning, the water flux is stabilized at a low but constant level after two to four days; in a long-term study, she demonstrated that this flow rate is maintained over a period of years. On closer analysis, she also discovered why the membranes do not become clogged. Because of the low pressure in the system, the fouling layer is not compressed and biological activity leads to the formation of channels through which the water can flow.

The Eawag team saw the potential of this self-regulation. Peter-Varbanets explains: "Our results show that the flow is maintained over the long term at a rate of four to ten litres per hour and square metre, which would be far too low for an industrial application. But, with a membrane area of half a square metre, that level is sufficient to produce safe drinking water for a family in a developing country."

Based on laboratory tests with various water qualities, the researchers developed a prototype. At the heart of the treatment system is a series of membrane sheets arranged vertically and connected by a central pipe. The membrane module is placed in a closed plastic container, with raw water being fed in from above. Driven by gravity, the water passes through the membranes and then flows through the connecting pipe into a tank underneath. Here, it can be withdrawn via a plastic tap. The major

advantage of this design is that no pump – and no external power source – is required to force the water through the membrane.

Initial scepticism overcome

The next step is to assess the practical applicability of the system. To this end, Eawag is currently conducting field tests in Kenya. Selina Derksen, one of the researchers involved in these tests, says: "We selected several households at four different sites, with quite different drinking water quality in each case. The first group of households are connected to the public water supply network in Nairobi. Two other groups use highly turbid water, drawn from a river or from a heavily polluted pond. In the fourth group people collect water from a borehole."

The conclusions drawn by Peter-Varbanets after almost a year of operation are encouraging: "People are satisfied with the system and use it regularly. With just one exception, all of the 24 systems installed are still in operation and working perfectly." Initially, she recalls, local communities were sceptical: "People didn't believe we could purify water without adding chemicals. But when they saw the clear water coming out of the tank, they were enthusiastic."

The filters are being closely monitored until the end of the test phase. Once a month, a Kenyan partner visits the participants to find out whether the filters are still working properly, and to collect water samples for analysis. Derksen says: "In an apartment in Nairobi, we've set up a small laboratory, where we can detect *Escherichia coli*, a bacterial indicator of contamination, in the water." But the presence of bacteria in a sample does not necessarily mean that the membrane is no longer effective: "It's also possible, for example, that the clean-water tank has been contaminated by spillage of raw water."

Optimization for scale-up

The microbiological analyses confirm that the new treatment system represents a major advance. "In most cases where contaminated water is fed in, no indication of pathogens are found after treatment," says Peter-Varbanets.

In a makeshift laboratory, Selina Derksen analyses samples of treated water for E. coli bacteria.

Accessible planning guidelines

In accordance with the goal of making expertise, technologies and tools available to practitioners and authorities, Eawag researchers have produced a set of practical guidelines designed to facilitate the planning and implementation of water management infrastructure projects in developing countries. The "Community-Led Urban Environmental Sanitation Planning Guidelines" are written in accessible language, so that they can also be used by non-experts. Defining seven planning steps, the guidelines explain how such processes can be initiated, how the situation can be assessed and problems prioritized, taking the community's needs into account, and how an action plan can then be developed and implemented. It is emphasized that successful implementation and sustainable solutions require the involvement of all stakeholders from an early stage in the process.

www.sandec.ch/clues

In view of the positive results, the researchers now plan to optimize the system so that it can also be used on a larger scale. In cooperation with industrial designers from Zurich University of the Arts, the team has developed three designs for serial production. "Firstly," says Peter-Varbanets, "we've taken technical considerations into account, such as the need to ensure that the membrane sheets are not accessible from the outside. Secondly, we've tried to design the filters in such a way that they will be acceptable to the local users." For this reason, the designers travelled to Kenya in October 2011, to find out what users consider to be particularly important.

And, as Peter-Varbanets points out, "If the new treatment systems are to be widely used, we also need to tackle economic and logistical questions." A household survey indicated that most respondents would be prepared to pay USD 18–30 for a system of this kind. The researchers are now exploring how production could be financed so that the filters could be sold at this price. "We're also looking into possible marketing and distribution channels," Peter-Varbanets adds. Clearly, the type of individual supervision provided in the field tests would not be possible on a larger scale. ○ ○ ○

www.eawag.ch/membranefilter

Contact:
Dr Maryna Peter-Varbanets, maryna.peter@eawag.ch

China – a future leader in on-site wastewater treatment?

Faced with acute water shortages, many rapidly expanding cities in China need to pursue new approaches to wastewater management. As the country implements technologies developed in the West, it could ultimately become a model for Europe.

No flush toilets or sewerage systems requiring large amounts of water to dispose of human faeces and urine, no extensive sewer networks conveying wastewater from thousands of households to a centralized treatment plant – instead, a local system for treating and recycling wastewater in every district or even in every building: this could well be the future of urban water management.

Limited potential in the West

As well as saving water, decentralized systems of this kind permit a much more flexible response to the expansion of urban areas than is possible with centralized wastewater treatment. On-site systems can be rapidly installed to meet local requirements and do not have to be integrated into an existing sewer network. The high costs of sewer construction and maintenance are avoided. Small-scale treatment plants could become affordable mass-produced goods, like washing machines.

Christian Binz, an economic geographer working in the Comprehensive Innovation Research in Utility Sectors (Cirus) department, says: "Decentralized approaches are especially suitable in regions of Africa, Northwest China, India or Indonesia where there is a combination of water scarcity and rapid urban growth – with only limited infrastructure in place." In cooperation with the Chinese Academy of Sciences in Beijing, Binz is studying the development of the wastewater sector and the application of innovative on-site treatment methods in China.

If new technologies are to be implemented, the relevant know-how must first be available. Using literature searches, expert interviews and market analyses, the researchers identified the key actors in the field of on-site wastewater treatment worldwide and investigated how they interact and what role is played by China. "Today," says Binz, "the technological knowledge is mainly concentrated in developed countries." But here, as he points out, the potential for on-site systems is severely limited by the extensive existing infrastructure, which is dominated by centralized approaches – sewer networks and large-scale wastewater treatment plants. A niche market exists only in peripheral areas.

In China, however, where the wastewater treatment sector is still undergoing development and there is a need to address pressing environmental problems, new technologies can be more readily implemented. Binz explains: "To some extent, the country obtains the knowledge it requires from the West, but in certain fields it already has considerable expertise of its own – in membrane bioreactor technology, for example, it is now among the world leaders." In the future, he is convinced, innovations will increasingly come from China.

Overcoming obstacles to innovation

But, according to Binz, technological expertise in itself is not enough – the right environment is just as important. Here, much remains to be done, as the example of Beijing illustrates: "In the metropolis, on-site systems can be found in numerous hotels and residential blocks. Over 2,000 small-scale plants have already been installed, and these plants are usually built and operated by Chinese companies." So while European corporations continue in many cases to advocate the approach which prevails in the West, a specialized local industry is emerging. "And yet," says Binz, "because appropriate business models, service concepts and support from the authorities are generally lacking, the development process is extremely chaotic." The new approach has yet to be embraced by scientists and policymakers.

In the wastewater treatment sector China already has considerable expertise and an emerging industry.

Nonetheless, Beijing is playing a pioneering role in on-site wastewater treatment, as water scarcity and rapid expansion make innovative solutions essential. In addition, the city was eager to present itself in a progressive light for the Summer Olympics in 2008. "In the rest of the country," says Binz, "people have so far been relying largely on conventional technologies."

But if coordination does improve among the various actors responsible for the development of the country's wastewater infrastructure, Binz believes that China could – at least in part – leapfrog the centralized approach and directly adopt on-site technologies, thus perhaps ultimately becoming a model for the West. ○○○

www.eawag.ch/jb11/tsum

Contact:
Christian Binz,
christian.binz@eawag.ch

Drinking water teeming with bacteria

Anyone who drinks tap water will also be consuming microorganisms, which occur naturally in drinking water and play an essential role in water treatment. But surprisingly little is known about the microbiological processes involved.

The ready availability of safe drinking water may be something we take for granted, but how much do consumers – or experts – actually know about this vital resource? As regards the role played by microorganisms in particular, scientists are still largely in the dark. "We know more about bacteria in wastewater than in drinking water," says Frederik Hammes of the Environmental Microbiology department (Umik). The method specified by Swiss legislation for assessing the microbiological quality of drinking water is the heterotrophic plate count, which has been in use for over a century. However, this method only detects bacteria which can be grown on culture media – about one per cent of the total microorganisms present.

Degradation of organic carbon

Thanks to modern analytical techniques such as the flow cytometry method developed at Eawag, it is now known that far more bacteria occur in drinking water than had long been assumed. According to Karin Lautenschlager, who wrote her dissertation on this topic at Umik, "Drinking water in the city of Zurich contains around 100,000 bacterial cells per millilitre." This, she stresses, is not a public health emergency, but a normal value for Switzerland.

Bacteria are a natural, and generally harmless, constituent of drinking water. In fact, as demonstrated by Lautenschlager's investigations at the Zurich Water Works treatment plant in Lengg, they help to purify it and maintain its biological stability. At the Lengg plant, drinking water is produced from lake water in a series of treatment steps. Raw water is first disinfected by means of ozonation and then passed through activated carbon and sand filters. As is the norm in Switzerland, there is no subsequent chlorination step.

Lautenschlager explains: "The filter surfaces are covered by biofilms – a layer of microorganisms." These bacteria play a key role in the purification process, degrading organic carbon compounds and thus limiting the nutrient content of the water. This prevents uncontrolled growth of bacteria during the distribution of drinking water, promoting biological stability. "The high level of bacterial diversity probably also impedes the growth of pathogens," Lautenschlager adds. But where the bacteria originate remains largely unclear.

Bacteria from the filters enter the distribution network with the treated water. Samples collected at a number of locations at various distances from the treatment plant confirm that microbiological stability is consistently maintained: whether water has resided in the system for 2 or 50 hours, the samples showed similar total cell concentrations. In addition, the composition of microbial communities showed more than 80 per cent similarity at the different locations and even over a 2-year sampling period.

Overnight stagnation

To study the quality of the water ultimately supplied to consumers, Lautenschlager also analysed water samples from twelve different household taps which had not been used during the night. In all the samples, bacterial cell concentrations were found to have risen two- to threefold overnight. A 50–100 per cent change in the microbial composition was also observed. In six cases, the concentrations measured actually exceeded the specified guide values. So far, Lautenschlager can only speculate as to the reasons: "Bacterial growth could be promoted by different piping materials, higher temperatures or the lengthy stagnation period."

At the Lengg drinking water treatment plant in Zurich, huge sand filters are used to purify lake water.

While these findings are not likely to represent a health hazard, Lautenschlager believes they do underline the need for reliable test methods and a better understanding of microbiological processes within the drinking water system. In the meantime, as she points out, a short flushing of taps should be sufficient to considerably reduce microbial concentrations. After five minutes' flushing (equivalent to roughly 30 litres), the quality of tap water was restored to the level found in the rest of the network. ○○○

www.eawag.ch/jb11/drinkingwater

Contact:
Dr Frederik Hammes, frederik.hammes@eawag.ch

Producing fertilizer from wastewater

Wastewater is more than just waste – it contains valuable nutrients. Using an innovative process, nitrogen can be recovered from wastewater and turned into a fertilizer. This saves energy and resources, and increases cost-effectiveness. A pilot plant at Glattbrugg (Canton Zurich) shows that the process can be implemented on an industrial scale.

In the future, farmers could once again obtain fertilizers from wastewater treatment plants (WWTPs). These would not be in the form of sewage sludge, the spreading of which has been prohibited in Switzerland since 2006 (as well as nitrogen and phosphorus, sewage sludge contains pathogenic organisms and potential pollutants, such as residues of medicines). Instead, if the vision of process engineers Hansruedi Siegrist and Marc Böhler is realized, a ready-to-use fertilizer would be produced with the aid of an advanced process at WWTPs.

First full-scale plant in Switzerland

The two researchers from the Process Engineering department of Eawag are studying how this could work in practice at the Kloten/Opfikon WWTP, in a project supported by the Canton Zurich Office for Waste, Water, Energy and Air (AWEL). At the treatment facility in Glattbrugg, the team installed a pilot plant in which stripping technology is used to recover nitrogen from wastewater and produce an agricultural fertilizer. In the "air stripping" process, volatile components (in this case nitrogen) are transferred from a liquid into an air stream. The pilot plant represents the first full-scale implementation and testing of this process in Switzerland.

WWTPs currently use elaborate processes to eliminate nitrogen from wastewater (see box), so that it is not released into surface water, leading to eutrophication. But this means that the nutrient itself is lost. Böhler says: "If instead we use it to produce a fertilizer, we can return it to agriculture and thus close the nitrogen cycle – from fertilizer, through food, excretion into wastewater, then back to a fertilizer." In addition, this method of producing fertilizer requires less energy than the synthesis of ammonia by the Haber-Bosch process. Air stripping also helps to reduce energy consumption at the WWTP and ease conventional nitrogen elimination. The fact that the liquid fertilizer which is produced can be readily sold is another significant economic argument.

Hansruedi Siegrist and Marc Böhler of Eawag with Christoph Liebi and Pascal Stutz of the Kloten/Opfikon WWTP (from right to left). Behind them are the three reactors where the stripping process takes place.

Optimizing temperature and pH

The stripping system at Glattbrugg comprises a series of three reactors. The sludge liquid, a by-product of sludge thickening and dewatering, contains around 20 per cent of the nitrogen arising at the WWTP in the form of ammonium. Inside the 10-metre-high reactor columns are packing elements, with a honeycomb structure, through which the sludge liquid descends. The nitrogen stripping step takes place in the second reactor, where a countercurrent of air is forced up through the liquid. Ammonium is first converted into volatile ammonia, which is then released as a gas from the liquid into the air stream and thus separated out.

As Böhler points out, "The process requires a high pH and a sufficiently high temperature." Alkaline conditions are needed so that the ammonium can be converted to dissolved ammonia gas, and higher temperatures lead to increased volatility. Accordingly, waste heat from wastewater treatment operations is used to raise the temperature of the sludge liquid to 60 – 65 °C, and sodium hydroxide is added until the sensor in the reactor indicates a pH of 9.5. "Under these conditions, about 90 per cent of the nitrogen can be recovered," says Böhler.

Lower sodium hydroxide consumption

However, to further improve the efficiency of the system, the researchers incorporated a preliminary step – carbon dioxide pre-stripping. In this process, which operates on the same principle as nitrogen stripping, CO_2 is removed from the sludge liquid by a stream of fresh air, which is blown into the first reactor. Böhler explains: "This already considerably increases the pH, and the operator then only has to add about half the sodium hydroxide that would normally be needed for nitrogen stripping. Again, this conserves resources and increases the cost-effectiveness of the system."

Lastly, in the third reactor, the ammonia-laden air stream from the nitrogen stripping step comes into con-

tact with liquid sulphuric acid. In a reversal of the stripping process, the gaseous ammonia is dissolved in the liquid and combines with the acid to form ammonium sulphate – a commercial liquid fertilizer. The ammonia-free air is recirculated to the second reactor to be re-used in the stripping process.

The nitrogen content of the fertilizer produced at the pilot plant amounts to around 26 tonnes a year. Sales are already assured for a 10-year period, thanks to a contract with a local fertilizer dealer.

Promising tests with urine

The researchers are also investigating whether the stripping system can be used to process source-separated urine in combination with sludge liquid. For some years, Eawag has been researching cleaner and more efficient technologies for treating human waste products. Urine source separation represents a highly promising wastewater management approach in terms of protecting surface waters, easing the load on WWTPs, reducing water consumption and recovering nutrients.

Initial tests indicate that source-separated urine can also be readily processed in the pilot plant. With a 10 per cent urine content in the sludge liquid, nitrogen concentrations were increased by 40 per cent.

Böhler comments: "With a higher nitrogen content, the overall costs and energy requirements of the process are lowered, as the fertilizer yield increases markedly with only a low rise in operating costs."

To increase the surface area, the reactor columns are fitted with plastic packing elements arranged in a honeycomb structure.

Lower nitrogen emissions better for the climate

Wastewater treatment is a source of greenhouse gas emissions. Of particular concern is nitrous oxide (N_2O), a gas which has approx. 300 times the global warming potential of CO_2 and also damages the ozone layer. In a joint Eawag/Empa project, Pascal Wunderlin is studying how N_2O emissions from WWTPs can be reduced. N_2O arises mainly from the biological treatment step, in which nitrogen is removed from wastewater. This process involves, firstly, microbial oxidation of ammonia to nitrate (nitrification) and then the reduction of nitrate by other microorganisms to nitrogen gas (denitrification), which is released into the atmosphere.

According to Wunderlin, "Analysis of nitrogen isotopes in nitrous oxide shows that N_2O emissions mainly derive from nitrification." Especially if operating conditions are not optimal, these emissions will be increased. For example, with a high nitrogen load in wastewater the microbial processes are "pushed to the limit". By preventing such peak loads, the stripping method used to produce fertilizer could also help to reduce the formation of nitrous oxide.

www.eawag.ch/jb11/nitrousoxide

Phosphorus fertilizer also an option

Recovery not just of nitrogen but especially of phosphorus is an attractive prospect, as this nutrient will become increasingly scarce. Urine source separation will thus become more important; today, urine is already being collected with the aid of waterless urinals, e.g. by SBB (Swiss Federal Railways) and certain restaurants. Among the pioneers in this area is Eawag, which has installed so-called NoMix toilets in its own buildings.

If magnesium is added to source-separated urine, phosphorus is precipitated in the form of magnesium ammonium phosphate (also known as struvite) and can be readily filtered out. Struvite is a phosphate fertilizer which is essential for agriculture – in other words, another marketable product.

The idea of the wastewater treatment plant as a producer of fertilizers has attracted favourable public attention. In 2011, for example, the Eawag scientists, together with the Kloten/Opfikon WWTP, received a Zurich "Climate Award" prize for innovation. In January 2012, the team also earned a special recognition award, as their project was one of three nominated for the Swiss Environmental Prize sponsored by the "Pro Aqua – Pro Vita" Foundation. ○○○

www.eawag.ch/jb11/stripping
www.eawag.ch/jb11/ako (in German)

Contact:
Marc Böhler, marc.boehler@eawag.ch
Professor Hansruedi Siegrist, hansruedi.siegrist@eawag.ch

Taking a holistic approach

With new methods, an organism's genes or proteins can now be analysed potentially all at once. This allows ecotoxicologists to gain a more detailed understanding of the impacts of chemicals or other stressors.

"If you want to understand why a chemical substance is toxic to fish, water fleas or algae," says Kristin Schirmer, head of the Environmental Toxicology department, "what you need is a holistic understanding of the molecular and biochemical processes occurring in these organisms' cells." Only then, she believes, is it possible to assess ecotoxicological hazards and develop reliable risk minimization strategies.

Genes respond to stress

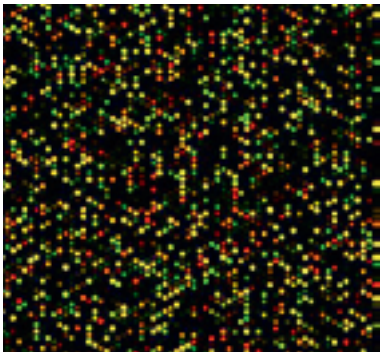
The research discipline pursuing this new approach is known as systems biology. Today, thanks to technological advances in gene sequencing and bioinformatics, it is possible to explore simultaneously how stressors affect the activity of all the genes of an organism, or the synthesis and breakdown of its proteins and metabolites. Transcriptomics analyses the set of all RNA molecules produced in a cell according to the genetic blueprint encoded in the DNA (transcriptome); proteomics is concerned with the complete set of proteins (proteome), and metabolomics with that of metabolites (metabolome). Automated analytical techniques permit the processing of the huge quantities of data involved – the single-celled green alga *Chlamydomonas reinhardtii* alone has around 17,000 genes, and the zebrafish *(Danio rerio)* 29,000.

Schirmer and her team apply systems biology methods to investigate the impacts of chemical substances, nanoparticles or adverse environmental conditions on the complex cellular machinery of aquatic organisms. Beat Fischer, for example, has studied how *Chlamydomonas* algae respond when they are exposed to photosensitizers. Here, reactive oxygen species are formed which can have detrimental effects on cells. Transcriptome analyses of around 2,700 genes revealed that the activity of a number of genes is markedly increased under stress. As Fischer explains, "Some of these genes are involved in oxidative stress defence mechanisms and in detoxification. The tolerance of the algae to reactive oxygen species is thus increased, providing a degree of protection against damage."

Fischer also found that most of the genes responsible for photosynthesis show decreased activity. This suggests that, for protective purposes, the photosynthetic activity of the algae is reduced and the harvesting of light energy is restricted.

Problematic nanoparticles

Ksenia Groh is studying the toxic effects of silver nanoparticles on zebrafish embryos. Her aim is to discover whether the adverse effects are caused directly by nanoparticles or rather by the release of silver ions. Proteomics analysis of 3,000 proteins indicated that cellular protein patterns are mainly affected by the presence of ions. However, Groh also observed that certain changes in the proteome were solely attributable to the influence of nanoparticles.



DNA microarrays are collections of DNA spots representing thousands of genes. These "gene chips" can be used to investigate how chemicals affect the activity of all the genes in an organism. Levels of activity are indicated by differences in colour intensity.

The fact that *Chlamydomonas* algae exposed to silver also exhibit changes in the transcriptome and proteome was shown by studies performed by Smitha Pillai. As the next step – true to the systems biology goal of understanding organisms in their entirety – Pillai intends to investigate how the altered gene activity and protein expression patterns affect the morphological and physiological characteristics of the algae.

Contact:
Professor Kristin Schirmer,
kristin.schirmer@eawag.ch

Fate of nanosilver in WWTPs

Synthetic nanoparticles are found in a wide variety of consumer products – e.g. cosmetics, deodorants, toothpastes, paints and varnishes – and may also be released into the environment. Studies by Eawag and other researchers indicate that these minute particles (measuring 1–100 nanometres) can have adverse impacts on aquatic organisms. Nanoparticles discharged to the sewer system will be transported to the next wastewater treatment plant. What happens there – specifically in the case of silver nanoparticles – was investigated by Ralf Kägi of the Process Engineering department.

With the aid of modelling and experiments carried out at the Eawag pilot plant, Kägi found that, as a result of treatment, over 95 per cent of nanoparticles are eliminated from wastewater and end up in sewage sludge. In addition, a large proportion of the nanosilver is rapidly converted into sparingly soluble silver sulphide. It can be concluded that only small amounts of silver nanoparticles enter receiving waters in treated effluent.

Contact:
Dr Ralf Kägi, ralf.kaegi@eawag.ch

Developing alternatives to animal testing

Tests involving fish are routinely conducted in the chemical industry. Environmental toxicologists at Eawag are developing alternative methods which produce comparable results – and also require less space. However, they cannot yet be used to assess the risks of all substances.

Each year, for the sake of the environment, hundreds of thousands of fish are used in animal testing worldwide. One of the methods used to assess the risks of chemicals is the acute fish toxicity test, in which fish placed in tanks are exposed to a test solution.

The number of dead fish recorded after four days provides authorities, manufacturers and researchers with an indication of the toxic effects of, for example, a newly developed pesticide or a new paint for wood products. As the end is desirable, but the means are ethically questionable, Eawag is working on two alternative test methods.

Replacing fish with cells …

The first method, rather than employing whole fish, only involves the use of gill cells isolated from a rainbow trout. "These cells can be cultured in unlimited quantities," says Katrin Tanneberger of the Environmental Toxicology department. Using gill cells as a replacement for fish makes sense because the gills are the main point of contact between fish and the environment. This organ is constantly subjected to a flow of water and is the first to react to waterborne pollutants. According to Tanneberger, another advantage of gill cells – apart from the fact that no further fish need to be killed – is that, compared to the acute fish test, the test period is reduced and less toxic waste is generated.

The method also saves space: gill cells are exposed to chemical substances in plates containing small wells, and so the assay can be performed in an area the size of a postcard. Toxicity is quantified using fluorescent dyes. The degree of fluorescence varies according to the level of cellular activity – a dark well indicates that all the cells have been killed by the test substance.

… or fish eggs

In the second alternative method, fertilized zebrafish eggs are used. "Within a few days, these develop into fish larvae," says Melanie Knöbel, who also works in the Environmental Toxicology department. Because the egg has a transparent envelope, it is possible to observe, for example, the embryo's heartbeat. The more toxic a chemical is, the fewer embryos with a detectable heartbeat will be left after two days.

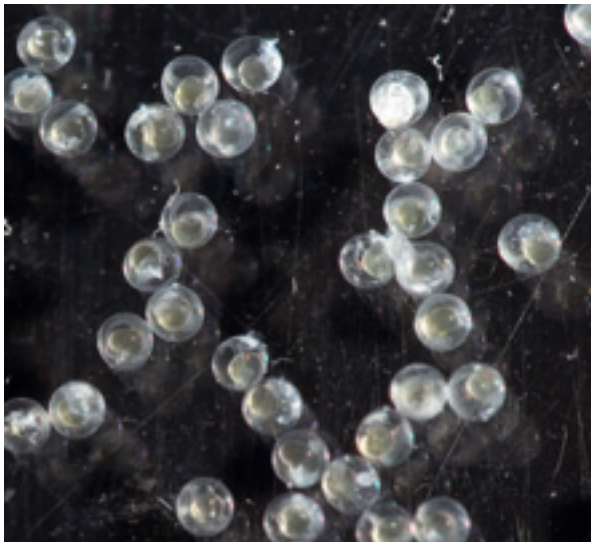
In the EU, fish embryos are not subject to animal welfare regulations since their nervous system is still underdeveloped at this stage, and so studies of this kind are not regarded as animal testing.

However, the fish embryo toxicity test cannot be used in all cases. Knöbel explains: "Neurotoxic substances will sometimes not be clearly identified as such because the fish embryo's brain is not yet fully formed." This limitation also applies to the test involving gill cells, which are likewise incapable of reacting in the same way as nerve cells.

Combining cell lines

Also potentially problematic are substances which only exert their toxic effects after being taken up and metabolized by the liver. Because transformation processes of this kind only occur to a limited extent in gill cells and fish eggs, the alternative methods may also be inadequate here too. "But," says Tanneberger, "that was only the case for one of more than 30 compounds tested."

According to Kristin Schirmer, head of the Environmental Toxicology department, one possible solution would be to simulate the metabolism of the fish by first transforming the test substances with liver enzymes before exposing the cell lines or embryos. Another possible approach would involve the development of an active liver cell line. Comparable cellular models are also conceivable, she believes, for the investigation of neurotoxic effects. Schirmer says: "We're working on test methods of that kind. My 'dream' is to combine various cell lines so that we can model the relevant processes occurring in the fish organism – and thus continuously reduce the need for experimental animals." ○○○



Fertilized zebrafish eggs offer an alternative to toxicity tests involving adult fish.

www.eawag.ch/jb11/animaltesting

Contact:
Professor Kristin Schirmer, kristin.schirmer@eawag.ch

Comprehensive lake fish inventory

While fishery statistics give details of the species caught or used for stocking, little is known about the actual diversity of fish in alpine and prealpine lakes. Now, a team of researchers led by Eawag is compiling an up-to-date inventory of fish populations on a sound scientific basis.

1

Surveying the hidden depths of lakes

Under Swiss fisheries legislation, the distribution of fish species is to be documented. Similar provisions are included in the EU Water Framework Directive. Statistical data are required to indicate which species are endangered and need to be protected. In fact, however, surprisingly little is known about the species occurring in Europe's largest lakes. Usually, the only available evidence comes from fishery statistics. These indicate how many of which species of fish have been caught or used for stocking, but the actual species diversity remains undocumented. In 2010 – the International Year of Biodiversity – Eawag therefore launched a project designed to shed light on the lakes' hidden depths. In "Projet Lac", lake habitats are systematically sampled, the specimens found are identified, measured and photographed, and the catch data are analysed statistically. In addition, a reference collection of preserved fish is being built up at the Natural History Museum in Bern. This should enable future generations of researchers to document changes.

For project leader Ole Seehausen of Eawag and the Bern University Institute of Ecology and Evolution, the results to date give rise to mixed feelings. On the one hand, it is clear from the sampling campaigns that numerous fish species have disappeared over the last 150 years – around 30 per cent in the case of Lake Murten, for example. On the other hand, the sampling nets have also brought to light certain species which had not been known to occur in the lakes in question – e. g. Italian rudd *(Scardinius hesperidicus)* and Prussian carp *(Carassius gibelio)* in Lake Murten. In Lake Brienz, whitefish were found which appear to spawn in very deep waters; genetic analysis should now reveal whether this is a previously undescribed species. What else does Seehausen expect to learn from the new data? His team is investigating the factors underlying the emergence and disappearance of species. Ultimately, their findings should also support the effective deployment of resources in species and habitat conservation efforts – e. g. lakeshore restoration projects or measures designed to improve water quality.

2

3

1 The vertical gill nets with variable mesh sizes used for sampling provide information on fish stocks in deep waters, as here in Lake Brienz, where whitefish were also captured at a depth of 250 metres.

2 Sampling sites on the lake can easily be relocated with the aid of echo-sounding and GPS equipment and precise charts.

3 Boldly going where no fisherman has gone before: Ole Seehausen uses electrofishing equipment to collect samples near the rocky lakeshore.

4 Grégory Tourreau – a diving specialist – hauls in a net set in the littoral zone the previous evening. Clearly, this is an attractive habitat for perch.

5 No fish is too small to be recorded: fish biologist Guy Périat sorts small fry from a shallow-water habitat.

6 Back on shore, fish are carefully removed from the nets, sorted…

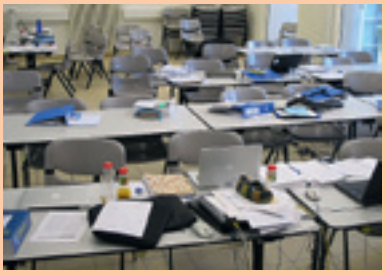
7 …weighed…

8 …measured and photographed.

Research

Teaching

Consulting



About 30 per cent of Eawag's scientific staff teach at the Federal Institutes of Technology in Lausanne (EPFL) or Zurich (ETH). In 2011, Eawag researchers were also involved in teaching and training at cantonal universities and universities of applied science, particularly in Bern, Zurich and Neuchâtel. They bring an applied research perspective to university teaching, providing examples from practice to supplement course content.

Numerous young scientists also receive training at the Eawag sites in Kastanienbaum and Dübendorf. Resources allocated to the supervision of doctoral, Bachelor's and Master's students continue to rise year by year. Overall, the number of Bachelor's and Master's dissertations supervised has increased by 50 per cent since 2008. While this is placing growing demands on Eawag's physical and other infrastructure, it is also boosting the supply of water professionals entering the Swiss labour market. The high quality of the education provided is reflected by the variety of awards won by young graduates.

Training for professionals is offered by the PEAK programme (practice-oriented Eawag courses). Here, Eawag cooperates closely with the Swiss Water Association (VSA). Since 2011, a committee of Eawag researchers has supported the organization of the PEAK programme, which last year focused on water protection and river restoration.

Petra Kunz

Transferring knowledge to practitioners

"It's not so easy to explain how a bioassay used in assessing water quality actually works," says ecotoxicologist Petra Kunz. This is what she has found when giving courses at the Ecotox Centre for professionals from authorities, industry or contract laboratories. She explains: "Most of the participants know that, in chemistry, the concentration of a substance in water can be unequivocally determined. But we work with living organisms such as crustaceans or fish, so the results can't be read off directly – they need to be interpreted." Kunz is involved in the development and certification of these biological test systems and makes them available to interested parties. How would she describe her motivation? "Through my work, I'd like to help improve the quality of surface waters." Among the topics Kunz is currently focusing on is mixture toxicity: "While we know quite a lot about individual substances, it's much more difficult to assess the impacts of cocktails of chemicals on natural waters." Although water professionals are aware of this issue, the feedback she receives from course participants shows that there is still room for improvement in the transfer of knowledge between researchers and practitioners.

Hong Yang

Globalization of water resources

"I'm the one they're looking for!" Hong Yang thought when she saw an Eawag job advertised in the *Economist* in 1999. After studying Geography in her native Beijing, she had gained her PhD in Australia and was working as an Assistant Professor at the University of Hong Kong. She was particularly interested in the relations between water, food and the environment. Yang landed the job and moved to Switzerland. Over the past 12 years, she has helped to establish this new field of research at Eawag. Using computer models, she studies for example, the impacts of climate change on water availability and food security. "But what's just as important as our research," says Yang, "is communicating our findings to policymakers." To this end, she collaborates with local research partners – or gives courses herself – in China, in developing countries and in Europe. For more than five years, she has also been lecturing at the University of Basel. "I try to raise students' awareness of the globalization of water resources." Via food exports, as she points out, water used to cultivate crops is transferred to other regions or continents: "This contributes to water scarcity in the region of origin."

Samuel Derrer

Championing vocational training

In performing experiments, a chemistry lab technician will analyse a question and try to draw conclusions. "And yet," as Samuel Derrer knows from experience, "the outcome of an experiment is often unpredictable." For the past year and a half, Derrer has been head of Vocational Training at Eawag, where he is currently responsible for 16 trainee chemistry and three biology lab technicians, three administrators and two IT systems engineers. Having originally trained as a lab technician, Derrer studied Chemistry at what was then known as the "Technikum Winterthur" and took his doctorate at Cambridge University. He subsequently spent twelve years working as a researcher in the Swiss perfume industry: "Then it was time for a change." As a member of the Cantonal Examination Commission, he learned of the retirement of his predecessor at Eawag – and took advantage of this opportunity. "It wasn't such an unusual move," he reflects. "My entire career has involved contacts with trainees, undergraduates or doctoral students." From the outset, Derrer has brought his own style to the new role, and he emphasizes: "One of my priorities is constantly to remind people about the importance of vocational training."

Committed to cooperation

In its teaching activities, Eawag cooperates closely with various institutions in Switzerland's higher education sector. Collaboration with the EPFL has been further expanded. In addition, Eawag offers continuing education programmes for practitioners and promotes knowledge transfer to developing and emerging countries.

In 2011, Eawag pursued its active commitment to teaching. Overall, scientific staff invested around 4,900 hours in a variety of teaching activities. At the Federal Institutes of Technology in Zurich (ETH) and Lausanne (EPFL) and the University of Bern, a total of 9 full professorships are held by Eawag researchers. Another 14 Eawag staff serve as titular professors at various Swiss higher education institutions. In 2011, two Swiss National Science Foundation professorships also went to Eawag staff (see page 48).

Closer collaboration with the EPFL

A central element of these activities is Eawag's close cooperation with the ETH Zurich. In addition, Eawag has intensified its collaboration with the University of Bern in the social science fields of innovation research and policy analysis. Teaching activities have been expanded at the University of Bern in the area of fish ecology and evolution, and cooperation has been strengthened with the University of Neuchâtel in hydrogeology and with the University of Zurich in environmental psychology. Since August 2011, in partnership with a number of other higher education institutions and non-profit organizations, Eawag has been contributing to the Bern University of Applied Sciences Certificate of Advanced Studies (CAS) course on "Integrated Water Resource Management in the context of developing and transition countries". Through its participation in various collaborative research ventures and infrastructure projects, Eawag is also actively supporting Switzerland's higher education system.

Closer collaboration is also being pursued with the EPFL. Alongside Eawag Director Janet Hering, drinking water specialist Urs von Gunten was appointed to a full professorship at this institution in 2011. As Professor of Drinking Water Treatment, he is concerned not only with drinking water quality but also, for example, with the removal of micropollutants from wastewater.

As well as giving introductory lectures on environmental chemistry for environmental engineers, von Gunten runs a course for Master's students on water and wastewater treatment. He also has a strong practical focus, supervising students in the development and implementation of so-called design projects. The aim of these projects – proposed by industry and government – is to design viable solutions for specific practical problems (e.g. in the wastewater treatment sector). In addition, von Gunten leads a research group at the EPFL which interacts closely with his Eawag group, with joint seminars being conducted alternately at the EPFL and Eawag.

Doctoral students attending the Summer School at Kastanienbaum learned how to "read" sediment cores and what information can be derived from them.

Courses for young researchers

Another key component of Eawag's teaching activities are the PhD Summer Schools. Though primarily addressed to doctoral students, these events – organized by Eawag researchers – are also open to postdocs and to outstanding Master's students. In 2011, a Summer School entitled "Sediments as archives of environmental change" was held at Kastanienbaum. The 20 participants learned how information on environmental changes, extreme events (e.g. floods) and human impacts (e.g. pollution) is preserved in sediments and how this can be read out of sediment cores.

The 2-week course comprised lectures, discussions, practical field work on Lake Lucerne, laboratory analysis and excursions. To promote a comprehensive understanding of sedimentary processes and how these are linked to the environment, the course covered a variety of approaches – sedimentological, geophysical, petrophysical, geochemical and microbiological. The Summer School received financial support from a Swiss National Science Foundation PhD programme.

Knowledge transfer to practitioners

Practice-oriented Eawag (PEAK) courses are designed to communicate the latest findings in the field of aquatic

research and, in particular, to promote dialogue between researchers and practitioners. To meet target groups' needs even more effectively in the future, Eawag has set up an internal committee which will seek to align the content of courses more closely with participants' requirements.

In 2011, two PEAK courses were devoted to the subject of near-natural surface waters. The high level of interest in these events reflected the topicality of this issue – with the entry into force of the new Water Protection Act and the new Water Protection Ordinance, the legal foundations of integrated water resource management have been further strengthened. The new legislation governs spatial planning safeguards ensuring the provision of adequate space for surface waters, river restoration procedures, measures to promote longitudinal connectivity and measures to control the impacts of hydropeaking. At the same time, it will permit improvements in flood protection. Eawag, which elaborated essential scientific foundations in partnership with water professionals and researchers, is now actively supporting implementation of the regulations in practice.

The limited resources available for restoration projects should be invested in areas where the maximum benefits are to be expected. The key points to be considered and the planning tools available were discussed at the course entitled "Successful river restoration", which attracted 40 participants. Restoration projects call for an interdisciplinary approach and interinstitutional cooperation, which were reflected in the organization of the course itself. The event was so popular that it is to be repeated in May 2012.

On a PEAK course, practising specialists were introduced to methods of assessing surface waters.

The second PEAK course focused on methods of assessing surface waters. In the "Modular Stepwise Procedure" project, Eawag – together with the Federal Office for the Environment and cantonal authorities – has developed methods for the analysis and assessment of watercourses in Switzerland. Tools developed by the Systems Analysis and Modelling department facilitate integrated assessment of the various modules. Aspects of the course particularly appreciated by participants included the insights into decision theory, the presentation of a systematic approach involving a goal hierarchy and value function, the use of software to support watercourse evaluation and prediction of the effects of measures, and the dialogue between participants and instructors.

Partnership with developing countries

Eawag is committed to promoting knowledge transfer to developing and emerging countries – and nurturing young researchers from these regions. Each year, under the Eawag Partnership Program for Developing Countries, it offers up to six research fellowships for talented Master's or doctoral students. On a three- to four-month research visit, young scientists can share ideas with colleagues and receive guidance and training within an Eawag department. In 2011, for example, fellowships were awarded to a Master's student from China and to four doctoral students from China, Vietnam and Iran.

www.eawag.ch/epp

www.eawag.ch/teaching

Research for the real world

In 2011, more than 50 students – mostly from the ETH Zurich – had their Master's thesis supervised at Eawag. Many of the studies have a practical focus and are integrated into larger-scale research projects.

Listeria in surface waters

Listeria are widely distributed in the environment and can infect humans via contaminated food. In the Environmental Microbiology department, Andreas Elmer investigated the occurrence of the pathogen *Listeria monocytogenes* and five other listeria species by analysing samples collected from a variety of surface waters in Canton Zurich – from creek to lake. Though listeria were detected in 80 per cent of the samples, *L. monocytogenes* was only found in 10 per cent. Listeria-positive samples mainly came from streams flowing through agricultural land. The bacteria presumably entered these waters from farms or food-processing plants.

Dissemination in rivers, reproduction in lakes.

In the laboratory, Elmer also investigated the growth potential of the pathogen. In stream water from which it had been isolated, *L. monocytogenes* showed surprisingly poor growth. The growth potential was much greater in water from small lakes and ponds. Elmer concluded that rivers and streams may play an important role in dissemination of the bacteria, rather than serving as reservoirs for reproduction. This knowledge should facilitate assessment of the risk of listeriosis in the future. The study is part of an interdisciplinary research project on transmission routes and strategies of environmental pathogens, conducted by the Competence Center Environment and Sustainability of the ETH Domain (CCES).

Optimizing phosphorus removal

At the two WWTPs Foce Maggia (Locarno) and Foce Ticino (Gordola), the biological removal of phosphorus from wastewater is inadequate. So, to prevent the release of phosphates into surface waters, precipitants are added. However, the use of large amounts of precipitants is costly. To study this problem in more detail, Lorenz Schwery carried out a mass balance analysis for the two WWTPs, in cooperation with the Process Engineering department and a private engineering firm.

It was found that precipitants themselves are one of the main factors affecting the efficiency of biological phosphorus removal. As phosphates are bound by the precipitants, they are no longer available to the phosphate accumulating organisms (PAOs) in the activated sludge; this limits the reproduction of these bacteria and the efficiency of the removal process. But the less efficient the biological removal, the more precipitants need to be added – a vicious circle! Schwery developed various optimization proposals for the two WWTPs. In particular, the addition of precipitants to the activated sludge tanks should be reduced. Another problem identified was that sludge is removed from the tank after only five to six days, but as the PAOs are not yet fully established, they are washed out with the sludge.

Drinking water quality in Ethiopia

Many of the people who lack access to safe drinking water – almost a billion worldwide – live in Ethiopia. In the Ethiopian Rift Valley, water quality is particularly poor. Here, levels of naturally occurring fluoride in groundwater pose a risk to human health. In 2007, defluoridation filter technology was introduced in a joint project involving Eawag, Heks (Swiss Interchurch Aid) and OSHO (Oromo Self Help Organization). Today, more than 300 household filters are used in seven villages.

Another problem is contamination of drinking water with faecal bacteria due to poor hygiene and inadequate sanitation; diarrhoeal diseases are widespread. In a Master's thesis prepared at the Department of Water and Sanitation in Developing Countries (Sandec), Nina Küng showed that, although fluoride filters also reduce

Defluoridation is not enough to ensure safe drinking water.

faecal indicator organisms in drinking water, contamination levels remain alarmingly high. Contamination occurs mainly in the course of handling – between the water source and the filter inlet. In Küng's view, therefore, there is a need both to install or improve sanitation facilities and to raise awareness of the relationship between water, hygiene and health.

Whitefish species diversity has declined in lakes affected by eutrophication.

Hybridization of whitefish species

As a result of environmental changes, species that are relatively closely related may interbreed, thus reversing the process of evolution. "Reverse speciation", leading to a loss of biodiversity, has been observed in Swiss lakes. As part of a study carried out jointly by Bern University and the Fish Ecology and Evolution department of Eawag, Sacha di Piazza compared present-day whitefish with specimens from the period 1882–1995. He showed that genetic differences between whitefish species in Lake Constance have decreased by two-thirds. The various head shapes have also become more similar.

Di Piazza attributes these developments to lake eutrophication, which persisted into the 1990s and was associated with increased algal growth. Because of the resultant oxygen depletion, whitefish species living at the bottom of the lake had to move to shallower waters. Here, they interbred with related species, thus losing their genetic and functional distinctiveness. These findings were included in a paper published in *Nature*.

Water footprint of paper products

As well as using water for washing, people use it indirectly by consuming products – e.g. paper. Each year, paper consumption in Switzerland amounts to 220 kilograms per capita. In the Systems Analysis, Integrated Assessment and Modelling department, Marco Felicioni assessed the associated water footprint by quantifying and analysing the amounts and types of water consumed in the production process. Switzerland's paper consumption was found to require between 1.2 and 1.6 billion cubic metres of water per year. This is equivalent to per capita consumption of the contents of a swimming pool roughly two metres deep and ten metres long and wide.

The bulk of this is natural (rain)water, required for tree growth. Most of the paper (and thus water) comes from European countries. Felicioni showed that the countries most likely to experience water shortages are not those from which most of the water derives, but those where water use is high in relation to availability – e.g. Italy, Spain or the Netherlands. In cases where wastewater is not adequately treated, grey water associated with paper products may also cause environmental problems.

Biogas from an old shipping container

Organic material accounts for 60 per cent of the municipal solid waste arising in Kumasi (Ghana's second-largest city). With appropriate plants, there is thus a major potential for the production of biogas – e.g. for cooking or electricity generation. Dry fermentation plants have already been successfully implemented in Europe, but the suitability of these systems for developing countries has been little studied to date.

In collaboration with Kwame Nkrumah University, Matthias Burri and Gregor Martius (Master's students at Sandec) therefore developed a pilot plant in Kumasi – a simple system based on an old shipping container. The plant was constructed at low cost, but it proved challenging to design an opening that would ensure airtight sealing.

Burri and Martius also analysed the economic potential of this system. They concluded that operation would only be economically viable if a high feed-in tariff were paid for the electricity produced, and that this would not be feasible given the current lack of political support in Ghana. An environment favouring investments in renewable energy technologies would be essential. ○○○

Functional, but not economically viable: a biogas plant in Ghana.

Right place, right time

In 2011, 32 doctoral and 52 Master's students completed their studies at Eawag. What kinds of career do Eawag graduates subsequently pursue? How did Eawag prepare them for their current professional lives? Here, we profile four alumni.

Jane Muncke: communicating complex findings

What she learned from the Eawag project Novaquatis, says Jane Muncke, is that pollutants can be most effectively eliminated at source. In her current work as an environmental toxicologist at Cham-based Emhart Glass – a supplier of parts and equipment to the glass container industry – she is still guided by this principle. "For example," she says, "if the endocrine-disrupting chemical bisphenol A was not used in the coating of thermal paper receipts, it wouldn't end up in recycled cardboard packaging." Here, glass containers offer an advantage: because glass is inert, unlike cardboard or plastic, no endocrine disruptors can be released from this material. As Muncke points out, "That's especially important for foodstuffs, which can be contaminated by packaging." Her interest in the effects of endocrine disruptors on health and the environment began with her dissertation at Eawag, which concerned the development of a zebrafish egg system for ecotoxicological testing.

"Another thing I learned at Eawag," says Muncke, "was how to communicate my findings." This involves distilling the key points and presenting the information in such a way that it is comprehensible to colleagues from completely different disciplines. She recalls: "We had to report on our progress regularly to a large audience – and deal with critical questions." She now benefits from this experience – in giving presentations, writing reviews for scientific publications, or training colleagues from the marketing department.

What motivates Muncke is a desire to make complex scientific information accessible to the public: "We consume packaged food every day, so we have a right to know what substances released from packaging we are ingesting in the process." In many cases, these have yet to be fully investigated. Muncke is currently involved in the development of a foundation for scientific communication on this topic. Though the project was launched by the glass industry, the foundation is to become independent in the medium term.

André Weidenhaupt: making water policy a priority in Luxembourg

In 1985, André Weidenhaupt moved from Esch-sur-Alzette in Luxembourg to Zurich, to study Chemistry at the ETH. "If it had been two years later," he says, "I'd have chosen Environmental Sciences – but that course wasn't available when I came." He pursued his interest in the environment as a postgraduate, writing his thesis at Eawag, and in 1994 he became one of the first to obtain a doctorate in Environmental Chemistry. He then took up a position as research associate in the ETH Chemistry Department, where a Foundation Professorship of Environmental Protection and Chemical Safety had been established following the Sandoz chemical spill in 1986. "This move wasn't easy," Weidenhaupt recalls. At that time, scientists at the ETH (in contrast to Eawag) did not yet attach much importance to the environment as a research topic. "But I was able to help change that."

Two years later, he returned to Luxembourg, to establish an environmental department at the CRP Henri Tudor research centre. In 2005, during Luxembourg's presidency of the EU Council, he led the negotiations in Brussels for the Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).

That same year, he was appointed Director of Luxembourg's newly created Water Management Authority. With his broad expertise in this field, he put water management on the country's political agenda for the first time. As Weidenhaupt says, "You can't plan your CV – you have to be

in the right place at the right time." While he was working on his thesis, Eawag had certainly been the right place to broaden his thinking and his horizons through exchanges with researchers from a variety of disciplines.

Friendships and a close attachment to Eawag have survived to this day: Weidenhaupt regularly gives presentations here, and Eawag's 75th anniversary provided a welcome opportunity for him to interact with doctoral students. The environment remains a subject close to his heart – also in his capacity as Chairman of the International Commission for the Protection of the Rhine: "When I see that salmon are returning to the Rhine, I know my efforts have not been in vain." ○○○

Tobias Vogt: tackling socially relevant challenges

Tobias Vogt, a hydrogeologist, works underground – at the Mont Terri rock laboratory near St-Ursanne (Canton Jura). As part of a Nagra research programme, he is investigating opalinus clay, a type of rock considered suitable for storing radioactive waste at a future Swiss deep geological repository. Vogt explains: "Opalinus clay is highly dense, which makes it difficult for radioactive substances to pass through the rock." He and his team are using heating elements to simulate how canisters containing fuel rods heat up the surrounding rock. For this purpose, they are developing an experimental gallery where the conditions of a future repository can be simulated realistically.

"Heat causes rock pore water to expand, and the pressure rises," says Vogt. Modelling suggests this is unlikely to destabilize the system – "But now we need to refine the models with the aid of real measurement data." Vogt first became familiar with the relevant measurement techniques and sensors when he was working on his dissertation at Eawag. This earlier research was also concerned with the permeability of rock, but in a quite different setting: on a restored section of the Thur, he studied how river water infiltrated into groundwater through the gravel riverbed. "My work is always scientifically challenging," he says, "but at the same time I appreciate its social relevance."

Finding an appropriate site for a deep repository for high-level waste is an ambitious long-term objective – operation is scheduled to begin 2040 at the earliest. A site is to be selected by 2020. At the three proposed siting regions in Northern Switzerland, extensive opalinus clay formations are present at depths of up to 900 metres. "Here in the Jura,"

says Vogt, "the rock is not suitable because of the folding, but we do have ideal conditions for the experimental gallery." ○○○

Michael Ochs: How can radioactive wastes be safely stored?

Michael Ochs, a geochemist, came to Eawag as a doctoral student at the end of the 1980s, after studying Geography and Chemistry in Heidelberg and gaining an MS in Soil Science at Oregon State University. Recalling his time at Eawag, Ochs says: "For me it was a stimulating environment – particularly because of the interdisciplinary and international collaboration with other researchers." As well as new knowledge, he acquired technical skills and learned how to manage projects himself. "It was also the period where I had to choose my future career path."

After working as an assistant on the Environmental Sciences programme, Ochs decided to join BMG Engineering in Schlieren, a consultancy specializing in efficiency and risk engineering. That was more than 15 years ago – today, he is a partner in the company and still finds his profession rewarding. He analyses the behaviour of radioactive substances, primarily for clients from Switzerland and abroad who are responsible for the safe storage of radioactive wastes. Ochs explains: "To demonstrate the safety of a deep repository, you need sound data on how radioactive substances will behave at the planned storage site." In general, he can only provide support on this one aspect of these complex, long-term projects, but as he points out: "There are still numerous questions to answer – and here my contribution can be crucial." Other fields in which Ochs is active include chemical risk assessment and contaminated site remediation. ○○○

Research
Teaching

Consulting

In 2011, Eawag further expanded its contacts with practitioners. A variety of consulting projects were successfully carried out in Switzerland and abroad. For example, Eawag scientists prepared an expert report on the planned pumped-storage plant in Poschiavo (the Lago Bianco project). Eawag also organized an international River Corridor Restoration Conference in Ascona, bringing together researchers, engineers and representatives of regulatory authorities. The Ecotox Centre is participating in two major projects on micropollutants, sponsored by the Federal Office for the Environment, which began in 2011. Also initiated in 2011 was the EU-funded Faecal Management Enterprises (FaME) project, which focuses on reuse-oriented faecal sludge management in developing countries.

Eawag's knowledge and technology transfer activities mainly involve national or cantonal agencies and consulting or engineering firms, as well as partners in emerging and developing countries. In 2011, Eawag's technology transfer function was merged with that of Empa, which should make it possible to meet the increasingly complex demands associated with contracts more efficiently and expertly.

Hans-Peter Kohler

Soil remediation with microorganisms

The insecticide lindane was banned in the 1970s, but according to biochemist Hans-Peter Kohler, "It's always turning up somewhere or other." The substance is poorly degraded and persists in the environment for long periods. "In India, lindane is still used today," says Kohler. He is collaborating with Indian scientists in a project which aims to remediate production sites and agricultural areas by means of microbial degradation of lindane. However, he explains, "In order to eliminate a substance from the environment, we first need to understand the relevant biochemical transformation processes." Kohler, who has been conducting research at Eawag since 1988, has already served as a consultant in numerous projects. He was among the first scientists to take an interest in so-called chirality – the fact that many molecules occur in two different, mirror-image forms. A case in point is the herbicide mecoprop, which Kohler studied at the Kölliken hazardous waste landfill in the 1990s. Only one of the chiral forms of this substance is herbicidally active: "We discovered that the two forms are degraded at different rates, and since then, to avoid unnecessary environmental impacts, only the active form of mecoprop has been used."

Regula Meierhofer

Developing needs-oriented solutions

"A lot of people were sceptical about whether such a simple solution could actually work," says environmental scientist Regula Meierhofer. It was recognized over ten years ago that microbial contaminants in water could be inactivated by ultraviolet radiation. But would it also be possible to improve the quality of drinking water in developing countries by exposing water placed in PET bottles to sunlight? The answer was yes, as Sodis (solar water disinfection) researchers demonstrated in numerous microbiological, epidemiological and materials-science studies. Meierhofer, now head of the Sodis Reference Center, joined the programme at a later stage, to help promote the method on the ground. Thanks to these efforts, the process is now used in 23 countries in Latin America, Asia and Africa and is recognized by the WHO as a standard method of water treatment. But Meierhofer emphasizes: "It's not enough just to persuade people to try it out once – it has to become routine for them." Today, the Reference Center is also promoting other methods, such as boiling, chlorination or filtration. In the future, established projects are to be continued by the development organization Helvetas.

Ralf Kägi

Assessing risks of nanoparticles

"Today," says Ralf Kägi, a geologist and expert on nanoparticles, "more and more products are being labelled nano without actually containing nano." Tiny particles of this kind are not fundamentally new – ultrafine metal particles which are harmful to health are also formed during welding, for instance. What is new is the increasingly widespread deliberate use of nanoparticles in consumer products. In many cases, the risks to health and the environment remain unclear. Kägi, who is head of the Eawag Particle Laboratory, is investigating the behaviour of various nanoparticles in wastewater treatment plants. "Carbon nanotubes, for example, are poorly eliminated," he says. These could pose a genuine hazard if large quantities were to be used in the future. The situation is different with silver: it is toxic, but in wastewater it is rapidly transformed into silver suphide, which is less problematic. "We aim to give policymakers, industry, and also private interested parties the information they need to make sound decisions," he says. Kägi's advice is widely sought. The "Blauer Anker" water sports association wanted to know what boat sealants they could use without harming the environment: "These people were really worried, but fortunately there was no nano in it."

Assessing micropollutants in wastewater

Thousands of chemicals used on a daily basis in Swiss households enter surface waters via the sewer system. Some of these substances are problematic for the environment. A new assessment concept makes it possible to define priority substances, identify areas where action is required and assess the effectiveness of control measures.

Numerous substances in municipal wastewater find their way into rivers and lakes, where – even at low concentrations – they can have adverse impacts on aquatic organisms. These include medicines excreted in urine which end up in wastewater treatment plants. Also entering WWTPs are certain problematic substances contained in cleaning products, pesticides, or biocides used to protect facades and roofs. These micropollutants are not – or not adequately – eliminated by conventional mechanical/biological wastewater treatment processes.

Defining priority substances

In a study commissioned by the Federal Office for the Environment (FOEN), organic micropollutants were investigated by researchers from the Environmental Chemistry department and the Ecotox Centre. The study was designed to identify surface waters where these substances could have detrimental effects, to define substances of concern, and to propose methods of assessing water quality with respect to these substances. The aim was to elaborate an assessment concept suitable for application in practice.

Project leader Juliane Hollender explains: "We focused on substances which enter surface waters via wastewater treatment plants, as they are easier to detect." More difficult to measure, as she points out, are temporally and spatially variable inputs from diffuse sources, such as run-offs of agricultural pesticides. In addition, micropollutants in WWTPs can be reduced by relatively simple measures.

There is a long list of potentially harmful substances, and it would not be possible for all of them to be continuously monitored. Accordingly, in cooperation with cantonal authorities, the FOEN and industry, the researchers selected around 50 substances of particular relevance to Switzerland, which they recommend should be covered by water monitoring programmes. Among the criteria used to define priority substances were that they should be used in large quantities, water-soluble (and thus actually found in surface waters), poorly degradable and amenable to analysis. Also included in the list are substances which, though only occurring in small amounts, are known to have adverse effects on aquatic organisms – e.g. the female hormone estradiol. The researchers also ensured that the substances selected came from a wide range of classes.

Concentrations of micropollutants are relatively high in small surface waters receiving effluents from treatment plants with a large catchment area.

Elevated concentrations in certain cases

The largest group of substances on the list are pharmaceuticals – not just hormones, but antibiotics and analgesics. The anti-inflammatory agent diclofenac, for example, is one of the drugs most frequently detected in surface waters. It is taken up by aquatic organisms and, at the concentrations measured, may cause pathological changes in organs and affect the immune system in fish. Also on the list are pesticides and corrosion inhibitors (as used in dishwasher detergents, for example). Lastly, the selection includes industrial chemicals which act as indirect endocrine disruptors. For the priority substances identified, the researchers derived individual limits, known as quality criteria; a risk to aquatic organisms is assumed to exist if these limits are exceeded. The proposed criteria, which are periodically updated, are published on the website of the Ecotox Centre.

For six widely used substances, the concentrations expected to occur in surface waters were calculated with the aid of computer simulations. The substances in question were diclofenac, four other commonly pre-

scribed medicines (two antibiotics, a heart drug and an antiepileptic) and a corrosion inhibitor. On the basis of per capita consumption and data on environmental degradation and behaviour, the researchers estimated the quantities occurring in the effluents of around 550 WWTPs and the environmental concentrations to be expected in the surface water network.

In 14 per cent of the WWTPs, the limits are exceeded for three of the six substances – at any rate under the worst-case assumption of low-flow conditions, when the dilution effect of receiving waters is least marked. According to Hollender, "This applies in particular to treatment plants which have a large catchment area and at the same time discharge effluents into small receiving waters, where substances are less well diluted." In such cases, the environmental chemist believes, action is required to reduce inputs of micropollutants by introducing additional treatment steps.

Elimination with ozone or activated carbon

On the basis of these findings, the FOEN has now specified criteria for deciding which 100 WWTPs are to be upgraded in the coming years. As well as protecting aquatic life, the aim is also to protect human health in accordance with the precautionary principle, since inputs of micropollutants to surface waters over the long term could pose risks to drinking water resources.

According to the researchers, two additional treatment methods could potentially be used to control micropollutants. Firstly, ozonation of wastewater could break down these substances into less harmful forms. Secondly, micropollutants could be removed from wastewater by the addition of powdered activated carbon. Both of these processes are already used in drinking water treatment.

The effectiveness of these methods has been extensively tested by Eawag and EPF Lausanne scientists at WWTPs in Regensdorf and Lausanne. It was shown that many, though not all, of the substances investigated were effectively eliminated. Among the substances which can be removed by these treatment steps are hormonal contraceptives and diclofenac. Certain iodine-based contrast agents (used in radiology) are, however, only partly eliminated.

Additional treatment with ozone gas can effectively eliminate many micropollutants from wastewater.

Routine monitoring possible

To provide a simple means of assessing the effectiveness of such treatment steps in practice, the researchers have selected five indicator substances – three pharmaceuticals, a corrosion inhibitor and the herbicide mecoprop, which is used in facade protection as well as in agriculture. The idea is that these indicator substances should represent the entire spectrum of micropollutants in routine monitoring.

Hollender says: "With the 50 priority substances, the indicator substances and the specified quality criteria, the cantons now have practical tools available for monitoring surface water quality and assessing the effectiveness of control measures." However, she points out that both the list of priority substances and the indicator substances need to be regularly reviewed and, if necessary, revised. The use of medicines and household chemicals may change over time as new substances are approved and older ones prohibited. ○ ○ ○

Harnessing the NADUF monitoring network

As part of the Swiss National River Monitoring and Survey programme (NADUF), water quality is assessed by measuring concentrations of classical pollutants such as nutrients and heavy metals. On behalf of the Federal Office for the Environment, Eawag scientists investigated whether routinely collected samples could also be used to measure micropollutants. Over a one-year period, they analysed a proportion of samples from five NADUF sites for twelve typical pharmaceuticals, biocides and herbicides.

At almost all the sites, the target substances were successfully detected in 90–100 per cent of the samples. According to Christian Stamm of the Environmental Chemistry department, "The sample volumes available were sufficient to allow micropollutants to be detected without adversely affecting the existing analyses." Most of the substances occurred in concentrations of less than 100 nanograms per litre on average; markedly higher levels – over 1 microgram per litre – were found for the corrosion inhibitor benzotriazole.

The results, Stamm believes, show that the existing sampling regime is also suitable for the monitoring of micropollutants. However, only those substances could be detected which are sufficiently widely used for measurable concentrations to be present in samples. To exploit synergies and avoid duplication of efforts, the researchers recommend that the NADUF programme, expanded to cover micropollutants, should be integrated into a national water quality monitoring scheme, coordinated with cantonal monitoring stations.

www.eawag.ch/jb11/beurteilungskonzept (in German)
www.oekotoxzentrum.ch/qualitycriteria

Contact:
Professor Juliane Hollender, juliane.hollender@eawag.ch

What limits for pesticides?

For plant protection products, Switzerland still lacks specific concentration limits based on the toxicity of individual substances to aquatic organisms. This should be remedied by using a standard method of assessment, which is also applied in the EU.

Plant protection products are regularly detected in Swiss waterbodies. As well as controlling plant or animal pests, these substances can have harmful effects on aquatic organisms: even at concentrations of one microgram per litre or less, they may be lethal to fish, crustaceans or algae. Under Swiss legislation, a limit of 0.1 micrograms per litre is currently applicable for individual pesticides in surface waters; however, this general value does not reflect the toxicity of each individual substance. According to the Water Protection Ordinance, it is possible to specify individual limits based on assessments of substances carried out as part of the authorization procedure for new pesticides. But because the method to be used is not clearly defined, no legally binding individual limits exist as yet.

Influence of expert judgement

For ecotoxicological water quality evaluation, it would be useful to have individual limits based on the toxicity of the active substances concerned – so-called quality criteria. "Exposure to concentrations below these limits should not be harmful for aquatic organisms," says Marion Junghans of the Ecotox Centre (Eawag/EPF Lausanne).

Not all pesticides are equally toxic to aquatic organisms.

How can these quality criteria be determined? As no standard procedure currently exists in Switzerland, Junghans and various other project partners were commissioned by the Federal Office for the Environment (FOEN) to compare three approaches which are widely used within the EU under the EU Water Framework Directive. European experts generally employ toxicity data from algae, water fleas *(Daphnia)* and fish. Because information on toxicity is more or less limited for most substances, the toxicity value derived from the data for a given substance is multiplied by an "assessment factor" of 1–1,000; this represents a margin of safety, depending on data availability.

The comparison was based on quality criteria derived by researchers at Lausanne University in accordance with the EU methods for a number of plant protection products frequently used in Switzerland. For the herbicides (diuron, mecoprop and terbuthylazine), fungicide (carbendazim) and insecticides (imidacloprid and diazinon) studied, the values derived lie within one to two orders of magnitude of the current legal limit of 0.1 micrograms per litre.

This confirms that, for a more comprehensive ecotoxicological assessment of water quality, specific limits for individual substances would be more appropriate than a general value.

In addition, a comparison of these results with the assessments of international experts revealed that the values obtained were significantly influenced by individual expert judgement. Junghans explains: "Depending on how the toxicity data were weighted and what assessment factor was selected, the values differed by a factor of up to 20." In contrast, the choice of method was much less important, as the resultant values never differed by more than a factor of three.

Harmonization with the EU

In Switzerland, the risks of pesticides must also be assessed for authorization purposes. However, the values obtained here cannot be taken over directly for water protection, as the protection goals of the underlying legislation differ. While temporary impacts on plant and animal communities are acceptable under the Plant Protection Products Ordinance, toxic effects are not permitted under the Water Protection Act or the EU Water Framework Directive even in cases where populations may recover. This is due to the fact that pesticide authorization focuses on small waterbodies bordering agricultural areas, which are generally only exposed immediately after application of the product concerned.

Over the medium term, the EU has decided that the Technical Guidance Document for Deriving Environmental Quality Standards under the Water Framework Directive – one of the methods studied by Junghans and her colleagues – is to be adopted in all member countries.

Accordingly, the Ecotox Centre recommends that this method should also be used in Switzerland. "However," Junghans adds, "to reduce the influence of expert judgement, the values should also be reviewed by independent external assessors." The Ecotox Centre is already using this method in a FOEN-sponsored follow-up project to derive quality criteria for a wide variety of plant protection products. ○○○

www.oekotoxzentrum.ch/pesticides

Contact:
Dr Marion Junghans,
marion.junghans@oekotoxzentrum.ch

Sneep – unsuspected differences

Once a common fish species, the sneep is now endangered in Switzerland. Stocking measures can help to re-establish populations that have been lost or support those that remain. But it is important to take genetic differences between populations into account.

In the rivers of the Central Plateau, the sneep *(Chondrostoma nasus)* used to be one of the most common fish species. For several decades, however, populations have been declining dramatically, and at many sites the sneep has already disappeared. This is due not only to impaired water quality but also to losses of suitable habitats resulting from straightening, fragmentation and damming of rivers. In the different phases of its life cycle, the sneep requires different types of physical structures. In the spawning season, for example, it swims upstream and into side channels, laying its eggs in gravel beds with fast-flowing waters.

Preserving differences

Sneep benefit from the restoration of river stretches and the removal of barriers to upstream migration. But sneep populations today are so highly fragmented and usually so small that it seems essential to provide additional support through stocking measures and, in particular, to re-establish locally extinct populations in restored reaches.

However, measures of this kind should not be implemented without a knowledge of the genetic relationships existing among sneep populations – which could belong to different evolutionary lines and differ substantially in their genetic characteristics. "It's vital to preserve such genetic differences," says Pascal Vonlanthen of the Fish Ecology and Evolution department. "They represent important adaptations to local environmental conditions, which have developed over long periods of time."

In a study commissioned by the Federal Office for the Environment, Vonlanthen and colleagues therefore investigated the genetic variability of sneep populations in Switzerland. For this purpose, the researchers captured specimens at twelve sites. The fish were anaesthetized and then weighed and measured. Tissue samples were taken from the anal fin for genetic analysis. To examine differences in body form, the biologists took photographs of the fish; the age of the specimens was determined by scale readings. The fish were then released again.

Distinct populations

The study revealed clear differentiations: for example, populations from the Lake Constance catchment differed markedly from those of the High Rhine; they appeared to belong to different evolutionary lines. In contrast, populations found below the Rhine Falls were found to be genetically similar – with the exception of the Schanzengraben in Zurich, where an isolated population with distinctive characteristics had evidently developed.

Differences in the body structure of sneep indicate local environmental adaptations.

However, morphological studies showed that the populations within the Rhine are not quite as homogeneous as the results of the genetic analysis would suggest. Thus, sneep from the upper catchment (Rotbach, Suhre) differ from those occurring in the lower reaches (Birs, Wiese) both in head size and in head and body shape. As Vonlanthen explains, "This could indicate local adaptations to the environment."

The biologists conclude that Switzerland is home to at least four distinct sneep populations, which need to be considered separately in conservation efforts. Accordingly, says Vonlanthen, "Only individuals from the appropriate population units should be used for stocking." But the priority, he adds, should be to support existing populations through specific habitat enhancement measures. ○○○

Contact:
Dr Pascal Vonlanthen, pascal.vonlanthen@eawag.ch

What spawning redds can tell us

In most Swiss rivers, the spawning season for brown trout begins in October. Using their tail fin, the females construct gravel nests known as spawning redds, where their eggs are subsequently deposited. In November 2011, these redds were the subject of a workshop held by Fiber – the Fishery Advice Centre jointly run by Eawag, the Federal Office for the Environment and the Swiss Fishing Federation. Spawning redds provide an indication of how well natural reproduction is functioning in a watercourse. The monitoring of spawning redds and counting of fry in the spring can support the implementation of management and conservation measures, offering an alternative to electrofishing. The two-part workshop, held in Sursee and Fribourg, attracted around 70 participants. A redd-mapping field trip revealed high levels of trout spawning activity.

www.fischereiberatung.ch (in German)
Contact: Jean-Martin Fierz, jean-martin.fierz@eawag.ch

Weighing up impacts and benefits

When hydropower plants are planned, environmental impacts on surface waters need to be assessed, so that construction projects can be optimized. This is shown by the Lagobianco project in Poschiavo, where a large-scale pumped-storage plant is to be constructed. Eawag scientists investigated how water temperature and turbidity will be affected in the two lakes concerned.

Over the past 20 years, greater weight has been attached to quantitative water protection in Switzerland. This also applies to the operators of hydroelectric power plants: when applications are made for new concessions, provision must be made for appropriate residual flows in all the river sections concerned. In addition, remedial measures must be taken for existing residual flow stretches, as far as this is economically reasonable. These requirements have been in force since 1992. Following the latest revision of the Water Protection Act in 2010, hydropower plant operators are now also required to reduce fluctuations in flow rates (hydropeaking) arising from power generation. At the same time, hydropower is becoming increasingly important, as renewable energy sources are to replace nuclear power in the medium term.

Warming of lakes

Accordingly, a number of pumped-storage plants are currently being planned or constructed in Switzerland. These systems use surplus base-load energy to pump water into reservoirs, where it is stored and used to generate power at times of peak demand. In Poschiavo, the electricity company Repower is planning to build a plant of this kind with a capacity of 1,000 megawatts. Under this scheme, water from Lago di Poschiavo (a natural lake) is to be pumped up into the existing Lago Bianco reservoir. According to the Water Protection Ordinance, such modifications must not have adverse impacts on aquatic ecosystems.

Among the contributions to the environmental impact assessment required for the Lagobianco project were three expert reports prepared by Alfred Wüest and colleagues from the Surface Waters department of Eawag. With the aid of computer simulations and modelling, these reports show how temperatures and particle concentrations in the two lakes will be affected by the exchange of water.

"With pumped-storage operations, a variety of changes in water mixing, temperature and turbidity are to be expected," says Martin Schmid, one of the researchers involved in the study. Initial assessments suggested that these variables would not be influenced primarily by the level of installed capacity, but by meteorological factors and the timing of pumped-storage operations. The researchers therefore performed further calculations based on local meteorological conditions observed from 1981 to 2009 and considered four hydrological scenarios.

It was found that the planned pumped-storage operations will lead to increased temperatures in both lakes. In particular, towards the end of the summer, Lago di Poschiavo will be three to four degrees warmer than it is today in the area where water from Lago Bianco enters the lake after passing through the turbines; in particularly dry years, the increase could be as much as six degrees. This is partly due to the fact that Lago Bianco – a relatively shallow reservoir – warms up readily during the summer, and the warm water is released to the lower lake. Additional heat comes from frictional losses occurring during pumping and turbine operations.

In the winter months, the temperature in Lago Bianco will rise as water is pumped up from the warmer lower lake. This will shorten the period during which the surface of the reservoir is frozen. This effect could be intensified by climate change.

Environmentally acceptable on balance

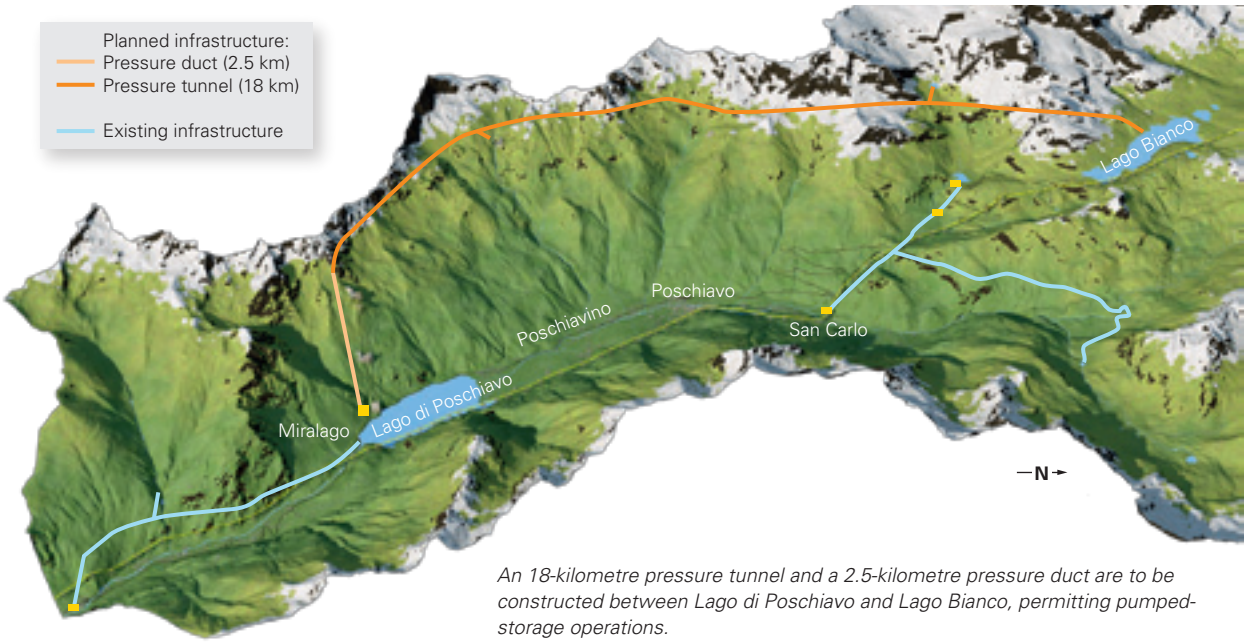
The exchange of water between the two lakes will also lead to a reduction of particle concentrations in Lago Bianco. In the summer, the decrease compared to current

Impacts of hydropower in Africa

As African rivers are increasingly being used to generate power, the ecological impacts in the countries concerned are also of interest to researchers. In Zambia, for example, Manuel Kunz and Roland Zurbrügg of Eawag investigated how the construction of the Itezhi-Tezhi Dam has affected the Kafue Flats, a Ramsar wetland site lying downstream. The dam, completed in 1978, has previously been used solely for storage purposes, supplying water to a downstream hydropower plant during the dry season. Now it is also to be fitted with turbines.

According to the Eawag study, over the roughly 30-year period of operation, the reservoir retained 330,000 tonnes of sediments per year, depriving the Kafue Flats floodplain of 50 per cent of nitrogen inputs and 60 per cent of phosphorus inputs. This reduction in nutrient inputs could be mitigated if bottom water were used to drive the planned turbines. But the low oxygen content of hypolimnetic water from the reservoir would be harmful to aquatic life. The researchers therefore recommend that 50 per cent of the water should be withdrawn from the surface and 50 per cent from the bottom layer. This would ensure that oxygen levels remained acceptable, while allowing six times as much nitrogen and twice as much phosphorus to reach the Kafue Flats as hitherto. The wetlands could thus be restored to a more natural condition.

www.eawag.ch/jb11/adapt



An 18-kilometre pressure tunnel and a 2.5-kilometre pressure duct are to be constructed between Lago di Poschiavo and Lago Bianco, permitting pumped-storage operations.

levels will be at least 50 per cent, making the reservoir much clearer. In Lago di Poschiavo, by contrast, particles will accumulate especially at the release depth. If mixing occurs as a result of turbulence, particles from the deep waters will also reach the surface. On average, the depth of the euphotic layer in Lago di Poschiavo will therefore decrease by 10–30 per cent, and so the habitat available for light-dependent aquatic organisms will be reduced. This effect is exacerbated by strong winds.

According to Matteo Bonalumi (another researcher participating in the study), particle concentrations at the surface could be markedly reduced if the withdrawal and release of water were carried out at a greater depth. But the temperature of the entire deep water layer could then rise to as much as eight degrees in the autumn. Equally, releasing particle-rich deep water from Lago di Poschiavo rather than surface water would not be helpful, as this would have adverse impacts on the thermal stratification of the lake.

The simulations indicate that pumped-storage operations will generally increase temperatures and turbidity to a greater extent in dry years than in wet years. This is because the effects described will predominate with low-flow conditions in the tributaries. Commenting on the findings, Schmid says: "The rise in water turbidity associated with pumped-storage operations is lower than expected, but the increase in temperature is significant and may have adverse impacts on the aquatic environment." On the other hand, as Schmid points out, the project will lead to mitigation of hydropeaking on the Poschiavino river (which flows through Lago di Poschiavo), as well as higher and more dynamic residual flows; in addition, various restoration measures are to be carried out. The environmental impact assessment therefore concludes that, although the project involves substantial disturbances, it is acceptable from an environmental perspective. A decision on approval is now to be taken by the concession-granting authority, Canton Graubünden.

Inadequate residual flows throughout Switzerland

Elsewhere, with regard to residual flows, less progress has been made. This at least is the conclusion suggested by an online map, recently developed by Eawag, which shows to what extent the residual flow regulations introduced twelve years ago have been implemented to date: the map covers all 1,318 residual flow stretches, with a total length of 2,700 kilometres. By clicking on a withdrawal site, users can read off the minimum residual flow rate specified for the river section in question. For half of all stretches no data are available, and it is to be assumed that a substantial proportion of these have no residual flows at all. Another 28 per cent of stretches can be seen to have no or very limited residual flows, and 11 per cent have 10–90 per cent of the minimum flow specified. In only 11 per cent of stretches (13 per cent of total river length) do the actual flows exceed 90 per cent of the legally required minimum residual flow. The Eawag researchers recommend that the map should be updated in 2014, as all the necessary remedial measures are to be implemented by the cantons and data gaps eliminated by the end of 2012. ○ ○ ○

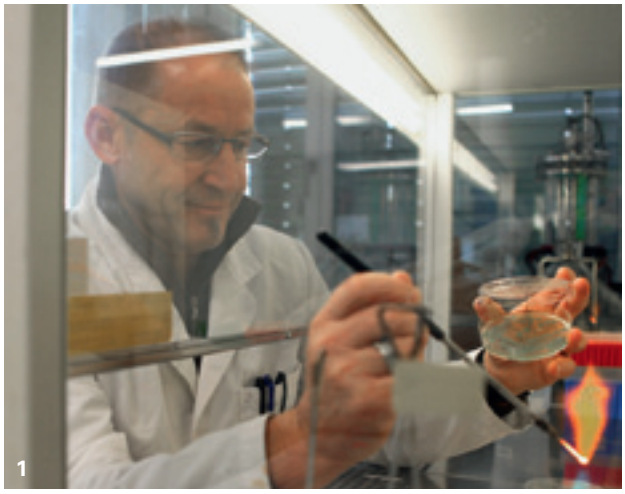
www.lagobianco.repower.com (in German)
www.eawag.ch/webkarte-restwasser (in German)

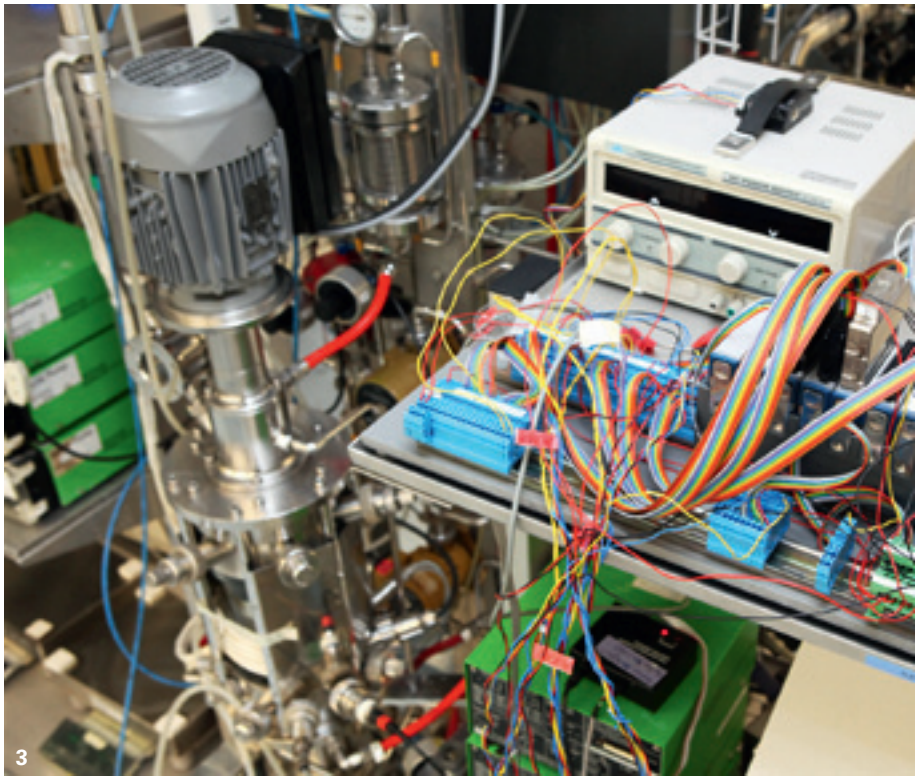
Contact for Lagobianco:
Professor Alfred Wüest, alfred.wueest@eawag.ch
Dr Martin Schmid, martin.schmid@eawag.ch

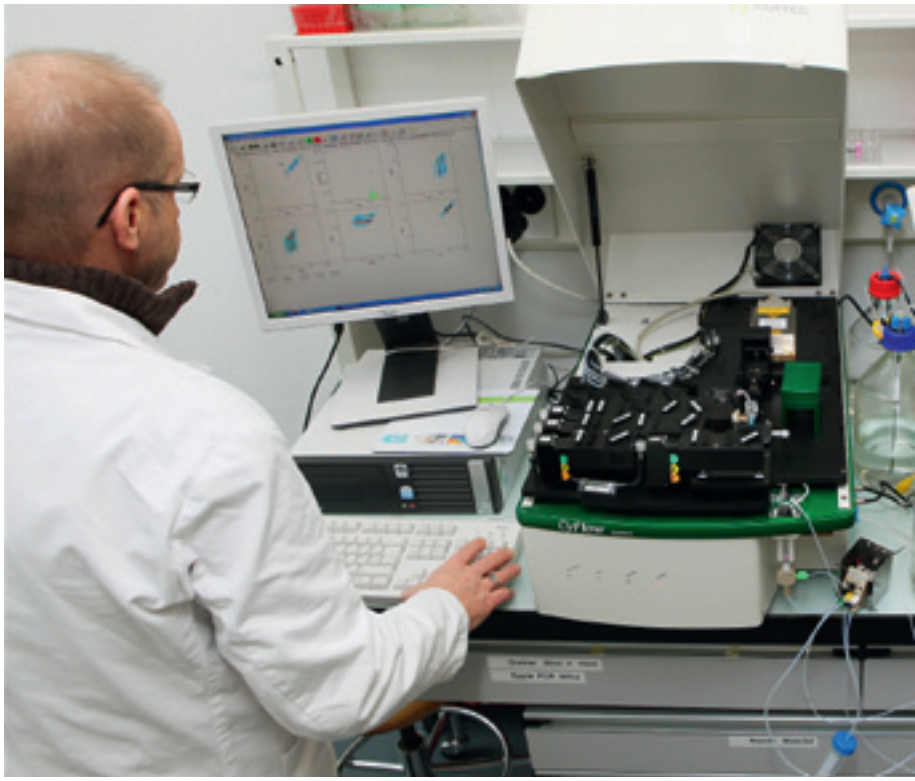
Contact for residual flow maps:
Professor Bernhard Wehrli, bernhard.wehrli@eawag.ch

Cell counting made rapid and easy

Being able to assess microbiological water quality at any time and after each drinking water treatment step – this vision has now become reality thanks to the development of a flow cytometric method coupled with a staining robot. The combined system has excellent chances of being successfully commercialized.







1+2 Eawag technician Hans-Ulrich Weilenmann sterilizes an inoculation loop before transferring a sample to a nutrient plate; here, the cultured bacterial colonies can later be counted. The time-honoured method.

3 At Zurich University of Applied Sciences (ZHAW), an initial prototype for online sample preparation was developed for the analysis of biotechnological processes.

4 Project leader Frederik Hammes of Eawag (left) in discussion with biotechnologists from the ZHAW Biochemical Engineering group.

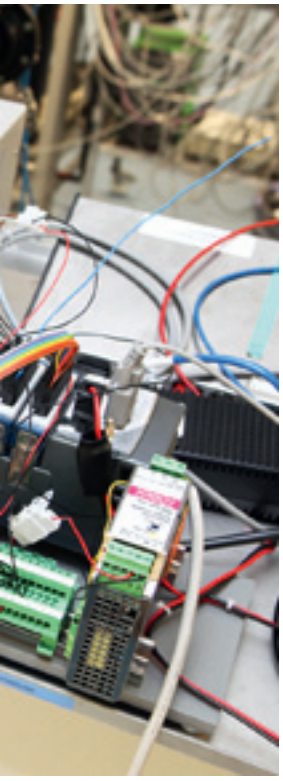
5 In an automated process, minute water samples are fed into the modified flow cytometer.

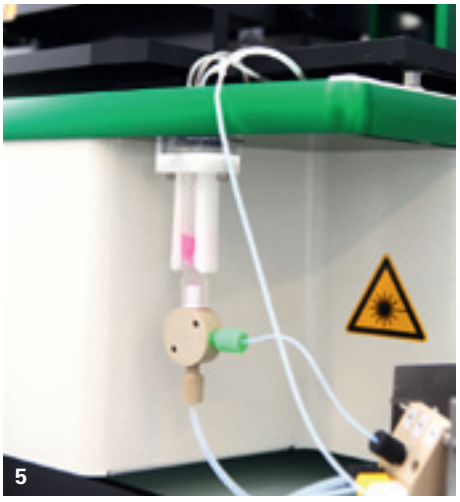
6 The laser beam strikes the sample stream.

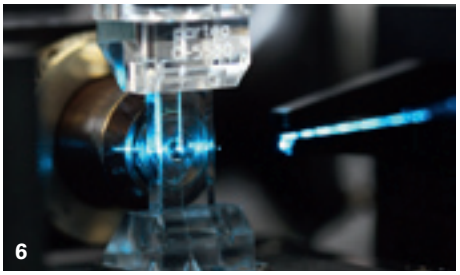
7 Laboratory testing of the system at the Environmental Microbiology department of Eawag: on the right, the newly designed device where cells in water samples are stained prior to the actual cell counting process in the flow cytometer.

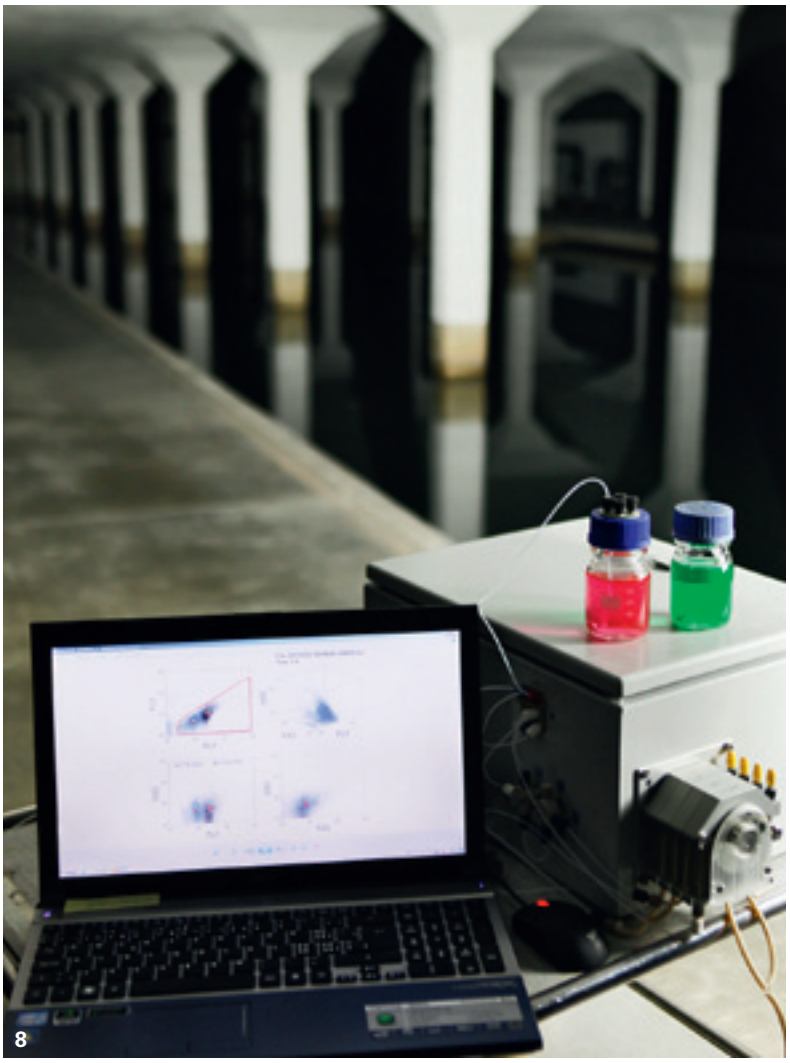
8 Online operation in practice: the staining robot automatically prepares samples collected from the sand filtration basin at Zurich Water Works (WVZ). After just a few minutes, the results can be viewed on the laptop.

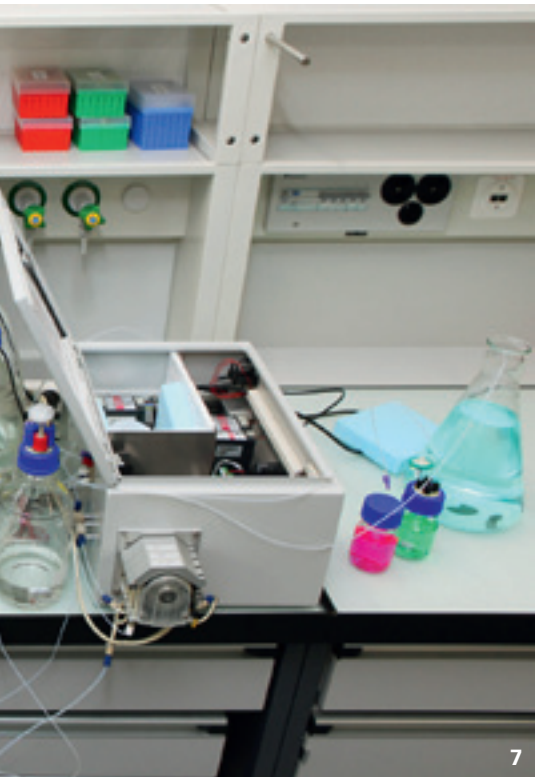

4




5


6


8


7

Fruitful partnership with biotechnologists

Cultivation of bacteria on nutrient media, with subsequent counting of visible colonies, is still considered the standard method of testing water samples. However, as well as taking at least 18 hours, this process only detects a small fraction of the cells contained in water. During the last ten years, microbiologists at Eawag have been seeking to refine an alternative method originally employed in medicine (e.g. for blood cell counts). In flow cytometry, a laser beam is used to enumerate previously stained cells. The results are available within minutes. The method is already being applied in practice for drinking water monitoring.

The researchers have now taken another step forward: together with biotechnologists at Zurich University of Applied Sciences in Wädenswil (ZHAW) and Zurich Water Works (WVZ), they have developed a complimentary system, namely a staining robot. This automatically prepares water samples before feeding them into the flow cytometer. It is thus possible to monitor bacterial counts online; depending on the settings, additional information can also be obtained on bacterial species, the proportion of viable cells, or bacteriological changes occurring during a process. While the initial experimental set-up at the ZHAW required a rather large and complicated system, the robot has now been reduced to the size of a PC case. Tests carried out in cooperation with the WVZ have proved so successful that the developers see a significant market potential for the system. A follow-up project is being supported by the CTI, Switzerland's innovation promotion agency.

Eawag in 2011

At the anniversary Info Day event, a wide variety of presentations provided an overview of Eawag's current research activities.

Eawag's anniversary year was dedicated in particular to dialogue with practitioners. Accordingly, for the 2011 Info Day event, water professionals and other interested parties were invited to Eawag's headquarters in Dübendorf, where a varied programme provided an overview of current research. A reception to mark the anniversary was attended by policymakers and representatives of industry and academia. An event organized for former doctoral students attracted experts from government, associations and industry, offering opportunities for young researchers to meet alumni. Rounding off the anniversary activities were numerous reports – appearing in diverse media outlets – and a trilingual publication celebrating Eawag's 75-year history. In addition, presentations by Eawag researchers brought professional associations in the water sector up to date on recent developments.

Broad dialogue

Water research in the spotlight

In 2011, Eawag participated in a number of events where water issues were discussed with the public. For example, Eawag scientists played a key role in the organization of the ETH Zurich's "Treffpunkt Science City", and a special guided tour at Dübendorf gave visitors an insight into various aspects of Eawag's research. Researchers also reached out to the public through contributions to the Zurich Environment Days and the Sempach "Fischer-Landsgemeinde" (an event hosted by the Canton Lucerne Fishing Association), as well as guided tours held regularly at the Dübendorf and Kastanienbaum sites.

South African Minister's visit

Eawag's activities and influence extend well beyond Switzerland. This is reflected not only by its involvement in international research projects and expert committees, but also by visits paid by high-ranking delegations from abroad. In 2011, for example, groups from South Korea, Brazil, the US and South Africa visited Eawag. Naledi Pandor, the South African Minister of Science and Technology, came to Eawag in June at the invitation of the State Secretariat for Education and Research, which is actively supporting bilateral research cooperation between Switzerland and South Africa. In Pandor's native city of Durban, Eawag is participating in a joint research project on nutrient recycling from wastewater, and close contacts are maintained with South African universities.

The South African Minister of Science and Technology, Naledi Pandor, visited Eawag at Dübendorf in June 2011.

Awards

Awards for five PhD dissertations

For young and more experienced scientists alike, recognition of one's efforts is an important motivator. In the past year, a number of Eawag researchers have won notable awards (see "Highlights", pp. 4–7). In addition, five young scientists have gained accolades for their PhD dissertations. Saskia Zimmermann was awarded the Otto Jaag Water Protection Prize for her work on wastewater treatment. Andreas Kretschmann, whose research is concerned with risk assessment of insecticides, received not only the Young Scien-

tist Award of the German Chemical Society's Environmental Chemistry and Ecotoxicology Division, but also an ETH medal for his dissertation. Monireh Faramarzi likewise received an ETH medal for her study of ways

Heidi Wunderli, Rector of the ETH Zurich, presents an ETH medal to Monireh Faramarzi at the PhD Awards Ceremony.

of alleviating water scarcity in Iran. In the US, Lee Bryant received the AEESP Outstanding Doctoral Dissertation Award for her work on substance fluxes in lakes and reservoirs. Lastly, Marius Vital was awarded an ETH medal for his dissertation on the growth of pathogenic bacteria in water.

Climate prize for nitrogen recycling

At the Zurich Climate Award ceremony in March 2011, the Eawag project "Nitrogen recycling with air-stripping at the Kloten/Opfikon wastewater treatment plant" received a special prize for innovation. Through its Climate Award, the Zurich Insurance Company reinvests CO_2 incentive-tax rebates in regional projects designed to reduce CO_2 emissions. Prizes are awarded in recognition of practicable projects which contribute to a reduction in atmospheric concentrations of CO_2 or promote changes of behaviour in this direction.

Infrastructure

Renovation work at Kastanienbaum

At the Kastanienbaum site, major renovation work began on the terraced facility originally constructed in 1970. The largest of the three existing buildings accommodates around 8 offices and 35 laboratories used by the Fish Ecology, Aquatic Ecology and Surface Waters research departments.

The renovation programme initiated in 2011 essentially involves renewal of the roof and windows, as well as the modernization of installations (heat recovery ventilation, heating, sanitary and electrical systems). Components containing asbestos which were discovered in the old ventilation ducts were rapidly and expertly removed, with elaborate safety measures. Research operations are continuing during the renovation work, which is to be completed by the end of 2012.

New spaces for recreation and interaction

It takes more than a sound technical infrastructure and adequate accommodation to make a good workplace: staff also need to have opportunities to relax or gather their thoughts. Accordingly, Eawag has opened a relaxation room for employees in the Dübendorf office building. Open to all, it is already being extensively used. The new coffee lounge in the atrium of the main building is also designed to offer space for relaxing and for sharing ideas. New seating, table tennis and table football facilities provide additional opportunities for interaction.

Eco-management

Lower energy consumption

Thanks to renovation measures, Eawag has substantially reduced its energy consumption for heating and cooling. In 1998 and earlier, total consumption was 7.5 terajoules, and it now amounts to around 2 terajoules – despite a marked increase in headcount. In addition, monitoring of

Renovation work has begun on the 1970s-era terraced facility at Eawag's Kastanienbaum site.

the energy consumption of individual buildings has been facilitated by the use of a data capture and processing system operated by the ETH Zurich Real Estate department, optimized by Eawag in cooperation with Empa. Control systems can now be fine-tuned, and more targeted measures can be taken to achieve further improvements.

More energy from renewable sources

Since 2005, electricity consumption has varied between 8 and 10 terajoules, which is equivalent to 20–25 megajoules per person. As Eawag is committed to the use of renewables, it produces its own solar power and meets the rest of its requirements at Dübendorf exclusively with "naturemade star" green electricity. The criteria specified for

Photovoltaic solar panels are one of the renewable energy sources used by Eawag.

this Swiss eco-label with regard to hydropower are based on Eawag research. Of the green power supplied, 97.5 per cent come from the certified hydropower plants in Aarberg and Niederried-Radelfingen, and 2.5 per cent from the certified Mont Crosin wind farm in the Jura.

From 2012, the requirements of the Kastanienbaum site will also be met with "naturemade star" power. In addition, Eawag's total solar power generation is to be increased from 0.25 to 0.5 terajoules. Together with Empa, Eawag is also investing in renewable forms of energy for heating and cooling. In the coming years, the two institutions plan to construct a waste wood gasification/power generation plant. Eawag's sustainability efforts also include a green mobility management scheme and a partnership with CO_2-monitor (an online platform for environmentally aware organizations).

Further information:
www.eawag.ch/sustainability

Equal opportunities

Successful mentoring programme

Eawag seeks to ensure equal opportunities and promotes a family/working life balance for all employees. Accordingly, it provides financial and administrative support for the Eawag/Empa on-site childcare centre and offers part-time employment for staff at all levels. It also encourages the appointment of women to management positions. 2011 saw the completion of a successful mentoring programme for female postdocs. Feedback from the mentees was highly positive, and they recommended that a similar scheme should be introduced for female doctoral students. In future mentoring programmes, Eawag intends to collaborate with other institutions – in particular, the ETH Zurich's Career Center.

In 2011, following the departure of Isabelle Perego from Eawag, postdoc Alexandra Kroll was appointed to succeed her as Chair of the Gender Equity and Equal Opportunity Committee.

Outdoor play is a regular activity at the Empa-Eawag childcare centre.

More women in management

In 2011, the number of scientific and administrative staff at Eawag increased slightly. Overall, the headcount rose by 17 employees (+3.8 per cent) or 11.6 full-time equivalents (+1.2 per cent). While women accounted for most of this rise, the female-to-male ratio (49/51 per cent) was not significantly altered. There was a slight increase in the average degree of employment. The already high proportion of management positions held by women has continued to rise: the increase – from 22.2 to 23.8 per cent – is mainly attributable to the retirement of male staff at these functional levels.

Equal pay

Once again, compensation statistics for scientific staff show a stagnation in median salaries for men and an increase for women. Among administrative staff, median salaries are higher than in the previous year, reflecting the integration of long-serving PSI and WSL employees into the newly merged library (Lib4RI). Detailed analysis indicates that there are no differences in the pay earned by men and women in the same function and with the same years of experience.

Personnel

Two new female professors

In 2011, two young female researchers were appointed to professorships. In August, Karin Ingold took up her post as Assistant Professor leading the Policy Analysis group, with a special focus on the environment. This tenure-track position (with the possibility of a permanent professorship) was established at the Bern University Institute of Political Science and is co-funded by Eawag. It is intended to promote joint Eawag/Bern University research activities in the field of water resource management and water policy. Karin Ingold is a political scientist concerned with water, energy and climate policy, focusing on the analysis of political processes and questions relating to the management of natural resources. The Policy Analysis group is based at Bern University, but some of the research on water policy is also conducted at Eawag in Dübendorf.

With the appointment of Lenny Winkel (in May 2011) as Assistant Professor of Inorganic Environmental Geochemistry in the Department of Environmental Sciences, the ETH Zurich aims to strengthen this field of research. Based at the Institute of Biogeochemistry and Pollutant Dynamics, this professorship is sponsored by the Swiss National Science Foundation. Winkel's research group works at Eawag.

Eawag's new Assistant Professors: Lenny Winkel (left) and Karin Ingold.

New head of Environmental Microbiology

In July 2011, Martin Ackermann took over from Thomas Egli as head of the Environmental Microbiology department. Egli had been in charge of the department since 2005 and will continue to conduct research there. Since 2008, Ackermann has been an Associate Professor of Molecular Microbial Ecology at the ETH Zurich, where he previously served as Swiss National Science Foundation Professor of Microbial Evolution. He has worked at Eawag since 2008.

Titular professorship at Bern University

In January 2011, Bern University appointed Eawag researcher Bernhard Truffer as Titular Professor in recognition of his outstanding teaching services. Truffer has worked at Eawag since 1996 and has been head of the Innovation Research in Utility Sectors (Cirus) department since 2006. He previously served as an assistant at Fribourg University and a lecturer at institutions including the ETH Zurich. He has lectured at Bern University since 2002, gaining his habilitation in Economic Geography and Sustainable Development in 2006.

38 years' commitment to vocational training

Having been responsible for vocational training at Eawag for over 38 years, Max Reutlinger retired on 1 July 2011. He was in charge of the training programmes for apprentice chemistry and biology lab technicians, administrators and IT systems engineers. Since he first joined Eawag in 1972, the number of apprentices has risen from 2 to 26. In 2011, his successor, Samuel Derrer, and numerous other dedicated staff oversaw the successful completion of nine apprenticeships. All of those who qualified have now found either employment or a further training place.

Retirement of Willi Gujer

As Professor of Urban Water Management at the ETH Zurich and as a researcher at Eawag, Willi Gujer helped to shape the urban water management sector in Switzerland and worldwide. After a 37-year career at Eawag, he retired in 2011. He was tireless in his efforts to build bridges between research and practice. He was also known as a gifted teacher, receiving the "Golden Owl"

Willi Gujer: a tireless bridge-builder and a dedicated teacher.

from the ETH student association in 2006 and the "Credit Suisse Award for Best Teaching" in 2008. In October 2011, a symposium in his honour – "On the practical benefits of a good theory" – was held at the Empa Academy. Gujer's successor at the ETH Zurich is Eberhard Morgenroth, who in 2012 also became head of the Process Engineering department at Eawag.

New members of Advisory Committee

In 2011, Peter Hunziker, Felix von Sury and Thomas Weibel joined Eawag's Stakeholder Advisory Committee. Peter Hunziker, Director of Hunziker Betatech AG (an engineering company) and a Swiss Water Association (VSA) Board member, replaces Jürg Meyer, a former VSA President. Felix von Sury, of Von Sury Consultants, replaces Peter Arbenz, President of the development organization Helvetas. Thomas Weibel, who lectures in bioengineering at the ZHAW School of Life Sciences and Facility Management, is a National Councillor for the Green Liberal Party.

ETH Domain

Close cooperation

In research and teaching, Eawag cooperates closely with other institutions within the ETH Domain. In the fields of bioinformatics and microscopy, for example, it has joined forces with the ETH Zurich to co-fund one position at the ETH Laboratory of Ion Beam Physics and one at the ETH/Zurich University Functional Genomics Center. This gives Eawag access to expertise in the increasingly important field of bioinformatics, and also to vital microscopy resources. But Eawag is also constantly seeking synergies and opportunities for collaboration in the areas of infrastructure, administration and IT. Since 2011, the libraries of the four research institutes within the ETH Domain (Eawag, Empa, PSI and WSL) have been merged as "Lib4RI". Scientists at all four institutes benefit from the combined expertise of the librarians within a single management structure, as well as from expanded holdings. The newly launched joint library website facilitates literature searches and offers a wide variety of information.

Joint solutions

Another example of successful cooperation between the four research institutes is the introduction of the SAP financial management system. As well as saving resources via joint procurement, the institutes have acquired a high-performance data processing system. Thanks to efficient cooperation, the SAP system went live at all four institutes, as planned, on 1 January 2012.

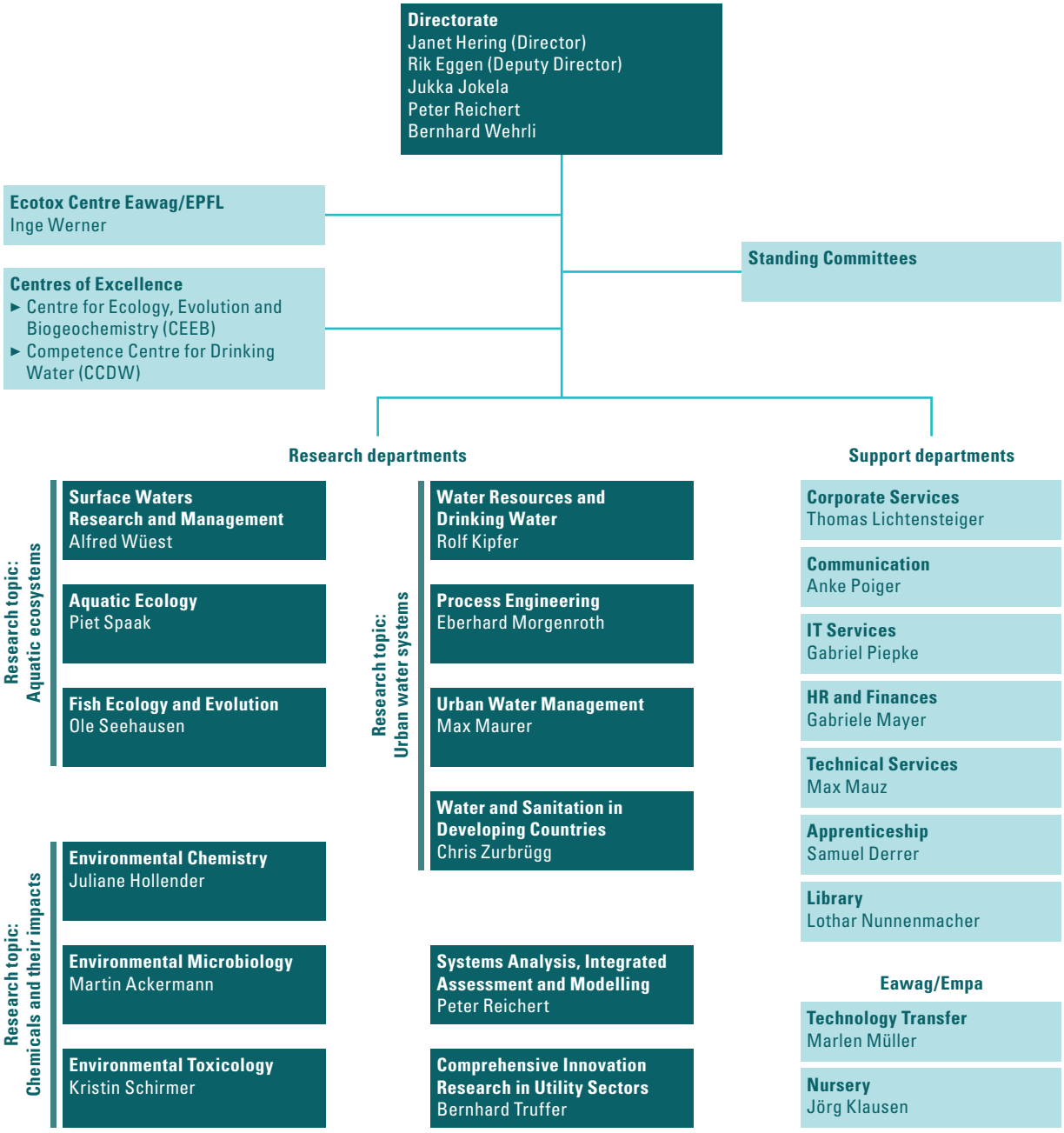
Because of the close physical proximity, there are also opportunities for smaller-scale cooperation between Eawag and Empa in particular. In 2011, for example, the two institutes merged their knowledge and technology transfer functions. This decision proved to be justified, as both parties are now benefiting from the integrated advisory services led by Empa. Cooperation between the IT departments of Empa and Eawag has also been intensified: in autumn 2011, a joint data storage and back-up solution was launched, using a system which also provides higher-speed and more secure data transfer. Additional joint projects are under way in the areas of telephony and network security.

Workshop relocated

From 1997, Eawag's workshop had been housed in Empa's northeast building. In 2011, as this space was required for a different purpose, the workshop was relocated to Empa's "metal shed". This move was ideal because, although it involved a loss of working area, the close proximity of Eawag's to Empa's workshop enables joint use of equipment and storage facilities, as well as mutual assistance and the sharing of expertise between the two workshop teams. ○ ○ ○

Since mid-2011 Eawag's workshop has been located close to the Empa workshop.

Organisation



Advisory Board

Ursula Brunner (President), ettlersuter Lawyers, Zurich
Peter Arbenz (until December 2011), President of Helvetas
Claus Conzelmann, Vice President for Safety, Health and Environment, Nestlé Group
Günter Fritz, Head of Environment, Health and Safety, BASF Schweiz AG
Urs Gantner, Head of Research and Extension Unit, Federal Office for Agriculture, Bern
Heinz Habegger, Head of Water and Waste Management Office (AWA), Canton Bern
Peter Hunziker (from December 2011), Director of Hunziker Betatech AG, Winterthur
Jürg Meyer (until December 2011), Director, ISS Infrastructure Services, ISS Schweiz AG
Stephan R. Müller, Head of Water Division, Federal Office for the Environment, Bern
Reto Schneider, Head of Emerging Risk Management, Swiss Re, Zurich
Felix von Sury (from December 2011), Consultant, Von Sury Consulting, Solothurn
Thomas Weibel (from December 2011), National Councillor, Green Liberal Party, Canton Zurich

People

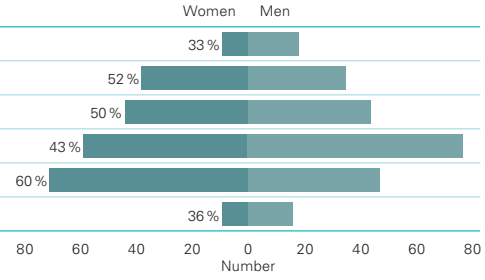
Personnel	People	Wehreof women	Wehreof non-Swiss	Full-time equivalents
Full professors [1]	9	1	3	9
Titular professors	14	3	4	14
Scientific staff (academic staff)	162	66	82	150
PhD students	105	51	69	103
Technical staff	92	42	12	76
Administrative staff	70	59	8	50
Apprentices	23	8	3	23
Total	**475**	**230**	**181**	**425**
Affiliated staff (nursery)	15	14	1	13
Trainees [2]	39	20	26	39

[1] 8 of them are not or not directly employed by Eawag
[2] Variable employment periods, total number in 2011

Percentage employment	Women	Men	Total
1–49 %	14	9	23
50–79 %	45	9	54
80–99 %	39	23	62
100 %	132	196	328
Total	**230**	**237**	**467**

Origin	Women	Men	Total
Switzerland	138	150	288
EU	71	65	136
Other	21	22	43
Total	**230**	**237**	**467**

Age structure	Women	Men	Total
60–65	9	18	27
50–59	38	35	73
40–49	44	44	88
30–39	59	77	136
20–29	71	47	118
15–19	9	16	25
Total	**230**	**237**	**444**
	(49.3 %)		



Apprentices	Women	Men	Total
Biology lab technician	1	2	3
Chemistry lab technician	5	10	15
IT systems engineer	0	2	2
Administrator	2	1	3
Total	**8**	**15**	**23**

Activities

	2009	2010	2011
Supervised dissertations	111	153	160
Supervised Bachelor's and Master's theses	109	142	145
Publications in refereed journals	232	259	268
Publications in non-refereed journals	114	72	106
Spin-offs	–	–	–
Patents, licence agreements	–	–	–
Service contracts	24	35	35
Prizes	19	26	10
Teaching programmes at ETHZ, EPFL	82	95	77
Teaching programmes at other universities	41	24	34
Teaching programmes at universities of applied sciences	6	0	1
PEAK-courses (further education)	5	6	5
Conferences	53	54	44
Committee memberships	184	190	276

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

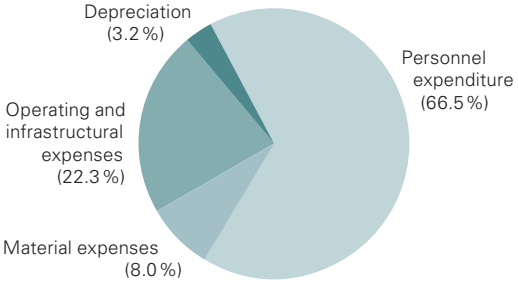
Finances

Financial statement	2009	2010	2011
Personnel	39 278 708	41 923 339	44 425 613
Materials	11 426 136	2 990 640	5 347 807
Operating and infrastructural expenses	14 011 009	14 920 290	14 856 606
Depreciation	1 896 647	2 109 090	2 110 493
Provisions	1 001 944	–210 058	–140 318
Expenditure	**67 614 444**	**61 733 302**	**66 600 200**
Federal government funding	47 596 574	54 239 254	55 251 566
Third-party resources (incl. changes in inventories)	11 068 789	14 246 016	14 274 585
Miscellaneous revenue	1 238 918	1 717 018	2 127 238
Income	**59 904 281**	**70 202 289**	**71 653 389**
Result	**– 7 710 163**	**8 468 987**	**5 053 189**

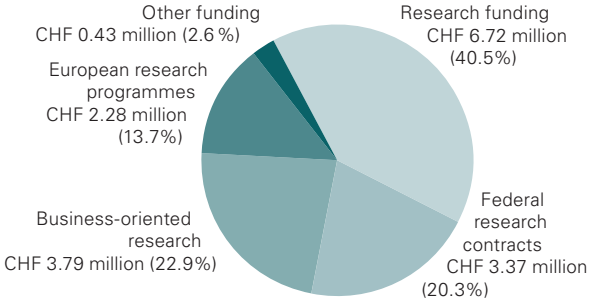
Investments	**10 786 584**	**6 181 458**	**5 030 479**
Real estate	8 462 580	3 121 000	2 723 000
Movables	1 953 614	3 006 300	1 820 471
IT	370 390	54 158	487 008

all figures in CHF

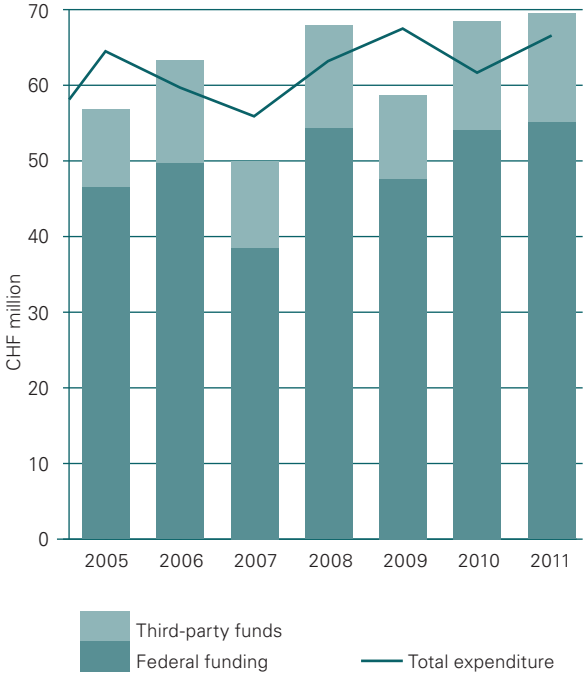
Breakdown of expenditure 2011



Third-party resources 2011

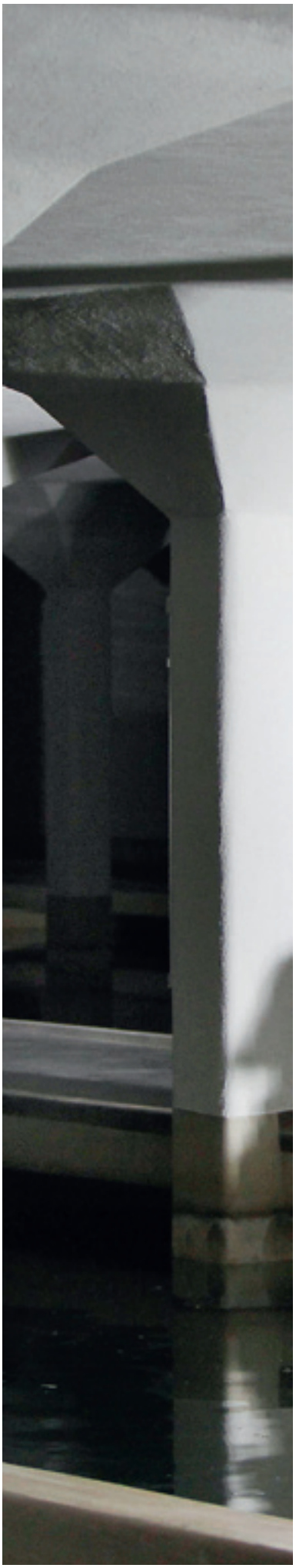


Development 2005–2011



The Annual Report 2011 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.



Publication details

Editing: Andres Jordi | **Contributors:** Fabio Bergamin, Atlant Bieri, Andri Bryner, Herbert Güttinger, Thomas Lichtensteiger, Beatrix Mühlethaler, Anke Poiger, Annette Ryser, Anke Schäfer, Evelin Vogler, Felix Würsten | **Translation:** Jeff Acheson, Bottmingen | **Design:** TBS Identity, Zurich | **Layout:** SLS Nadler, Fällanden | **Printing:** Mattenbach AG, Winterthur |

Eawag, Überlandstrasse 133, P.O. Box 611, 8600 Dübendorf, Switzerland, Phone +41 (0)58 765 55 11, Fax +41 (0)58 765 50 28
Eawag, Seestrasse 79, 6047 Kastanienbaum, Switzerland, Phone +41 (0)58 765 21 11, Fax +41 (0)58 765 21 68
www.eawag.ch

Photo credits

Cover photo: Gesa Lüchinger | **Page 1:** *1* Selina Derksen, *2* Matthias Burri, *3* Frank Bonell, *4* ETH Zurich | **Page 2:** Eawag | **Page 4:** *1* Yvonne Lehnhard | **Page 5:** *2, 3, 5* Esther Ramseier; *4* Hanna Berger, *6* Peter Penicka | **Page 6:** *7* International Water Association | **Page 7:** *8* Raoul Schaffner, *9* Oliver Bartenschlager, *10* Peter Penicka, *11* Eawag, *12* Anke Poiger | **Page 8:** Olaf Cirpka | **Page 9:** *top left* Cathrine Wagner, *bottom left* Raoul Schaffner, *right* Susi Lindig | **Page 10:** Hansruedi Bürgi | **Page 11:** Maria Alp | **Page 12:** Philipp Dubs | **Page 13:** *left* O.A. Sherwood, Memorial University of Newfoundland, Canada; *right* Andri Bryner | **Page 14:** Olaf Cirpka | **Page 15:** Maria Alp | **Page 16:** Selina Derksen | **Page 17:** Maryna Peter-Verbanets | **Page 18:** Christian Binz | **Page 19:** Gesa Lüchinger | **Page 20–21:** Peter Schönenberger | **Page 22:** Agilent Technologies Inc. | **Page 23:** Ruedi Keller | **Page 24–25:** *1, 5* Andri Bryner; *2, 3, 4, 6, 7, 8* Stefan Kubli | **Page 26:** Stefan Kubli | **Page 27:** *top left* Anke Schäfer, *bottom left* Martina Bauchrowitz, *right* Andres Jordi | **Page 28:** Eawag | **Page 29:** *left* Eawag, *right* Yvonne Lehnhard | **Page 30:** *left* Okapia, *right* Eawag | **Page 31:** *left* Nina Küng, *right* Matthias Burri | **Page 32–33:** zvg | **Page 34:** Max Maurer | **Page 35:** *top left* Peter Penicka, *bottom left* zvg, *right* Martina Bauchrowitz | **Page 36–37:** Andri Bryner | **Page 38:** plainpicture | **Page 39:** Frank Bonell | **Page 40:** Alfred Wüest | **Page 41:** Repower | **Page 42–43:** Gesa Lüchinger | **Page 44:** Andres Jordi | **Page 45:** Esther Ramseier | **Page 46:** *top left* ETH Zurich, *bottom right* Tom Kawara | **Page 47:** *bottom left* Stefan Kubli, *top right* Yvonne Lehnhard | **Page 48:** Peter Penicka | **Page 49:** *top left* Tom Kawara, *bottom right* Peter Penicka

eawag
aquatic research

Eawag
Überlandstrasse 133
8600 Dübendorf
Switzerland
Tel. +41 (0)58 765 55 11
Fax +41 (0)58 765 50 28
www.eawag.ch
info@eawag.ch