Eawag –
Swiss Federal Institute of Aquatic
Science and Technology

Annual Report 2012

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

Cover photo
Environmental scientist Caroline Baumgartner (centre) of the Aquatic Ecology department instructs students in the use of a microscope. Eawag makes important contributions to the academic and practice-oriented training of water professionals. (Photo: Aldo Todaro)

Content

Bridging between science and society

It is one of Eawag's core goals to bridge between theory and practice. This requires expertise in the underlying science, a willingness to invest over the long term and the integration of social sciences with natural sciences and engineering. Eawag is focusing its efforts on three strategic themes: water for human welfare, water for ecosystem function and strategies for trade-offs and competing demands.

For Eawag, as well as for other federal institutions and offices, 2012 was a bridging year between two planning periods: 2008 – 2011 and 2013 – 2016. This led to the compromise that, for implementation, 2012 was linked to the past, while for planning, it was included with the future. Thus 2012 offers an interesting vantage point to look both back and forward.

Rewards and opportunities derived from past investment

A strong base of research expertise, involving sustained effort in key areas, is necessary if technologies are to be successfully implemented in practice and if scientific understanding is to be incorporated into policy and decision-making.

In 2012, Eawag was recognized for innovation in the Reinvent the Toilet Challenge (RTTC). Yet the success of the RTTC project (p. 26) was based on two types of expertise – one with source separation and decentralized treatment, the other with the successful implementation of technology in developing countries – both of which were developed over years, if not decades, of prior work. Eawag's two decades of investment in solar disinfection of drinking water (Sodis) was also recognized, with the award of the 2012 Brandenberger Foundation Prize to Martin Wegelin (p. 57). In addition to its humanitarian impact, the Sodis project generated new scientific understanding of the mechanisms of bacterial inactivation by sunlight, and of the motivation of human behavioural change that determines whether Sodis is used effectively.

Bringing knowledge into policy and practice

The beginning of 2012 witnessed an intense debate over phosphorus inputs to Lake Brienz for higher fish production. Eawag research into the consequences of excess nutrients for biodiversity (p. 8) provided a basis for informed political decision-making. Studies in China demonstrate that eutrophication continues to be a relevant issue for water managers (p. 30). Research using flow cytometry was the basis for development of a new standard analytical method for health safety assessment (p. 45). A new procedure for the assessment of drinking water contamination from synthetic pipe materials also relies on flow cytometry (p. 44). New methods of interrogating sediment records provide insight into sources of nutrients and other contaminants (p. 13). The detection of antibiotic-resistant bacteria in the sediments of Lake Geneva demonstrated yet another effect of human activities on bacterial communities in the environment (p. 14).

Research into the fate and effects of nanoparticles in the environment (p. 24) is needed as the basis for future regulation. Reviews of the current status of knowledge and, in particular, identification of knowledge gaps – e. g. in wastewater treatment (p. 51), ecotoxicology (p. 48) and lake assessment (p. 46) – provide the basis for planning, prioritization and further research. Similarly,

Peter Penicka

research on the fundamental phenomena affecting climate (p. 20) and on projected water availability in Africa (p. 22) is needed to anticipate future challenges in water management. Finally, Eawag's research has provided the basis for upgrading and optimization of the wastewater treatment system at the Monte Rosa hut (p. 50).

Technical approaches, however, provide only part of the solution. Another, often more important role, is played by people. Thus, psychological studies in Haiti demonstrated that promotion campaigns for hygiene are not all equally effective, and their optimization could benefit human health (p. 52). Eawag's newly established Department of Environmental Social Sciences addresses this and will develop measures to assess and manage the trade-offs inherent in the use of water to meet direct human needs and the conservation of aquatic biodiversity and ecosystem function.

A fast start for 2013

Thanks to the bridging year of 2012, Eawag will begin the new year with key elements of its Target Agreement with the ETH Board for 2013–2016 already initiated. Throughout this planning period, Eawag will strengthen its focus on the themes of water for human welfare, water for ecosystem function and strategies for trade-offs and competing demands. This will include technical studies of energy conservation in the NEST project led by Empa, and of renewable energy sources, particularly hydropower. In the context of river restoration, Eawag will expand its collaboration with practice through its new programme on Swiss rivers and will continue to explore the underlying science – e. g. the effects of connectivity on diversity (p. 10 and 12). In support of the revised Water Protection Act, Eawag will be working with water professionals on the upgrade of wastewater treatment plants and will be examining the effects of micropollutants at the ecosystem level in the interdisciplinary project EcoImpact (p. 17). These projects will benefit from Eawag's planned investment in new experimental facilities for pilot-scale studies.

With these activities, Eawag continues to build its scientific expertise. Two new professorial appointments – Max Maurer at the ETH Zurich and Alfred Wüest at the EPF Lausanne – will help to carry this knowledge into society via education of young professionals.

Janet Hering, Director

Highlights of 2012

June

At the ETH Water Talks, Eawag Director Janet Hering addressed the question "What is the value of water?". → **page 56**

ETH-Zürich

January

Eawag

Eawag now hosts the World Health Organization's Collaborating Centre for Sanitation and Water in Developing Countries. → **page 57**

December

The flow cytometry method for drinking water analysis was included in the Swiss Food Compendium by the Federal Office of Public Health. → **page 49 and 56**

Gesa Lüchinger

August

A team led by process engineer Tove Larsen won a special recognition award for outstanding design in the Gates Foundation's Reinvent the Toilet Challenge. → **page 26 and 57**

Keystone

Peter Penicka

Max Maurer was appointed Full Professor of Urban Water Systems at the ETH Zurich. → **page 59**

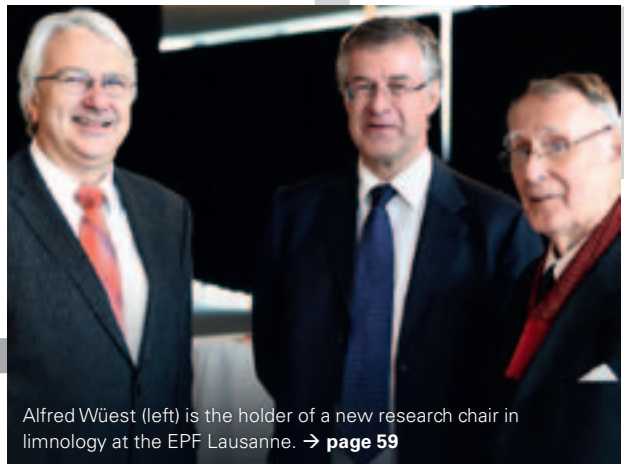
September

November

Martin Wegelin was awarded the Brandenberger Foundation Prize for his work on solar water disinfection. → **page 57**

Andri Bryner

December



Alfred Wüest (left) is the holder of a new research chair in limnology at the EPF Lausanne. → **page 59**

Alain Herzog

Aldo Todaro

Research

The Reinvent the Toilet Challenge (RTTC) project showcased Eawag's expertise in the areas of sanitation and wastewater treatment technology. The success of this project was due to fruitful interdisciplinary cooperation not only within Eawag, but also with external water professionals – and to decades of prior research. In particular, the cross-cutting Novaquatis project ensured the availability of the scientific, technical and methodological expertise needed to develop a viable solution. Conducting basic and applied research with a long-term perspective – and delivering solutions which can be successfully implemented in the water sector – are key goals for Eawag.

Ivana Logar: Where the environment meets economics

As Ivana Logar has always been interested in both economics and the environment, she first took a degree in Economics and then specialized in Ecological Economics. Since 2011, she has been working as a postdoctoral researcher in the new Environmental Social Sciences department. "I appreciate the integration of knowledge from the natural sciences into my social scientific work," she says. One of her main research interests is the economic valuation of ecosystem services: "That means, for example, determining how much we're willing to pay to ensure that our drinking water is clean." This information can then be fed into cost-benefit analyses of improving or deteriorating the quality of ecosystem services. In a recent study, she found that, on average, households in German-speaking Switzerland would be prepared to pay on average CHF 100 a year for upgrading wastewater treatment plants so that micropollutants can be effectively removed (see page 24). At present, Ivana Logar is the only member of the Environmental Economics group in Dübendorf, which is led – from Amsterdam – by Professor Roy Brouwer. However, she is planning to recruit a number of doctoral students and to initiate a series of new projects. And she will soon be joined by another postdoctoral researcher: "Finally, our research group is really taking shape!"

Lake Brienz: should it be "fixed"?

To boost fish yields, some members of the fishing community would like to see phosphorus levels artificially increased in Lake Brienz. However, Eawag research on water fleas and whitefish shows that the species composition of a lake is irreversibly altered by higher nutrient levels.

Thanks to local wastewater treatment, the water in Lake Brienz is once again nutrient-poor, as phosphorus inputs have been reduced to a fraction of the levels seen in the past. While in the early 1980s a litre of lake water contained around 20 micrograms of phosphorus, concentrations today are below 1 microgram per litre. For some fishermen, however, these water pollution control measures have gone too far: they claim that the lack of nutrients is responsible for a decline in catches. Today – as in the 1950s – the annual whitefish yield is 2 kilograms per hectare of lake surface, while yields of 15 kilograms were recorded during the years of increased phosphorus inputs. Accordingly, they argue that phosphorus elimination at wastewater treatment plants should be reduced: higher nutrient inputs would promote algal growth and thus support the water flea populations – a food source for fish.

However, as the proposed reduction in phosphate precipitation would contravene water pollution control regulations, motions have been tabled in both houses of parliament calling on the government to approve a pilot project. Similar plans are under consideration for Lake Lucerne. Scientists at Eawag take a highly critical view of such experiments. Their position is supported by recent studies which demonstrate the extent to which species and communities are affected by eutrophication.

Ole Seehausen

Eawag scientists investigating biodiversity in Lake Brienz as part of "Projet Lac" found a number of endemic whitefish species.

One water flea species displaced by another

A study by Piet Spaak and co-workers from the Aquatic Ecology department focused on water fleas *(Daphnia),* which are zooplanktonic organisms. With the aid of genetic analyses of resting eggs retrieved from lake sediments, the researchers showed that – before Swiss waterbodies were exposed to pollution – *Daphnia longispina* was the predominant water flea species in all the lakes studied.

During the period of eutrophication, the invasive species *Daphnia galeata* became established at the expense of the native species in heavily polluted lakes. In most cases, the two species formed hybrids. Where *Daphnia longispina* was displaced altogether – e. g. in Lakes Constance and Greifen – the change has proved irreversible. Spaak comments: "Today, *Daphnia galeata* and the hybrid forms are the only *Daphnia* species occurring in these and other lakes, even where the nutrient status has returned to normal." In oligotrophic waterbodies such as Lake Brienz, which were never as polluted as the lakes of the Central Plateau, the native water flea species tended to survive. Although it sometimes also hybridized with *Daphnia galeata*, it became predominant again as the waters became cleaner.

In laboratory experiments involving clones of the two *Daphnia* species, the researchers demonstrated the importance of different types of food supply: *Daphnia longispina* fared better when reared under oligotrophic conditions, while *Daphnia galeata* performed better with a eutrophic food supply. Accordingly, few or no resting stages of *Daphnia galeata* were found in sediments from lakes minimally affected by eutrophication. In earlier times, Lake Brienz was too nutrient-poor to support even the native water flea. As Spaak points out, "It's been shown that there were no permanent populations of *Daphnia* in this lake before 1950."

Disappearance of specialist whitefish

Eutrophication not only alters the composition of water flea species in lakes – it also has adverse effects on whitefish, as shown by researchers from Eawag and Bern University. Using a survey carried out 60 years ago, the scientists compared historical and current whitefish populations in 17 lakes. They found that the number of endemic whitefish species has decreased by 38 per cent since 1950. Ole Seehausen of the Fish Ecology and Evolution department, who led the study, says: "The higher the maximum phosphorus concentrations

recorded in a lake, the greater the loss of species." In seven lakes, the original whitefish populations are now extinct, and they have been replaced by hatchery stocks.

Most whitefish species found in Switzerland are endemic – i.e. they occur exclusively in the lake in question. But, says Seehausen, "Around a third of these species have already become extinct as a result of eutrophication." In the case of highly eutrophic lakes, all the whitefish species have disappeared. In lakes less severely affected by eutrophication, species adapted to life in the bottom and deep waters have been lost: as these waters became oxygen-depleted owing to phosphorus inputs and the accumulation of dead algal matter, the specialists were deprived of their ecological niches. They thus died out or moved to shallower waters. Here, they interbred with other whitefish species and, as a result, lost their genetic and functional distinctiveness within a few generations. In all the formerly polluted lakes, genetic differentiation has therefore declined among the surviving populations – a development which also affects ecological behaviour. Populations are therefore now much less specialized in terms of appearance, type of feeding and spawning time. Seehausen comments: "This loss of variation amounts to a reversal of speciation."

Lower yields, but greater diversity

Although whitefish are also believed to have hybridized in Lake Brienz, it seems that none of the original species disappeared completely. Further information will be provided by the systematic survey of fish biodiversity in pre-alpine lakes which is being carried out as part of "Projet Lac". This project, launched by Eawag and various partners in 2011, is recording the occurrence of fish at all depths and in all types of habitat. Endemic species and naturally spawning populations of whitefish were detected even in the depths of Lake Brienz. In addition, numerous whitefish were netted. The researchers concluded that, while there is no scarcity of fish, they are smaller than those found in other lakes, which helps to explain the relatively low yields.

The fact that Lake Brienz now harbours smaller whitefish and fewer water fleas means that it has been restored to a more natural condition. As Seehausen emphasizes, "Switzerland has a number of highly productive, nutrient-rich lakes, and so the few naturally oligotrophic waters – with their unique biodiversity – should be preserved." In his view, Switzerland also has a responsibility to the international community, since the endemic species are included in the Red List. And the evolutionary biologist also has an eye to future developments: "Oligotrophic waters such as Lake Brienz represent a unique reservoir of genetic diversity where new species can evolve through specialization."

The case for phosphorus elimination

Experts at Eawag take a critical view of proposals to restrict phosphorus removal at WWTPs:

- Lake Brienz is a naturally oligotrophic waterbody. After years of excessive phosphorus loads, it has been successfully restored to its natural condition – in accordance with the goals of Swiss environmental policy – and this should not be jeopardized.
- Only a few large oligotrophic lakes exist in Switzerland. They harbour unique, diverse communities of species, some of which only occur in one lake. These distinctive species and ecosystems should be preserved.
- Even a slight rise in nutrient levels affects biodiversity.
- Available data strongly suggest that community composition can be permanently altered by an increase in phosphorus inputs: endemic species adapted to oligotrophic waters are irretrievably lost.

www.eawag.ch/fb-brienzersee
(factsheets in French and German)

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River networks and biodiversity

Patterns of biodiversity along rivers and streams are determined not only by local environmental factors but also by the structure of the network. Evidence confirming what is suggested by monitoring data has now been provided for the first time by laboratory experiments and a mathematical model.

Rivers are among the world's most species-rich habitats, but losses of biodiversity are disproportionately high within these aquatic ecosystems. Such losses are caused by, for example, the draining of wetlands, the fragmentation of rivers (construction of embankments and dams), the spread of invasive alien species and chemical pollution.

Dispersal paths determined by structure

To facilitate conservation efforts, it is important to understand the factors underlying the diversity of river systems. "Diversity" here refers firstly to local species richness at a particular site – e.g. the mouth of a river – and secondly to the (sometimes substantial) variation in community composition between similar, but spatially separated habitats – e.g. two headwaters within the same river system. Waterways permit the dispersal not only of fish and macroinvertebrates but also of riparian plants, and the paths they can follow are determined by the structure of the river network.

In the past, biologists explained the occurrence of species mainly in terms of local environmental conditions. It was assumed, for example, that certain species are dependent on the cold temperatures typical of headwaters or can only survive within a specific pH range. But this approach fails to take account of the dispersal of organisms; in addition, it assumes that every suitable habitat will be occupied. More recent models indicate that characteristic diversity patterns may also be due to constraints on the ability of organisms to disperse along rivers and streams. Accordingly, if the occurrence of species is to be fully explained, waterways

Okapia

The network structure of a river system influences species dispersal and can help to explain patterns of diversity.

need to be conceived of not as (simple) linear systems, but as (complex) networks.

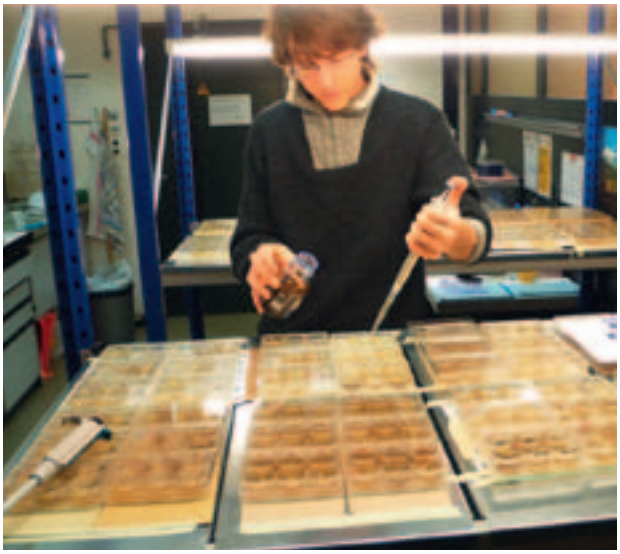
Monotonous pattern in lattice network

This idea has now been confirmed experimentally for the first time by a team of Eawag researchers led by Florian Altermatt of the Aquatic Ecology department, in collaboration with the EPFL Laboratory of Ecohydrology. In an experiment involving aquatic microcosms, the dispersal of microorganisms was simulated in a river-like network. The spatial structure of a river network was extracted from a realistic landscape model and reproduced in a simplified form in the laboratory system, which consisted of culture plates. Each of these microcosms represented a habitat at a particular site within the river network. All the cultures were initially inoculated with eight protozoan and one rotifer species. To simulate dispersal, small amounts of nutrient medium were then transferred by pipette between neighbouring communities. For comparison, the same procedure was followed using a homogeneous lattice network. Environmental factors were thus eliminated or standardized: the systems differed only in their connectivity, not in their "habitat" conditions. As the experiment covered dozens of generations, it was also possible to investigate long-term effects of species interactions and population dynamics on diversity patterns.

In the river-like networks, the "confluences" were found to have greater local species richness than the more isolated "headwaters", while marked variation in community composition was seen among the various headwaters. In the homogeneous lattice networks, by contrast, a monotonous pattern arose. In both experimental set-ups, similarity of species composition decreased with increasing distance between the local communities, but the differences were more pronounced in the river-like networks. The patterns observed experimentally were confirmed by a mathematical model developed in parallel with the laboratory study; this makes it possible to draw more general conclusions.

Relevance for restoration projects

The results demonstrate that the connectivity and continuity of rivers have a direct influence on species distribution and diversity. Variation in community composition among habitats is particularly important for the maintenance of a high level of regional diversity. Changes to the network structure of a river system – e. g. as a result of the construction of dams or the linking of rivers by channels – influence species dispersal and will affect biodiversity. As Altermatt notes, this needs to be taken into account when restoration measures are planned for a river section: "What's crucial is not just the nature and quality of the individual habitat, but its position within the river network."



Florian Altermatt

To simulate the dispersal of species in a river-like network, researchers transferred microorganisms in nutrient medium between culture plates (microcosms).

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Adaptation in Alpine trout

Intensive stocking of rivers in the Alps led to the mixing of trout species. But genetic differences still exist between the populations of different drainage systems – and there is even evidence of local adaptation to different altitudes.

The four major European rivers rising in the Alps – the Rhine, Rhône, Po and Danube – originally harboured five different species of trout. Representing evolutionarily distinct lineages, these species were well adapted to their respective habitats. However, the isolating effects of geographical barriers were partly offset by fishery management practices: in the last century, in order to increase yields, large numbers of trout of Atlantic origin were translocated from the Rhine to other drainage systems. These stocking measures led to extensive hybridization between native and introduced species. As biologist Irene Keller of the Fish Ecology and Evolution department explains, "If local populations interbreed with non-native individuals, genetic adaptations may be lost and species may merge."

Differentiation maintained

Genetic diversity in Alpine trout was investigated by Keller, together with Master's student Jolanda Schuler and other colleagues, in a three-year project. In particular, the researchers were looking for evidence of genetic divergence among populations – indicating evolutionary adaptations – either between or within river systems. Using tissue samples taken from fins for genetic analysis, Keller and Schuler studied around 400 trout caught by electrofishing at 16 sites in the drainage systems of the Rhône, Rhine and Po.

Irene Keller, Jolanda Schuler, Ole Seehausen

Certain trout populations still differ genetically – and in their appearance.

The investigations confirmed that historical stocking measures led to extensive losses of genetic diversity. Nonetheless, at a number of sites in the various drainage systems trout populations still showed significant levels of genetic differentiation. "Fortunately, the original genotypes of the different forms of trout have not been completely intermixed," says Keller. This suggests that – at least in some habitats – the native fish had certain advantages over the introduced individuals. In addition, the researchers found evidence of "divergent selection" – i. e. selection pressures varied between drainage systems and trout had adapted to the local environmental conditions. "That was to be expected," says Keller, "because geographical isolation prevented genetic exchanges between the populations, so they were able to develop in different ways."

Adaptation to altitude

More striking, however, was the finding that local forms adapted to different altitudes had also developed within the three drainage systems studied. Keller explains: "Within a river system, fish can breed and exchange genes, but we still found clear evidence of genetic differentiation along altitudinal gradients." The researchers conclude that strong selection pressures are at work: increasing altitudes are often associated with dramatic changes in factors such as temperature and the composition of communities of prey and parasites. The differences between the habitats promote altitudinal adaptation in spite of gene flow.

As well as demonstrating the richness of genetic diversity in trout, these findings have important implications for conservation efforts. Keller cautions: "Stocking should only take place within closely circumscribed areas, so that locally adapted forms are preserved."

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Lakebed archive of micropollutants

Our knowledge of what chemicals polluted surface waters in the past remains sketchy. A method developed by researchers at Eawag makes it possible to detect micropollutants in sediments and thus generate records of historical contamination.

Today, thanks to modern analytical techniques, we know in detail to what extent lakes and rivers are contaminated with household, industrial and agricultural chemicals. To date, however, only limited data have been available on historical contamination of surface waters – partly because not all the substances we look for today were sought in the past. A team led by Juliane Hollender of the Environmental Chemistry department has now developed a method for the analysis of micropollutants in sediments which allows the history of surface water contamination to be reconstructed.

Identifying unknown compounds

The new method involves the use of high-resolution mass spectrometry. With this technique, the mass of a molecule can be measured extremely accurately, and substances can thus be identified. "With older systems," Hollender explains, "compounds could be detected if you knew what you were looking for. Now, with high-resolution mass spectrometers, it's much easier to distinguish between substances, and we can even identify unknown compounds." The method makes it possible to discriminate between molecules differing in mass by only 0.001 atomic mass units (1.66×10^{-30} kilograms).

The Eawag researchers have optimized the method so that it can be used to analyse a wide variety of persistent environmental contaminants from pharmaceuticals, personal care products, perfumes and pesticides. Prior to analysis in the mass spectrometer, however, mixtures of compounds first have to be extracted from sediment samples and separated into individual substances. The sediment samples are freeze-dried and then undergo pressurized liquid extraction with organic solvents. Finally, the individual substances are obtained from the extracts by means of liquid chromatography.

Time series for Lake Greifen

The researchers have already tested the new method using sediment cores – around one-and-a-half metres in length – which were retrieved from the deepest point of Lake Greifen. For a period extending from 1920 to the present, the chemicals deposited in these sediments have been extracted – layer by layer – and analysed by mass spectrometry.

In this way, time series were obtained for over 180 compounds, including tonalide (a synthetic musk fragrance used in perfumes) and the three biocides triclosan, terbutryn and prometryn. The time series data revealed that contamination of Lake Greifen with these and other compounds increased steadily from the 1950s to the mid-1970s. Thereafter, in most cases, concentrations decreased again. According to Hollender, "The decline is partly due to the expansion of wastewater treatment plants, where many environmental contaminants are effectively eliminated from municipal wastewater. At the same time, certain substances were used less frequently because of measures adopted in agriculture for example." One surprising finding was that concentrations of the algicide Irgarol in Lake Greifen have continued to rise – possibly because this substance is now used more frequently as a replacement for antifouling paints containing organotin compounds, which were banned in the 1990s.

Hollender concludes: "Sediments are excellent archives of micropollutants, which can be explored with the new method." As well as providing records of the chemicals used in past decades, they allow researchers, for example, to assess retrospectively the effectiveness of particular environmental protection measures.

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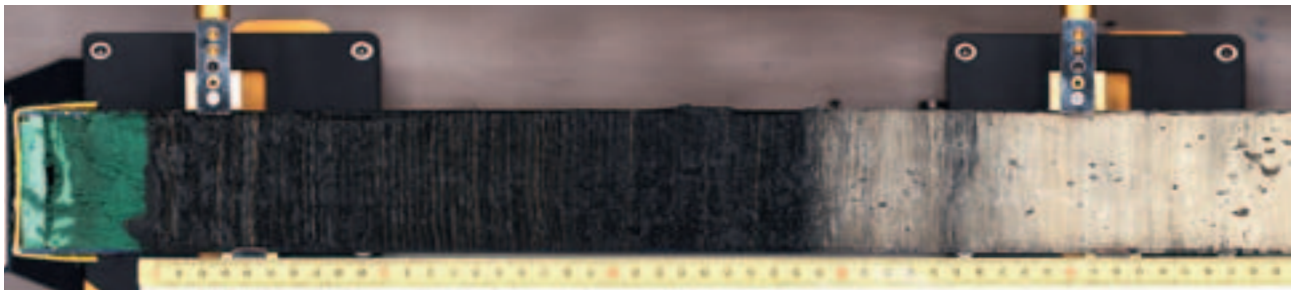

Aurea Chiaia-Hernandez

Compounds extracted from a laminated sediment core from Lake Greifen were used to produce a record of historical contamination.

Resistance genes in Lake Geneva

Municipal wastewater contains antibiotic-resistant bacteria. Although wastewater treatment plants reduce the total number of bacteria, some strains – including hazardous multiresistant bacteria – survive and enter the environment with effluents.

Photos: Eawag

Environmental microbiologist Nadine Czekalski collecting wastewater samples at the Lausanne wastewater treatment plant and from a Lausanne hospital drain; the samples were analysed for antibiotic-resistant bacteria.

Treated wastewater from the city of Lausanne – around 90,000 cubic metres per day – is released into Lake Geneva. The discharge point in Vidy Bay is located 700 metres offshore, at a depth of 30 metres. While Lausanne does not have a pharmaceutical industry or intensive animal production, its treatment plant receives wastewater not only from the region's 214,000 inhabitants and a number of smaller healthcare centres, but also from a major hospital. Studies from the healthcare and veterinary medicine sectors have indicated that the prevalence of antibiotic resistance is increasing. A group of researchers from Eawag and other institutions therefore investigated whether resistance genes also enter the environment – specifically, Lake Geneva – via wastewater treatment plants. Resistance testing was performed using both traditional culture methods and elaborate genetic analysis.

WWTPs: a hot spot for multiresistance?

In the first sampling programme ever conducted on this scale in Switzerland, data were obtained for municipal wastewater, lake water and lake sediments. Some of the findings were in line with expectations, e. g. particularly high levels of highly multiresistant bacteria in wastewater at the university hospital. But the study also produced surprising results: while, overall, more than 75 per cent of bacteria are eliminated at the treatment plant, the proportion of especially resistant strains is increased in treated wastewater.

According to microbiologist Helmut Bürgmann of the Surface Waters department, the treatment plant itself may provide particularly favourable conditions for the exchange of antibiotic resistance genes. Here, bacteria which otherwise inhabit the human body encounter others already adapted to the environment, and mobile genetic elements can be readily transferred as a result of the high bacterial cell densities.

At the same time, the accumulation of resistance genes could be promoted by antibiotic residues and other pollutants in wastewater. Bürgmann comments: "The uptake of resistance genes by bacteria is not unusual and doesn't in itself pose a hazard; what wasn't previously known was that levels of multiresistance genes are elevated in the lake, and particularly also in the sediment, close to the wastewater discharge outlet." This, he believes, increases the risk of resistance genes also being transferred to pathogens. That could occur in the lake itself or in the human body – if, for example, mobile

Multiresistance

The term "multiresistant" is used to describe bacteria which – by incorporating resistance genes into their genome – have become resistant to multiple antibiotics. These bacteria are frequently also resistant to other substances, such as heavy metals or disinfectants. Environmental releases of multiresistant bacteria are considered to be a matter of concern: in the long term, the prevalence and variety of resistance genes in the environment is increased. This in turn increases the risk that, at some point, such genes will also be transferred to pathogens, which would then no longer be susceptible to conventional antibiotics.

genetic elements for antibiotic resistance were to find their way into drinking water.

Keeping a close eye on drinking water

A drinking water pump is situated three kilometres from the point where wastewater is discharged into the lake. So do antibiotic resistance genes actually end up in drinking water? Nadine Czekalski, who carried out most of the investigations as part of her dissertation, believes that there is little risk of this happening at present. Concentrations of multiresistance genes decrease with increasing distance from the WWTP outlet. The researchers detected such genes in sediment samples collected close to the pump, but not in lake water at this site. In addition, water taken from the lake is treated before being fed into Lausanne's water supply system. But Czekalski and Bürgmann agree that there is a need for caution. After all, around fifteen per cent of Switzerland's wastewater is discharged, after treatment, directly into lakes. Vidy Bay can be regarded as a typical model of this situation.

Indeed, in a second project involving 20 Swiss lakes, certain resistance genes were shown to be present in almost all lake water. Particularly prevalent is resistance to sulphonamides, a group of synthetic compounds first used as antibiotics in the 1910s. Although sulphonamide drugs are now less commonly used in human medicine, this class is still widely used in veterinary medicine to treat parasitic disease. Resistance to tetracyclines – used as antibiotics since the 1950s – was also detected, but at considerably fewer sites. The researchers involved in the study believe that the increased occurrence of resistance genes in certain lakes indicates local sources of contamination.

Benefits of WWTP upgrades

Czekalski and Bürgmann see the federal government's plans to introduce an additional process for the removal of micropollutants at selected treatment plants as a step in the right direction: the scientists expect that the advanced treatment process would largely inactivate resistant microorganisms as well as micropollutants. They recommend that separate treatment of hospital wastewater – which contains the highest load of multiresistant bacteria – should also be considered. Chemical disinfection of wastewater is already standard practice in many parts of the US, for example.

In follow-up projects, Eawag is now studying – together with partners including the Lausanne WWTP and drinking water plant operators – how effectively antibiotic resistance genes can be removed by various wastewater and drinking water treatment methods. In particular, processes involving ultrafiltration (filtration using membranes with a pore size of less than 0.1 micrometres) and ozonation are being investigated. This is a challenging undertaking, as Czekalski explains: "Mere inactivation is probably not enough, because even after bacteria have been killed, resistance genes can enter surface waters via segments of DNA and be taken up by living organisms."

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Biofilm carriers work well

At present, micropollutants in wastewater are not adequately removed at treatment plants in Switzerland. For this reason, large plants in particular are to be upgraded. But processes at smaller plants could also be optimized so as to enhance micropollutant removal.

Peter Penicka

Moving bed bioreactor: plastic biofilm carriers enhance the degradation of certain micropollutants in wastewater.

The fact that Switzerland's rivers and lakes are so clean today is largely due to the expansion of the country's wastewater treatment network over the past 50 years. Phosphate precipitation at wastewater treatment plants (WWTPs) – together with the ban on the use of phosphates in detergents which dates back to 1985 – ensures that lower levels of nutrients are now discharged into surface waters, and eutrophication has declined dramatically as a result. However, today's WWTPs are not well equipped to deal with organic micropollutants – e. g. from pharmaceuticals, personal care products, cleaning agents or biocides – which can have adverse effects on aquatic organisms and threaten drinking water quality even at concentrations as low as a few nanograms per litre.

Because many of these substances cannot be eliminated by conventional treatment processes, Switzerland is planning to invest CHF 1.2 billion in upgrading around 100 (of a total of 700) large and medium-sized WTTPs over the next 20 years. Levels of micropollutants are to be reduced by additional treatment with ozone or powdered activated carbon (PAC). The effectiveness of these measures has been confirmed in research carried out by Eawag and other institutions. But, according to Adriano Joss of the Process Engineering department, the removal of micropollutants at small treatment plants could also be improved to a certain extent by using the moving bed biofilm reactor (MBBR) process.

Enhanced degradation in biofilms

The removal efficiency of the MBBR process, as compared with the conventional activated sludge process, was investigated by Joss and co-workers as part of the European Research Council's Athene project. The aim of this project – jointly led by the German Federal Institute of Hydrology and Eawag – is to gain a better understanding of the biodegrad-

ation of organic micropollutants in wastewater treatment. Based on the findings obtained, effective technical solutions are to be designed and tested in practice. Launched in April 2011 with a budget of around EUR 3.5 million, the project is to run for 5 years.

MBBR is a variant of the biological treatment step – a process increasingly used at WWTPs. The core element of the biological step is the activated sludge reactor. Here, wastewater is exposed to microorganisms which degrade organic contaminants. In the conventional process, the microorganisms are aggregated into activated sludge flocs. In the MBBR process, plastic carriers about a centimetre in diameter are added to the activated sludge reactor, and – as well as forming flocs – the microorganisms form biofilms on the carrier material. As a result, the biomass of microorganisms retained in the reactor is increased. This increase, together with the different biochemical processes occurring in biofilms, leads to improved treatment efficiency.

Joss and his colleagues found that the MBBR process is also more effective than the conventional process in the biodegradation of certain micropollutants. Their study was carried out at the Bad Ragaz WWTP, where the biological step consists of a hybrid biofilm-activated sludge process. Using laboratory experiments with Bad Ragaz wastewater, full-scale measurements and modelling, the researchers compared the removal capacity of the two processes for 20 substances. Joss says: "Our analyses show that, for certain micropollutants, the biofilm process is more effective." This is true of diclofenac, for example – a widely used analgesic and anti-inflammatory agent (the active substance in Voltaren products, among others). Here, experiments showed that after 12 hours only 10 per cent of the initial concentration of this substance remained in the carrier reactor, while virtually no degradation was observed in the active sludge reactor. "Nevertheless," Joss adds, "the activated sludge process was superior to the biofilm process in individual cases."

Complementary effects

Accordingly, the process engineer believes that, at plants where no treatment with ozone or PAC is planned, MBBR could represent an advantageous alternative to the conventional activated sludge process in order to further reduce micropollutant levels. But as he points out: "Not all compounds can be removed in this way. No degradation was seen with either of the processes for about a third of the substances we investigated." Joss also emphasizes that the MBBR process is less effective than ozonation or PAC treatment: "With those methods, removal rates of more than 80 per cent are expected, whereas the reduction with the biofilm process is estimated to be about half that."

What are the effects of micropollutant reduction?

To accompany the WWTP upgrades which are designed to substantially reduce contamination of Swiss surface waters with micropollutants in the coming years, Eawag has launched a major research initiative. The interdisciplinary EcoImpact project will examine how micropollutant reduction at WWTPs affects surface water quality and ecosystem functions. In the initial phase, using laboratory experiments and field studies, researchers will investigate the impacts of micropollutants on the aquatic environment at various levels of biological organization – from cell to ecosystem. The effects of WWTP upgrades on aquatic systems are to be studied in the second phase of the EcoImpact project.

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Putting a value on water quality

Switzerland is upgrading selected wastewater treatment plants so as to reduce the contamination of surface waters with micropollutants. These measures will require billion-franc investments, but the public's willingness to pay indicates that they are also justified from an economic viewpoint.

Over the next 20 years, around 100 of Switzerland's 700-plus wastewater treatment plants (WWTPs) are to be upgraded in order to reduce the contamination of surface waters with organic micropollutants from pharmaceuticals, cleaning agents, personal care products , material protection products or pesticides. Wastewater is to undergo additional treatment with ozone gas or powdered activated carbon. This will involve investments estimated at CHF 1.2 billion. But are these measures justified from an economic viewpoint? Put differently, is the Swiss public prepared to pay this amount for lower levels of micropollutants in the country's rivers and lakes? This question was investigated by environmental economists Ivana Logar and Roy Brouwer of the Environmental Social Sciences department.

Awareness of risks of micropollutants

The public's willingness to pay was assessed in an online survey involving a representative sample of 1,000 households in German-speaking cantons. In a cost-benefit analysis, the findings were then compared with the estimated investment costs. First, however, the researchers wished to determine what importance is attached to water quality in Switzerland more generally. Logar reports: "For 63 per cent of respondents, water quality is very important." The majority consider this issue to be just as important as healthcare, employment or climate change and more pressing than, for example, immigration. In addition, surface water quality is rated as "good" by 65 per cent of respondents; the majority thus feel that there is still room for improvement.

Aldo Todaro

For the Swiss, having clean water to bathe in is worth paying for.

Financing via wastewater levy

The Federal Council plans to introduce a special levy to cover the investment costs of upgrading 100 selected WWTPs for micropollutant removal. A charge is to be levied on all WWTPs, depending on the size of the population served. A maximum charge of CHF 9 per person per year should deliver three quarters of the estimated CHF 60 million required each year. The Water Protection Act is to be amended so as to provide a legal basis for this special levy.

The study also revealed that people in German-speaking Switzerland are relatively well informed about micropollutants and the risks they pose to the environment and human health. Micropollutants are rated as "risky" or "very risky" by 54 per cent of respondents. Nonetheless, as Logar notes, "Around three quarters of the respondents were not aware of the potential environmental risks of contamination with micropollutants in their own area before they took part in the survey."

Variation in willingness to pay

On average, people in German-speaking Switzerland are willing to pay about CHF 100 per household per year – in addition to their current water bill – for the removal of micropollutants throughout the country. In cantons such as Schwyz or St Gallen, which are less seriously affected by micropollutants, willingness to pay is significantly lower than in cantons where the potential environmental risk is higher, such as Zurich or Basel-Stadt.

The extent to which respondents are prepared to pay for a reduction of micropollutants and for research into the impacts of these substances on human health depends on various factors. Willingness to pay is generally higher if the measures taken reduce the environmental risk to a low level and if the whole country benefits as a result. However, respondents' willingness to pay for research decreases the longer it takes for knowledge to become available. Willingness to pay is also reduced if the measures lead to an increase in one's own water bill.

Positive conclusions

On the basis of the data for individual cantons, the researchers estimated the potential sums available for the country as a whole over a period of 33 years – the expected average life span of the upgrades. Their calculations suggest that CHF 4.3 billion would be available for upgrading the most important WWTPs and to cover operating costs. "This is a conservative estimate," says Logar.

This amount is to be set against the estimated investment, operating and interest costs, which come to CHF 2.5 billion. In the cost-benefit analysis, these costs are simply subtracted from the total "willingness to pay" amount – resulting in a surplus of almost CHF 2 billion. It can thus be concluded that the upgrade programme approved by the federal government and already initiated is justified not only environmentally but also in economic terms.

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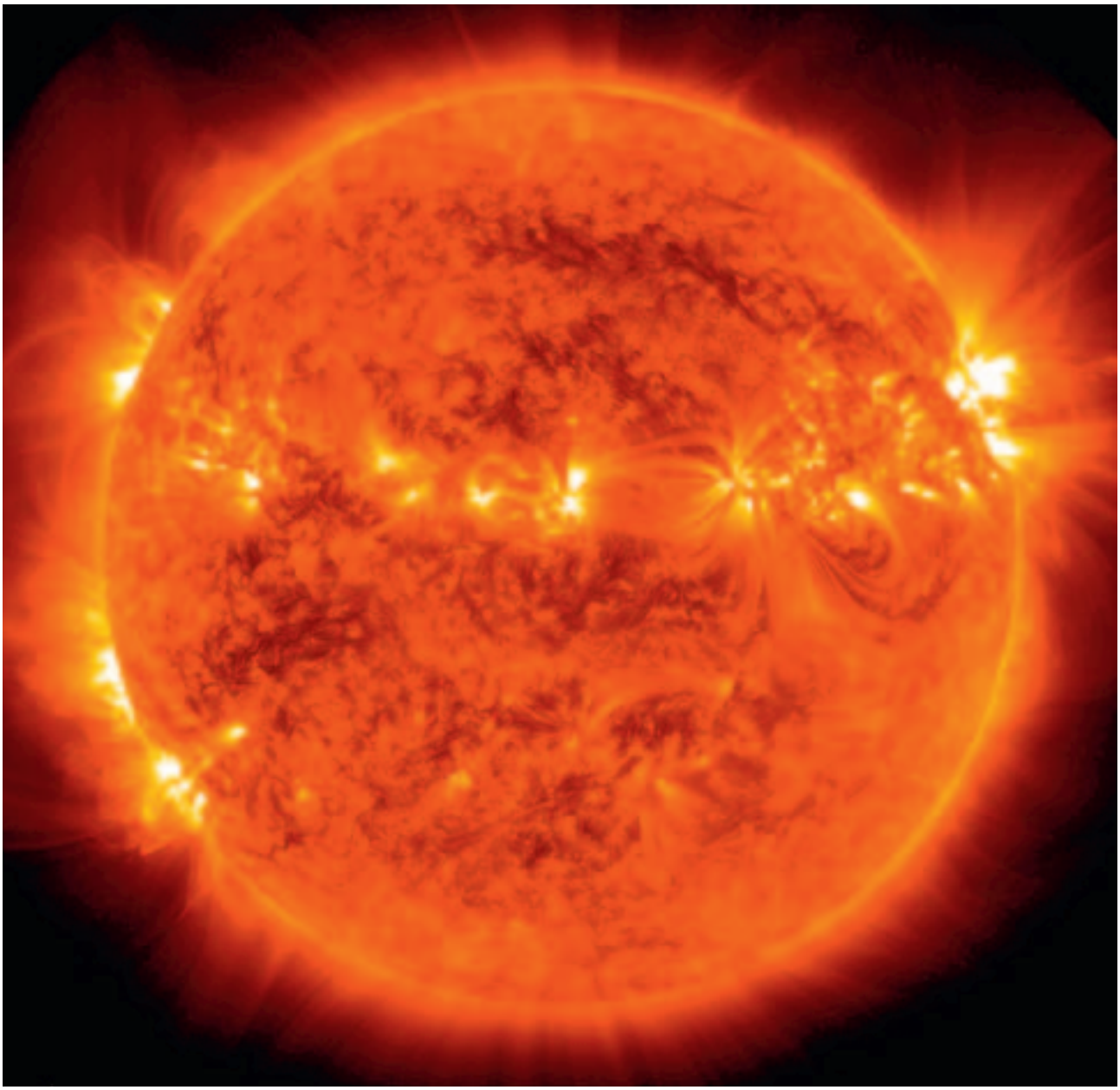
Towards space climate forecasts?

The planets appear to have more influence on the sun than was previously assumed. Long-term cycles of increased solar activity – as reconstructed from ice cores – have been shown to correspond closely to changes in torque exerted by the planets on the sun.

The sun accounts for over 99 per cent of the total mass of our solar system, and its gravitational field keeps the planets in their orbits. To date, the effects exerted by the planets on the sun have been regarded as negligible. Now, however, an international research team led by José Abreu and Jürg Beer of Eawag has discovered that changes in the relatively small torque collectively exerted by the planets on the sun could be the cause of long-term cycles of solar activity. The scientists found a strikingly precise correspondence between the well-known periodicities (88, 104, 150, 208 and 506 years) observable for the last 10,000 years and the periodic changes in planetary torque. While they do not claim that the planets are the cause of solar activity, they suspect that the planets influence magnetohydrodynamic processes in an area of the sun's



Nasa

Billions of tonnes of gas are hurled into the atmosphere as a result of massive plasma eruptions on the sun.

interior known as the tachocline. This relatively thin layer (marking the transition between the radiative and convective zone) is believed to play a fundamental role in the operation of the "solar dynamo" which generates the sun's magnetic field.

Radionuclide archive in polar ice

The fact that the five most prominent periodicities of solar activity traced back over the last 10,000 years agree closely with the periodic changes in total planetary torque is striking in itself. But further strong evidence is provided by the observation that the peaks and troughs reappear with precisely the same periodicity even after being attenuated or vanishing altogether for some time. Frequency and phase thus coincide. Beer comments: "This makes it highly unlikely that the sun generates all these cycles itself, as an isolated system. So everything points to an external 'clock', and that can really only be the planets."

Direct evidence of the number of sunspots (a measure of solar activity) has only been available for about 400 years – the era of telescopic observations. Anyone wishing to trace the history of solar activity further back over the last 10,000 years has to rely on indirect evidence. This evidence was obtained from polar ice cores (from Greenland and Antarctica), in which radionuclides produced by cosmic rays are stored. During the sun's quiescent periods, more cosmic rays enter the atmosphere – with increased production of radionuclides – as the blocking effect of the solar magnetic field is weaker. In addition to ice-core Beryllium-10 data, also tree-ring Carbon-14 data were used for the study. The time series from these two independent sources show excellent agreement.

Nonetheless, the question arises whether the good agreement between the time series and the planetary data could not have occurred by chance. To test their findings, the scientists analysed a million time series produced by a random generator. Some of the above-mentioned cycles were indeed also found in the simulated series. However, the probability of all five periodicities in question occurring simultaneously ranged from 1 in 10,000 to 1 in 100,000 – depending on whether time series with a white or red spectrum were used.

Improved understanding of the sun

Abreu and Beer are still describing their conclusions cautiously as a hypothesis; however, if these findings are confirmed, they will be of major importance. Firstly, they should help to improve our understanding and develop more realistic models of the sun. In addition, they could help to generate more reliable forecasts of the "space climate" – a matter of great importance for longer space voyages. But those of us who remain earthbound are also affected by solar magnetic activity, as our society is increasingly dependent on technologies which are vulnerable to space weather events.

Vulnerable electronic systems

Superflares are massive eruptions of solar plasma, hurling billions of tonnes of gas into the atmosphere and causing magnetic storms in space and polar lights on the Earth. Satellites, aircraft avionics, power grids, radio signals and many other systems could be disrupted or destroyed by an event of this kind. In 1859, the solar flare observed by the British astronomer Richard Carrington only disrupted the telegraph networks which had recently been established in Europe and North America. Today, it is estimated that a geomagnetic storm of the same magnitude would cause up to two trillion dollars' worth of immediate economic damage in the US alone. Jürg Beer cautions that "Storm warnings are still a long way off." But an improved understanding of solar magnetic activity could help to predict the frequency and intensity of such eruptions.

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When water turns rusty

Climate change in Switzerland is affecting groundwater as well as surface waters. In future, rising temperatures may increasingly lead to anoxic conditions in river-fed aquifers – with adverse impacts on drinking water quality and infrastructure.

Clogging of pump filters and water with a rusty appearance and an unpleasant metallic taste – the effects of Switzerland's 2003 summer heatwave which were seen at a number of pumping stations close to rivers could become all too common in an era of climate change. David Livingstone of the Water Resources and Drinking Water department explains: "This type of situation arises when the groundwater is too warm and the oxygen runs out." Livingstone and his team are studying how climate change is affecting groundwater as part of the National Research Programme on sustainable water management (NRP 61), since groundwater supplies around 80 per cent of Switzerland's drinking water.

Rising temperatures over past 30 years

Using historical records from pumping stations, the researchers demonstrated that groundwater temperatures have risen as well as air and river water temperatures. Livingstone says: "Aquifers fed by rivers have been affected, whereas those recharged by precipitation underwent almost no change in temperature." In the case of river-fed aquifers, mean groundwater temperatures have increased by 0.7 – 1.1 °C per decade since the 1980s. In most of the aquifers studied, oxygen concentrations tended to decrease as groundwater temperatures rose. But here, Livingstone emphasizes, the findings are less unequivocal, varying from one aquifer to another. Recent studies indicate that oxygen concentrations are influenced not only by groundwater temperature but also by hydrogeological factors (e. g. riverbed permeability) and flood events.

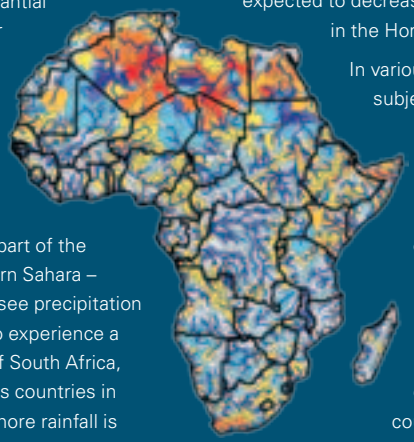
The question of what happens when oxygen in groundwater becomes depleted has been investigated by Urs von Gunten and his colleagues in the Water Resources and Drinking Water department. This group analysed the biogeochemical processes which occur when water enters an aquifer via riverbank and riverbed infiltration. Field experiments were performed on a section of the River Thur which is equipped with a wide variety of sensors. The parameters measured included groundwater level, temperature, electrical conductivity, pH and oxygen concentrations. To allow the factors of interest to be varied under controlled conditions, the river system was also simulated in a laboratory experiment, using plexiglas columns filled with sediment from the Thur and fed with river water.

Oxygen consumed by microorganisms

As it passes through the subsurface, river water is subject to chemical changes, with impurities and pathogenic organisms being removed in the process. This explains why river-fed groundwater can be used as drinking water without any further treatment. Aquifers of this kind account for about a

Changes in availability of water resources across Africa

As a result of climate change, the amount of freshwater available in Africa could increase in the future – but with substantial regional variations. Impacts on water resources for the period 2020–2040 were studied by researchers from the Systems Analysis, Integrated Assessment and Modelling department. In this study, climate projections from five models – under four different greenhouse gas emission scenarios – were fed into a hydrological model.



The results indicate that countries in the northern part of the continent, such as Egypt, Libya, Algeria and Western Sahara – where conditions are already extremely arid – will see precipitation decreasing by 25–50 per cent. Other areas likely to experience a decline in precipitation include the southern part of South Africa, northern Angola and northern Cameroon, as well as countries in the Horn of Africa. By contrast, up to 25 per cent more rainfall is expected to occur in regions of southwest Africa (Namibia, Zambia, Botswana, DR Congo) and western Africa (Guinea, Ivory Coast). In general, surface and groundwater resources are predicted to increase in the southern part of the continent, whereas they are expected to decrease by up to 100 per cent in countries located in the Horn of Africa and the Sahel.

In various regions, water availability will also be subject to greater uncertainties. Thus, the arid northern region is predicted to experience severe fluctuations in year-to-year precipitation, leading to prolonged droughts. The duration of dry periods will also increase in the south, although it will decrease in central Africa and in the southeast. The researchers conclude that the changes and spatial variations will have significant impacts on economic development, especially in the agricultural sector. There could also be an increase in conflicts over the use of water resources.

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third of Switzerland's water supplies. In the natural purification process, a key role is played by microorganisms, which obtain energy by degrading organic matter. But this biochemical reaction requires an oxidizing agent, and the preferred source is oxygen, as it enables microorganisms to derive the greatest energy from the biodegradation process. However, if oxygen becomes depleted, they resort to compounds with a lower energy yield – first nitrate, and then manganese and iron hydroxides.

In the field and laboratory experiments, the scientists were able to show that this is precisely what happens when groundwater temperatures rise. Von Gunten explains: "Higher temperatures increase the metabolic activity of microorganisms, which then degrade more organic matter and consume more oxygen." Accordingly, anoxic conditions were observed at certain monitoring sites on the Thur in the summer, and degradation proceeded via the nitrate pathway. Once the available nitrate has also been used up, the reduction of manganese and iron hydroxides begins – and hence the problems. The compounds are initially present in groundwater in a soluble form, but in contact with air at a pumping station dissolved manganese and iron are oxidized and form precipitates – with the unpleasant consequences described above. This was not, however, observed during the summer sampling campaign on the Thur since, as von Gunten points out, "Nitrate now usually provides an adequate buffer, preventing precipitation of manganese and iron."

Additional treatment of drinking water

But the situation could well change in the future. By 2085, according to recent climate scenarios, parts of Switzerland could experience mean increases in temperature of four to five degrees. In addition, extreme weather events such as heatwaves and flooding are expected to occur more frequently. The researchers are concerned that conditions similar to those seen in the summer of 2003 could become more common. Von Gunten sees flood events in particular as a critical factor. Rivers then receive greater inputs of organic particles which, together with higher temperatures, drive microbial degradation and thus oxygen consumption: "Over longer periods," he says, "the nitrate reserves could probably be completely used up."

Von Gunten believes that, in the future, water suppliers might – temporarily – need to apply additional treatment measures in order to prevent precipitation of manganese and iron at drinking water wells. For this purpose, he adds, proven methods – "pump-and-treat" systems or in situ removal – are available.

Analysis of historical time series revealed that groundwater temperatures have increased.

Photos: NRP 61

A plexiglas column filled with riverbed sediment provides information on biogeochemical processes during infiltration.

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Nanoparticles in water

Silver nanoparticles can be toxic to green algae. The toxic effects are due not to the particles themselves, but to dissolved silver ions. In natural waters, only a small fraction of nanosilver is present in dissolved form – but there may still be grounds for concern.

Engineered nanoparticles are now widely used in consumer products, such as cosmetics, textiles or paints, and they may end up in surface waters. However, relatively little is known about their behaviour in the environment or their toxicity to aquatic organisms. For example, it remains unclear in what form these minute particles (measuring 1 to 100 millionths of a millimetre) occur in lakes and rivers. Niksa Odzak and Laura Sigg of the Environmental Toxicology department have now shown that nanoparticles are present in different forms, depending on the metal used and the chemical conditions of the aquatic environment. They studied the dissolution of various metallic nanoparticles in water samples from three lakes (Greifensee, Lake Lucerne, and Lago Cristallina) and the effluent of a wastewater treatment plant in Dübendorf.

Influence of pH

In all samples, carbon-coated copper nanoparticles occurred predominantly in agglomerated form and were deposited in sediments. After 9 days, less than 5 per cent was present in the form of dissolved copper ions. By contrast, zinc oxide nanoparticles dissolved almost completely in all cases within a matter of hours. The solubility of copper oxide nanoparticles depended on the pH: they dissolved more rapidly and completely in the more acid water of Lago Cristallina than under more alkaline conditions. Silver nanoparticles showed similar behaviour, with around 4 per cent occurring in dissolved form in water from the Canton Ticino lake and less than 1 per cent in the other water samples. In addition, laboratory experiments conducted by environmental toxicologists Flavio Piccapietra and Renata Behra showed that the agglomeration of silver nanoparticles increased with higher concentrations of sodium and calcium. Even so, the nanoparticles were only slowly deposited in sediments and persisted in the water for several days. Aquatic organisms are therefore exposed to them for relatively long periods.

Nanosilver is of particular ecotoxicological interest, as it can have adverse effects on aquatic organisms. At the same time, it is currently the most widely used nanomaterial, with industrial production totalling around 500 tonnes per year worldwide. Silver nanoparticles are in demand particularly because of the antibacterial properties of the silver ions which they release.

Silver ions: toxic to algae

The fact that nanosilver is mainly present in water in particulate form, with a low fraction of dissolved ions, is an advantage – at least in the case of the green alga *Chlamydomonas reinhardtii*. For, as Piccapietra and Behra showed, while the particles cannot enter Chlamydomonas cells, silver ions pass through the cell membrane and impair cellular processes such as photosynthesis. Behra concludes: "The toxic effects of nanosilver are thus attributable to the silver ions alone." These findings have been confirmed by other Eawag studies.

But, as Behra points out, this does not mean that there are no grounds for concern: "Nanoparticles can be oxidized by chemical compounds on cell membranes, giving rise to free silver ions." In addition, when silver nanoparticles are manufactured, silver ions may arise as by-products (up to 10 per cent). The researcher also emphasizes that the findings only apply to *Chlamydomonas reinhardtii* and that long-term data are lacking: "We still know very little about how other algae or other organisms react." Certain studies have, however, shown that nanoparticles are taken up by animal cells. And, in the case of biofilms of bacteria and algae, ongoing research at Eawag would suggest that toxic effects are also due to nanoparticles themselves, rather than primarily to ions.

Keystone

Because of their antibacterial properties, silver nanoparticles are increasingly being used in activewear – as displayed at the Zurich Marathon.

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Business models for faecal sludge

Numerous ideas have been proposed for faecal sludge management in urban areas of developing countries, but only a few have been successfully implemented in practice. The importance of a viable business model is demonstrated by case studies of sludge disposal in Manila and Bangalore.

In many cities of the developing world, the problem of safe disposal of solid wastes remains unresolved. Sanitation projects often have a weak link – systems for the collection and disposal of faecal sludge do not work in practice as originally planned. According to Heiko Gebauer of the Environmental Social Sciences department, "What's lacking in many cases is an economically viable idea for earning money from sludge disposal."

Together with Linda Strande and Lars Schöbitz of the Department of Water and Sanitation in Developing Countries (Sandec), Gebauer – an economist – has therefore sought to identify successful business models which could serve as examples for other cities. As he explains, "We've deliberately studied approaches that are not dependent on subsidies or donations. Only solutions of this kind are effective on a larger scale over the longer term." The team's research included case studies which focus on two completely different approaches – and thus demonstrate the variety of ways in which the problem can be addressed.

A large company and a micro-enterprise network

The first approach analysed by Strande and Gebauer is that adopted by Manila Water. This company, run as a public-private partnership, extended its existing water supply business into the areas of sludge collection and treatment. Manila Water offers its customers a tank-emptying service for a small additional charge, which is included in the household water bill. The company now operates a fleet of 90 vacuum trucks, emptying over 50,000 septic tanks per year. After being treated, the faecal sludge is used to produce fertilizer, which is then distributed at cost. As the service fee is based on water consumption, lower-income households – who use less water – pay a lower price.

The second business model studied by Strande and Gebauer provides a marked contrast to the first. In Bangalore, innovative entrepreneurs have shown that it is indeed possible to earn money from faecal sludge. The so-called honeysuckers, operating on an informal basis, use leased vacuum trucks to empty household septic tanks. The sludge is then dried and sold as fertilizer to local farmers. This business model offers advantages for all parties: for honeysucker micro-enterprises, the barrier to entry is low, since no major investments are required, and customers are free to choose which emptying service to use in a competitive market.

Vishwanath Srikantaiah

Honeysuckers at work in Bangalore – a successful business model for the disposal of faecal sludge.

Avoiding potential pitfalls

However, the researchers' analysis also identified certain pitfalls associated with these two approaches. With the first business model, the need for substantial initial investments may be a significant disadvantage – in many cities, the resources required are simply not available. With the honeysucker model, the fact that micro-enterprises operate in the informal sector – without legal contracts – could be problematic. This approach would appear to involve a risk of abuses, although the system seems to work well in Bangalore.

As the next step, the researchers plan to investigate whether these two business models – possibly in a modified form – could be transferred to other cities. Discussions have already begun with the authorities in Hanoi and Kampala. Gebauer emphasizes: "If we want to solve the problem of faecal sludge management, viable business models are essential. The approaches pursued in Manila and Bangalore show what form such models could take."

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Reinventing the toilet

Worldwide, 2.6 billion people lack access to proper toilets. A "grid-free" toilet which has received an award from the Gates Foundation should offer a hygienic, dignified, environmentally sound and economically viable sanitation solution.

The type of sanitation established in developed countries – with flush toilets, water-borne sewage and centralized wastewater treatment – is not necessarily suitable for every region of the world. There may be insufficient water to convey human waste, the gradients required for sewer pipes may not be attainable, or it may not be possible for sewer networks to be expanded rapidly enough to keep pace with urbanization. And even in Switzerland, experts are increasingly asking whether it is appropriate to first dilute urine and faeces with large quantities of water and then, at wastewater treatment plants, use elaborate processes to eliminate components such as phosphorus or nitrogen, which are valuable resources.

No more than five cents a day

However, only recently has research into alternative systems begun. Toilets without piped water or sewer connections have tended to be perceived as "primitive", while the lavatory from which excreta and odours are removed at the press of a button is seen as the ultimate Western modern convenience. Also taken for granted in developed countries is the availability of water for hand-washing. In certain countries (e.g. China), waterless or urine-diverting toilets have a long history; but here water is generally not available for toilet-cleaning, hand-washing or anal cleansing. Such installations not only fail to meet the demands of modern sanitation but also carry a social stigma.

For an interdisciplinary research team at Eawag, therefore, the Bill & Melinda Gates Foundation's Reinvent the Toilet Challenge (RTTC) came at just the right time. Strict requirements were stipulated for this competition: the next-generation toilet must operate without requiring a sewer connection or electricity, while at the same time allowing resource recovery and costing less than five cents per user per day. The Eawag team – involving participants from the Eawag workshop and six different departments and collaborating with the Austrian design firm EOOS – managed to secure support from the Gates Foundation for its "diversion toilet" project. It was initially granted around USD 400,000 and, having won a special recognition award for outstanding design in the summer of 2012, the team has now received additional funding of over USD 1 million to invest in further development and field-testing of the innovative toilet.

Photomontage: EOOS

The new toilet could be housed in existing structures.

Urine separation technology

Process engineer Tove Larsen, the leader of the project, has been working on urine separation at Eawag for several years. "Although it wasn't explicitly stipulated, it seemed obvious that the model developed for the competition should also be based on the principle of separation of urine and faeces," she says. "Separation technology permits efficient recovery of valuable resources from human wastes and simpler recycling of water." Aiming to design and develop a urine-separating model that would be acceptable to a wide variety of cultures and user groups, the Eawag/EOOS team produced a modern squatting toilet which incorporates a sophisticated odour trap. Water is also provided, although only about one and a half litres are required per use. As Larsen explains, "Water is necessary for cleaning the toilet, hand-washing and anal cleansing, as practised by Muslims and Hindus." Even so, the diversion toilet does not require piped water supplies: when users press a pedal to pump water into the small reservoir, used water is also pumped up behind the toilet. This is then purified with the aid of a membrane filter. A solar-powered electrolytic process ensures that the recycled water remains free of contamination.

For Larsen, the crucial factor is not just the new technology: "It's essential that our toilet is integrated into a sanitation system which can be operated at the local level in such a way as to cover costs or even generate a profit." Her team has therefore developed a transport logistics concept adapted to the conditions typical of burgeoning informal settlements in developing countries. A modular system of self-sealing faeces containers and urine barrels, together with a transport vehicle,

As well as the ingeniously designed toilet, the concept encompasses transport logistics and a treatment plant where urine and faeces are converted into fertilizers, biogas or other saleable products.

Graphic: EOOS

ensures that the collection process is likewise efficient and hygienic. The researchers also envisage the establishment of semi-centralized treatment plants where urine and faeces can be converted into saleable products such as fertilizers and biogas. A complete business model has thus been conceived for the diversion toilet: a local entrepreneur rents out toilets to users, coordinates waste collection, operates the treatment plant and sells the recycled products. While the toilet is designed for two households, treatment plants are dimensioned for around 175 households.

Planned field tests

This combination of different scales – from individual household to neighbourhood, community or district – is one of the advantages of the diversion toilet concept. While the toilet itself can be readily integrated into existing stalls or other structures, the business model allows for the implementation of modern resource recovery technologies and also ensures appropriate maintenance. In addition, the toilet has been specially designed so that it can be assembled by local manufacturers from a small number of parts. Thus, in the case of production, as for toilet rental, value creation remains at the local level.

Despite their successful proof of concept, the engineers, technicians, social scientists and designers involved have not been resting on their laurels. Since the competition, a working model has been built and the components have been rigorously tested. In 2013, the toilet is to be field-tested in Kampala (Uganda) – first at the university and then in six households. On the basis of this experience, the prototype will be further optimized, prior to final testing with a "Version 0" model scheduled for the beginning of 2014. Several years' more work will doubtless be required before the fully developed diversion toilet, collection vehicles and processing plants can be widely deployed in large numbers. Larsen is optimistic, but under no illusions: "Whether our system can really become established depends not just on the technology but especially on the quality of the business model. No system that is permanently reliant on subsidies will succeed in the long run."

Closing the sanitation gap

No toilets nearby – just a foul-smelling pit with no privacy? No water available to wash your hands? A constant risk of diarrhoea caused by contaminated water? Conditions we may find hard to imagine are facts of life for the 2.6 billion people who lack access to sanitation and have to resort to open defecation. Every day, over 3,000 children die from diseases transmitted by unsafe drinking water. Inappropriate disposal of human wastes also places a huge burden on the environment. Investments in sanitation are highly effective: according to a study by the Swiss Agency for Development and Cooperation and the State Secretariat for Economic Affairs, every franc invested generates three to five francs in social and economic benefits for the regions concerned.

www.eawag.ch/rttc
www.gatesfoundation.org
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Mitigating geogenic contamination

In many countries, groundwater is heavily contaminated with arsenic or fluoride. To protect people from exposure to these geogenic contaminants, a multifaceted approach is required – in particular, taking social and cultural factors into account.

Millions of people in developing countries suffer severe health problems as a result of regularly consuming water contaminated with arsenic or fluoride. These naturally occurring substances are dissolved in groundwater under certain geochemical conditions. Despite the serious health risks, people may continue to drink contaminated water either because no alternative supplies are available or because they are not prepared to accept the extra efforts involved in obtaining safe water.

Learning from case studies

In the Water Resource Quality (WRQ) project, which has been running for a number of years, Eawag researchers have collaborated with local partners and representatives of NGOs to develop strategies for mitigating the effects of geogenic contamination in affected regions. On the basis of the results of two case studies, the researchers are elaborating general principles for facilitating access to contaminant-free water in practice.

In the light of the studies carried out to date, project leader Annette Johnson of the Water Resources and Drinking Water department is convinced that a multidisciplinary approach is indispensable: "If you want to improve the situation for the communities at risk, then social scientific and economic questions need to be considered as well as scientific and technical issues." The procedure developed by the researchers addresses the problem from two different angles. Firstly, the situation on the ground is analysed: How is water quality impaired in the region? What water resources are available? How is water used in everyday life? Secondly, mitigation options are identified: What treatment technologies could be deployed? What kind of institutional support could be provided for mitigation efforts? And what types of behaviour change on the part of those affected would help to reduce the risks?

Lars Osterwalder

Using water from a community filter protects people living in the Ethiopian Rift Valley from exposure to excessive levels of fluoride.

No ideal filter material

One of the two case studies was carried out by the interdisciplinary research team in the Ethiopian Rift Valley, where water heavily contaminated with fluoride is widely used for drinking and cooking. In this low-precipitation region, the lack of alternative water resources means that it is essential to use appropriate fluoride removal methods. The WRQ project involved the evaluation of various filter materials used for this purpose, such as animal bone char and aluminium hydroxide.

Ideally, a filter material used for defluoridation should meet a number of requirements: it should be efficient, easy to handle and reliable even under the rigorous conditions of daily use, so that the need for maintenance is minimal. Not least, it should also be affordable for low-income users. As co-worker Anja Bretzler explains, this is particularly crucial in Ethiopia, where the costs of filter materials are driven up by the high concentrations of fluoride in groundwater: "But the ideal material – efficient, suitable for everyday use and inexpensive – has yet to be discovered." One option that is to undergo further testing is synthetic apatite, which has chemical properties similar to those of bone char. Although it is more expensive than the natural material, it removes fluoride more efficiently, and so the costs could ultimately be lower.

In the Rift Valley case study, human behaviour was also investigated in detail. Given the lack of alternative sources of water, people can only avoid damaging their health by using filtered water, which is more expensive. With the aid of questionnaires, the researchers sought to identify the most effective ways of getting people to accept the additional costs.

One approach found to be particularly effective involved not merely explaining the health risks, but showing – by a comparison with other food products – that it is worth paying extra for water of better quality. The survey also revealed another potential obstacle: most people prefer to obtain their water from household filters, but water quality tends to be better

Mickey Sampson

Arsenic poisoning produces horny growths on the skin (keratosis) and can even cause cancer.

with community filters, where it is easier to ensure that the filter material is regularly replaced.

Information alone is not enough

Behavioural factors also play a key role in Bangladesh, where the second WRQ case study was performed. Here, the problem of widespread exposure to high levels of arsenic in drinking water has been recognized for some time. As adequate supplies of safe water are often available locally, the best mitigation approach in this case is not to filter contaminated water, but to motivate people to switch to safer wells. However, this option requires extra efforts, as users can no longer obtain their water from the nearest, most convenient source.

The researchers investigated the factors which promote the adoption of mitigation options – even if these involve additional effort. The results indicate that merely providing information is the least effective approach. Significantly more people are prepared to modify their behaviour if information is supplemented by other measures – e. g. the use of reminders, routines for obtaining water supplies and possibly also public commitments ("pledging").

Hans-Joachim Mosler of the Environmental Social Sciences department explains: "Our goal was to influence people's behaviour by changing certain beliefs and attitudes. In our study, we were able to identify the key psychological factors." This was only possible because the researchers took into consideration both prevalent social norms and the economic and social factors influencing water use.

Guidance on implementation in practice

The methods developed by the researchers can now be applied in other countries. However, just as environmental conditions vary from one country to another, so may institutional, social and psychological factors differ. In practice, therefore, a wide-ranging assessment will be required in each case, covering the local conditions, available technologies and the relevant institutional and psychological aspects.

As Johnson points out, the combination of the two different case studies proved particularly fruitful: "The breadth of coverage enabled us to develop a comprehensive approach." The findings of this research provide the basis for a handbook which is to be published shortly, offering guidance for local authorities and NGOs on the implementation of mitigation strategies. The handbook will complement the existing online WRQ Geodatabase, which includes global risk maps of geogenic contamination. In partnership with the World Health Organization, the Eawag team is currently revising the database so that it can be combined with other sources of data. The new tool should allow decision makers to identify high-risk areas even more effectively.

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River pollution in China

The Haihe river system in Northeastern China is heavily polluted with nutrients and chemicals, as wastewater treatment plants often operate beyond their design capacity and with poor elimination performance. The urgent need for action has been recognized by the authorities.

The region incorporating Beijing and Tianjin in Northeastern China has the highest rates of economic and population growth nationwide. In spite of increasing water scarcity, the agricultural area lying between these two megacities accounts for roughly a quarter of China's wheat and maize production. Given the dry climate, this is only possible thanks to intensive irrigation with water from the Haihe river system, which extends from above Beijing to Bohai Bay near Tianjin, covering a distance of over 250 kilometres.

But rapid development has taken its toll. Surface waters are severely degraded as a result of massive inputs of nutrients and chemicals. Over the past 40 years, concentrations of nitrogen and phosphorus from fertilizers and untreated wastewater in the Haihe river system have risen dramatically. The consequences of this eutrophication – oxygen depletion and algal blooms – are now widespread. Pollution also enters the soil, groundwater and the sea: parts of China's coastal waters are among the world's largest "dead zones" – oyxgen-depleted areas where almost no marine life can survive.

New WWTPs – an effective solution?

Before the 2008 Olympic Games, no fewer than nine new wastewater treatment plants (WWTPs) came into operation in Beijing, with the aim being to reduce pollution by treating 90 per cent of the wastewater discharged from the city into the Haihe river system. The effectiveness of these measures has now been evaluated – for the first time – by Eawag researchers in collaboration with the Chinese Academy of Sciences. The environmental chemists Michael Berg and Beat Müller assessed nitrogen and phosphorus loads, while their colleague Heinz Singer investigated contamination of surface waters with organic micropollutants. Water samples were collected monthly for a year at 16 sites along a 240-kilometre river section and analysed in the laboratory. In addition, the four tributaries (Qing, Beixiao, Tonghui and Liangshui) draining wastewater from Beijing were investigated, and effluents were sampled at the city's five largest WWTPs.

First, it was necessary to determine water discharge at the study sites. Berg recalls: "That wasn't easy, because the data collected by the local authorities wasn't accessible. In the end, persistent negotiations conducted by our Chinese partners paid off." It turned out that the four tributaries downstream of Beijing account for 90 per cent of total discharge, while the outflow of the Shahe Reservoir north of Beijing is a mere trickle of less than 1 cubic metre per second. Via the tributaries, Beijing releases an annual average of 29.5 cubic metres per second of raw and treated wastewater into the Haihe river system.

Wastewater: a major source of pollution

Beijing and its suburbs release over 50 tonnes of nitrogen and almost 5 tonnes of phosphorus per day into the Haihe river system. The overall budget of nutrient fluxes established by Berg and Müller confirms what was to be expected on the basis of the discharge data: over 90 per cent of these nutrients come directly from wastewater, with the Tonghui river alone contributing more than half of the total load. "By comparison," says Berg, "inputs from industrial, agricultural and atmospheric sources are negligible."

Berg explains that, while increasing numbers of households in Beijing do have connections to WWTPs, population growth was underestimated when the plants were planned in the early 2000s – "So they often operate beyond their design capacity." Assessments of treatment performance indicated that nitrogen removal in particular is inadequate. In contrast, phosphorus removal is relatively efficient. "But – because of low water levels – phosphorus concentrations in some rivers are still very high," says Berg.

A similar picture emerged as regards contamination with organic micropollutants – i. e. synthetic compounds such as pharmaceuticals, household chemicals and pesticides which can have adverse impacts on aquatic organisms even at very low concentrations and, in some cases, may also be of toxicological concern for humans. Environmental chemist Singer reports: "Our analyses of mass fluxes of micropollutants show that Beijing's wastewater treatment plants are again the main source."

The analytical technique that was used to detect micropollutants in water samples is a combination of two different methods. Mixtures are first separated into their individual components by liquid chromatography, and the substances are then identified with the aid of high-resolution mass spectrometry. Singer was thus able to determine the relevant micropollutants in the Haihe river system and to investigate inputs and spatiotemporal concentration patterns. "Various compounds were observed at levels of ecotoxicological concern," he says. For example, the maximum allowable concen-

Benoit Pernet-Coudrier

Algal blooms are commonplace in the highly eutrophic Shahe Reservoir near Beijing.

trations – above which acute effects may occur in aquatic organisms – were exceeded in some cases for the fungicide carbendazim and the antibiotic clarithromycin.

Polluted water used for irrigation

Concerns are also raised by the finding that around 95 per cent of the water flowing through the Haihe river system is diverted to irrigate agricultural land downstream of Beijing. The river water used exceeds the highest grade of the Chinese quality standard – i. e., strictly speaking, it is too polluted to be used for any purpose.

Via irrigation, organic micropollutants could enter not only soils but also food crops. As Singer points out, "If groundwater is fed by the extensive irrigation network, these substances could possibly also contaminate aquifers and accumulate in drinking water." This question is to be investigated in further field studies.

Remedial measures initiated

The researchers conclude: "The most effective way of dealing with dramatic eutrophication and chemical pollution is to build additional, state-of-the-art wastewater treatment plants, which are sufficiently large and can efficiently remove nutrients, especially nitrogen, and micropollutants." The results of the joint Sino-Swiss study were communicated to stakeholders at various workshops held in Beijing, and the urgent need for remedial action was discussed. "It was clear that China is determined to tackle these issues," says Berg. The authorities have already installed pilot plants for advanced wastewater treatment at a number of WWTPs in Beijing, with plans to upgrade to full-scale operations in the near future.

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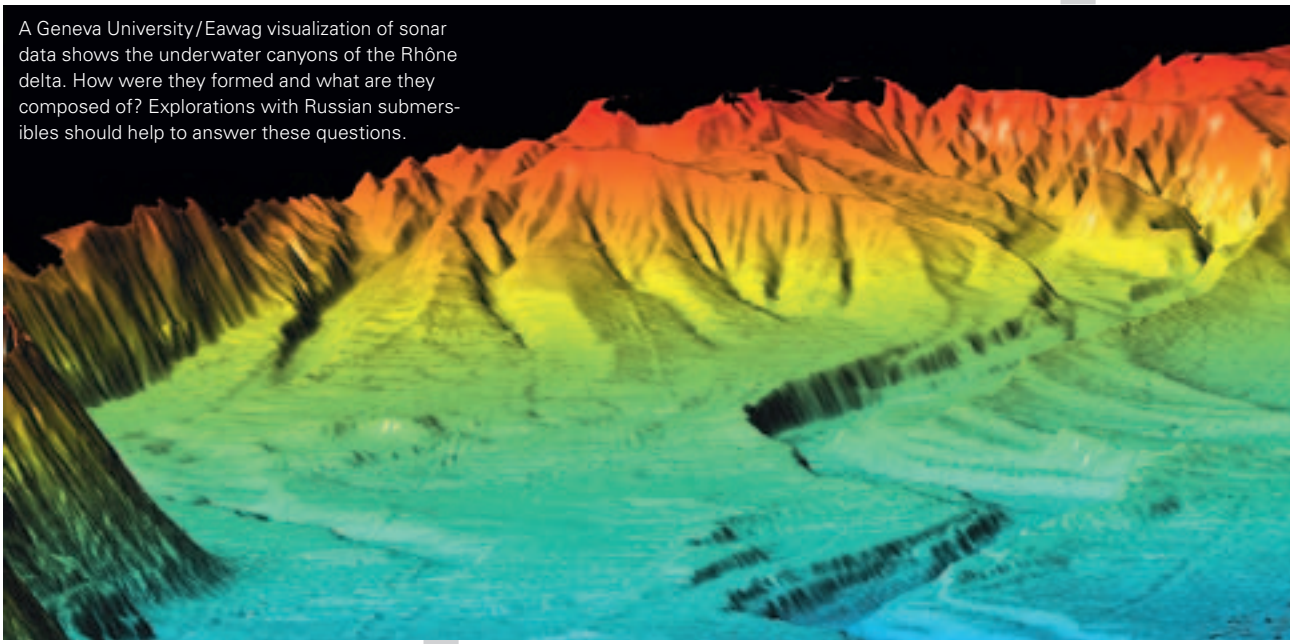
Research through the lens

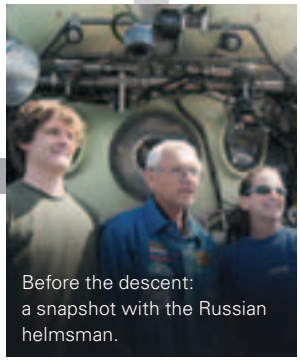


A Geneva University/Eawag visualization of sonar data shows the underwater canyons of the Rhône delta. How were they formed and what are they composed of? Explorations with Russian submersibles should help to answer these questions.

Michael Hilbe

Technicians equip the Mir-1 with plastic pipes used to retrieve sediment cores from the lake bottom.

Stéphanie Giardclos



Before the descent: a snapshot with the Russian helmsman.

Flavio Anselmetti

The sediment cores are analysed in the lab.

Tonya Del Sontro

Submersibles explore Lake Geneva

As part of the EPFL-led "elemo" programme, Eawag researchers used two Russian submersibles to explore the depths of Lake Geneva. They focused on the Rhône delta, where – over thousands of years – huge amounts of sediments have been deposited, forming underwater canyons. The submersibles enabled the researchers to collect samples and carry out investigations at a depth of more than 200 metres. Horizontal sediment cores retrieved from the steep canyon walls (up to 50 metres high) should provide information on the stability of the delta slopes. Sliding of sediment masses can trigger devastating tsunami-like waves; it also explains lake bottom structures and is responsible for the dispersal of stirred-up material. Other projects with Eawag participation studied the incorporation and behaviour of organic matter in sediments and physical exchange processes between different layers of the lake. One question of particular interest is how much methane reaches the surface and is then released – as a potent greenhouse gas – into the atmosphere. www.elemo.ch

Eagerly awaited moment: the launching of the submersible.

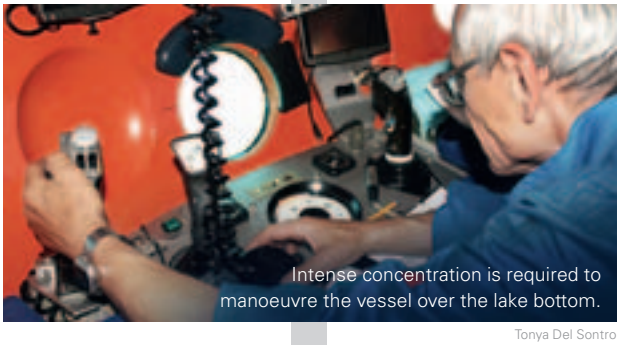
Jean-Marc Blache

A final check on the instrumentation.

Jean-Marc Blache

A gripper arm lifts the plastic pipes which are to be driven into the bottom of Lake Geneva.

Stéphanie Giardclos

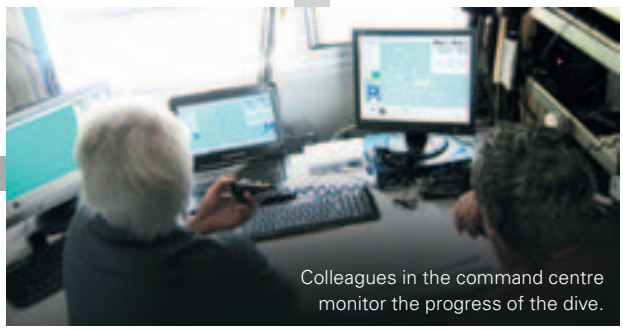


Intense concentration is required to manoeuvre the vessel over the lake bottom.

Tonya Del Sontro

Uranine tracer dye is released for an additional experiment to study underwater flows.

Michael Schurter



Colleagues in the command centre monitor the progress of the dive.

Flavio Anselmetti

Teaching

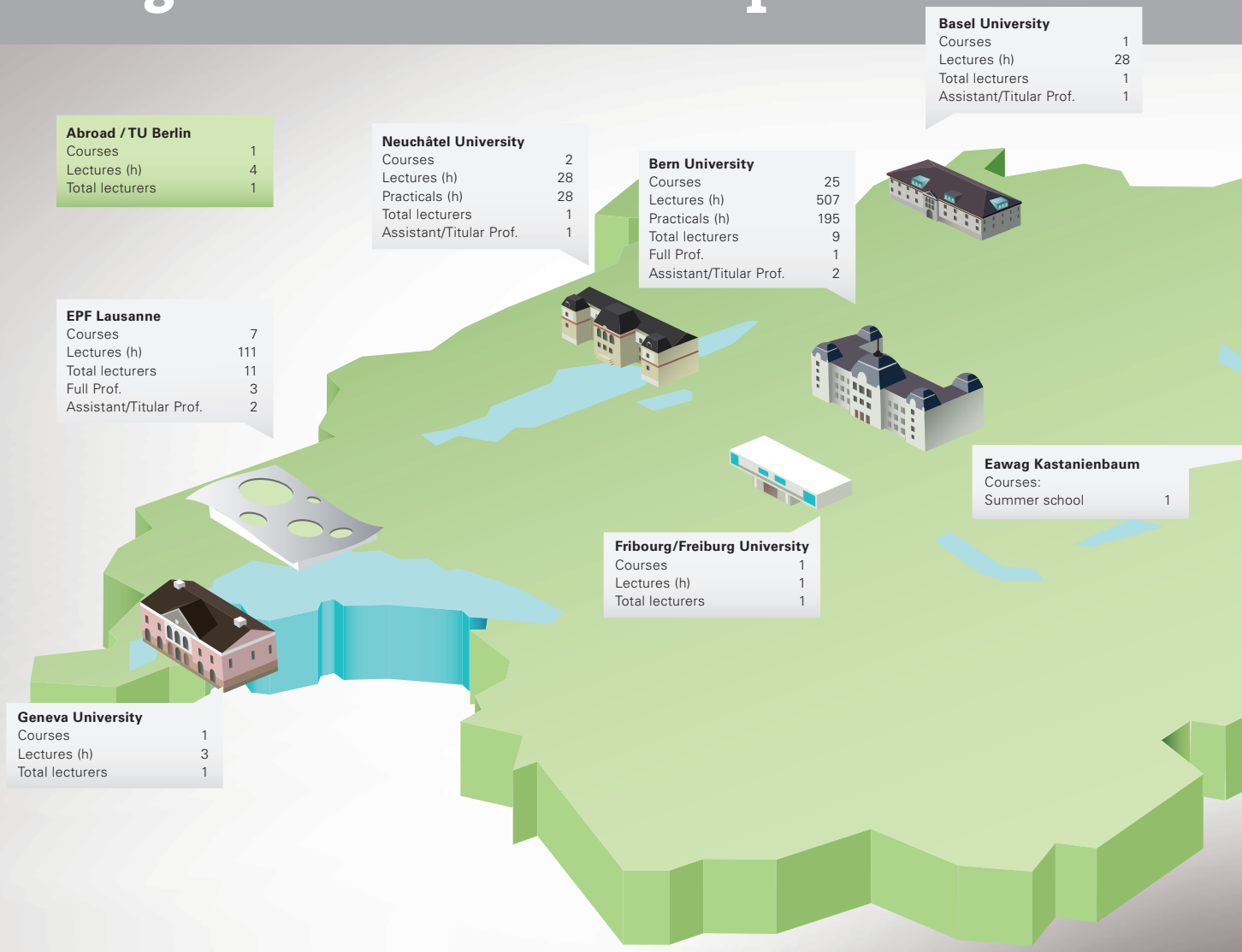
In 2012, two Eawag scientists were awarded full professorships at the Federal Institutes of Technology in Zurich and Lausanne, respectively. These appointments further strengthened Eawag's strategic partnership with the ETHZ and the EPFL. Researchers at Eawag are currently committing around 4,000 hours per year to teaching, thus making significant contributions to education in Environmental Systems Science, Environmental Engineering and Environmental Social Sciences. However, growing student numbers at the Federal Institutes of Technology also pose challenges for Eawag. To ensure the provision of first-class teaching, more placements are required for students, and facilities at the Dübendorf and Kastanienbaum sites need to be modernized and adapted.

Jürg Beer: Teaching people of all ages

One of Jürg Beer's main research interests is the sun. The physicist has been able to reconstruct the history of solar activity by measuring the concentration of beryllium-10 atoms deposited in ice cores. In collaboration with other researchers, he used this method to show that long-term cycles of solar activity are probably influenced by planetary configurations (see page 20). Beer says he is keen to communicate his knowledge because "People are fascinated by the sun" – and so his public lectures are always well attended. In 2012, he introduced the topic of water to an enthusiastic new audience – 200 children aged between 8 and 12 who attended a children's university event at the Zurich University of Applied Sciences. Beer originally joined Eawag 25 years ago as one of the first researchers applying a new method for the detection of beryllium-10 atoms. Since 2003, he has also served as a Titular Professor at the ETH Zurich. And what does he seek to pass on to future researchers? "In natural science, we're always dealing with highly complex, interlinked systems – but it's worthwhile and fun learning to understand them."

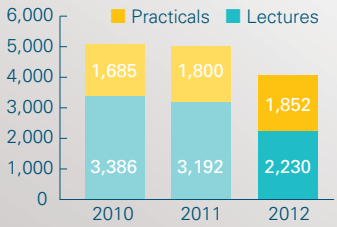
Aldo Todaro

Eawag's education landscape

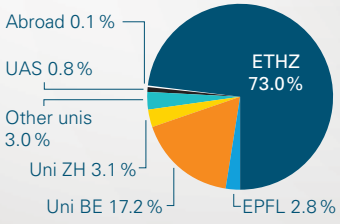


Academic education

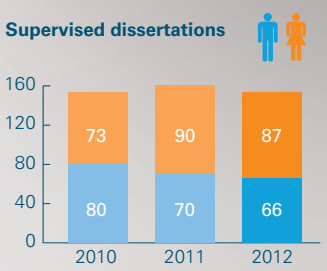
Teaching efforts (h)



Tertiary-level teaching

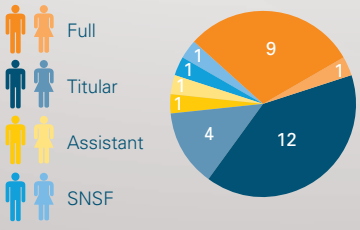


Supervised dissertations

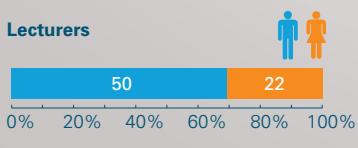


Summer school	No.
Environmental systems analysis	30
Environmental fluid mechanics	34
Total participants	**64**

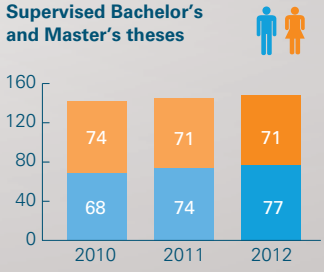
Professorships



Lecturers



Supervised Bachelor's and Master's theses



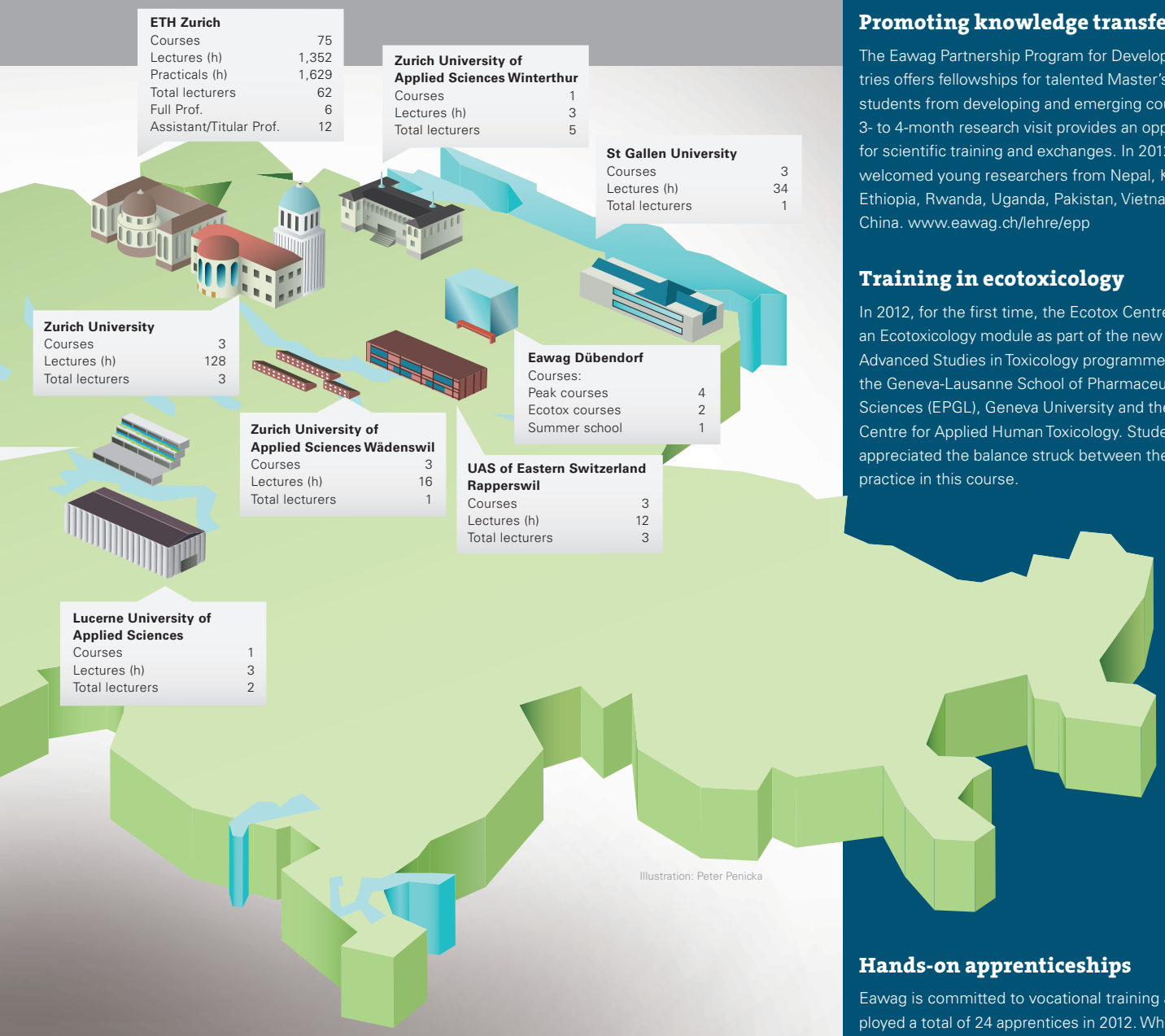


Illustration: Peter Penicka

Briefly noted

Promoting knowledge transfer

The Eawag Partnership Program for Developing Countries offers fellowships for talented Master's or PhD students from developing and emerging countries. A 3- to 4-month research visit provides an opportunity for scientific training and exchanges. In 2012, Eawag welcomed young researchers from Nepal, Kenya, Ethiopia, Rwanda, Uganda, Pakistan, Vietnam and China. www.eawag.ch/lehre/epp

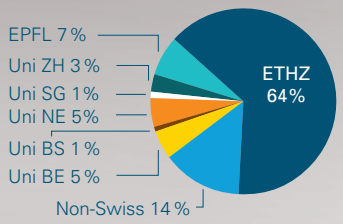
Training in ecotoxicology

In 2012, for the first time, the Ecotox Centre offered an Ecotoxicology module as part of the new Master of Advanced Studies in Toxicology programme run by the Geneva-Lausanne School of Pharmaceutical Sciences (EPGL), Geneva University and the Swiss Centre for Applied Human Toxicology. Students appreciated the balance struck between theory and practice in this course.

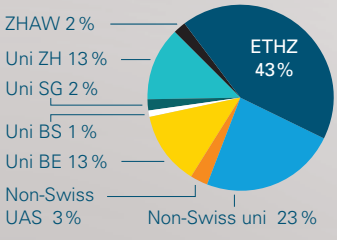
Hands-on apprenticeships

Eawag is committed to vocational training and employed a total of 24 apprentices in 2012. While the majority of apprenticeship places are for chemistry and biology lab technicians, Eawag also trains administrators and IT systems engineers. The Analytics and Training (AuA) Lab provides support for internal researchers and also performs contract work for industry. www.eawag.ch/lehre/bb

PhD student home institutions



Student home institutions



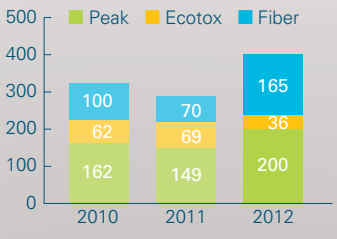
Practical education and training

Practice-oriented Eawag courses (PEAK)	No.
Successful river restoration	61
Pollutants in lake sediments	34
Sustainable water management challenges	82
Nanomaterials in the aquatic environment	23
Total participants	**200**

Ecotox Centre courses (Ecotox)	
Introduction to ecotoxicology	20
Evaluation of ecotoxicological tests	16
Total participants	**36**

Fishery Advice Centre courses (Fiber)	
New water protection legislation: next steps?	70
Detection, mapping and measurement of brown trout spawning redd	95
Total participants	**165**

Course participants



Bachelor's and Master's theses

Environment Agency UK

Martina Blaurock

Blickwinkel

SPREAD OF THE KILLER SHRIMP

As a result of increased human mobility, invasive species are becoming ever more widespread. A case in point is the amphipod crustacean *Dikerogammarus villosus*, which is native to the Black Sea region but has spread across Western Europe (via the Danube) over the past few decades. This predatory, omnivorous species – known as the killer shrimp – tends to displace numerous native species. It is now the dominant amphipod in Lake Constance (where it was first detected in 2002), but, as Roman Alther showed in his study, it has not colonized the small rivers and streams which flow into the lake.

D. villosus was not found in any of the 13 Swiss tributaries of Lake Constance sampled in the study. However, populations of various native amphipod species formerly abundant in Lake Constance were found in the tributaries. The small streams may thus serve as important refuges for these species. But it remains unclear whether these populations are spatially and genetically isolated as a result of the occurrence of the killer shrimp in the lake. The data on the distribution of *D. villosus* and other amphipod species provide a valuable baseline for future studies.

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ECOLOGICAL VS SOCIOECONOMIC INTERESTS

As the total area of Switzerland's alluvial zones has decreased by over 70 per cent since 1850, a quarter of the country's heavily degraded rivers are to be rehabilitated in the coming decades. Rehabilitation scenarios for the Sandey floodplain near Innertkirchen in Canton Bern were studied in a diploma thesis by Martina Blaurock (an Environmental Protection student at the Weihenstephan-Triesdorf University of Applied Sciences), supervised at the Aquatic Ecology department.

For various proposed rehabilitation measures, Blaurock used a hydraulic model in combination with an elevation model and spatial data to investigate environmental and socioeconomic aspects (e. g. resource use conflicts or flood risk). The simulations indicated that morphological interventions have the potential to significantly enhance floodplain dynamics while having a minor effect on flood protection. However, additional flood protection measures were proposed. In the decision-making process, discussions among local environmental protection authorities, land owners and hydropower operators should be facilitated by the results of this study.

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ANALYSIS OF COCAINE IN WASTEWATER

Wastewater analysis is a new method for estimating cocaine consumption in cities. In his study, Jonas Eppler showed that it can also be used for smaller catchment areas. He statistically analysed data on cocaine loads in 1,369 wastewater samples collected daily between 2008 and 2011 at a wastewater treatment plant in a Bavarian community with a population of around 7,000. Cocaine use was found to have increased during the study period: the mean number of daily consumers was estimated to be about 30 for the first 100 days and almost 80 for the last 100 days. Cocaine consumption was found to be higher at weekends than on weekdays, in agreement with observations in larger cities. In addition, the analysis also indicated strong variation in cocaine loads over time. It remains unclear whether this is mainly due to differences in the availability of cocaine or to other factors.

Eppler also compared this estimation method with three conventional epidemiological approaches and showed that wastewater analysis offers several advantages – high temporal resolution, a lack of selection bias and the best cost-effectiveness.

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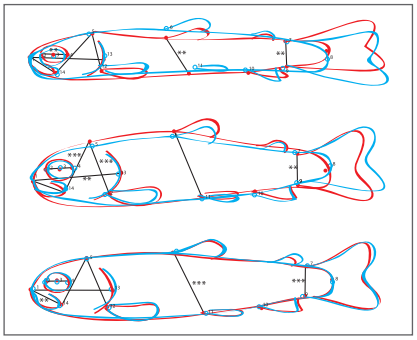
Mario Schirmer


Eawag


Samuel Wechsler

TRACKING GROUNDWATER FLOWS

About a third of Switzerland's drinking water comes from alluvial, often river-fed aquifers. But before infiltrated river water can be extracted from a well, it must have resided in the subsurface for a sufficient length of time so that microorganisms and contaminants are filtered out.

In the event of unexpected contamination, it is important to know how long water takes to reach a well. Infiltration and decontamination of river water are currently being investigated in two major Eawag projects, and the Master's thesis of Lena Frøyland (Norwegian University of Science and Technology) was a contribution to this research.

Using temperature and electrical conductivity data, Frøyland studied the travel times of Thur river water and mixing ratios at various groundwater wells. Statistical analysis revealed that, in most cases, travel times increased with increasing distance from the river. In addition, all the wells observed were found to contain more than 50 per cent freshly infiltrated river water.

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FILTERS FOR FLUORIDE-FREE WATER

200 million people worldwide drink water containing high levels of fluoride and are thus exposed to the risk of dental or skeletal fluorosis. Fluoride can be removed from water with the aid of household or community filters, but these need to be used consistently. To identify factors that can increase the use of filters, Anna Gamma of Zurich University carried out a field study involving 174 households in the Oromia region of Ethiopia.

Gamma showed that filters are mainly used if people are aware of the health risks associated with fluoride, believe that most members of the local community also filter their water, do not regard filter use as too time-consuming and like the taste of filtered water better than unfiltered water.

Certain interventions, such as action planning, were also found to be effective: here, promotors discussed suitable times for filter use with the people responsible. Information workshops combined with a public commitment ("pledging") to use only filtered water for drinking and cooking also appeared to be a promising approach.

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RISKS OF HATCHERY REARING

Stocking measures designed to support declining wild populations frequently use fish reared in hatcheries. In a Master's thesis supervised at the Fish Ecology and Evolution department, Samuel Wechsler (ETH Zurich) demonstrated measurable changes in the morphology of hatchery-reared fish. He compared the development of juvenile brown trout originating from different groups of broodstock – 511 offspring of wild-reared and 672 offspring of farmed mothers.

Shortly after birth, the offspring of the wild trout were morphologically differentiated from those of the captive trout. After a year in the hatchery environment, however, the appearance of the wild fish became more similar to that of the captive fish. Accordingly, the release of hatchery-reared fish needs to be carefully considered since cross-breeding with wild fish could lead to the loss, in the offspring, of evolutionary adaptations to natural conditions.

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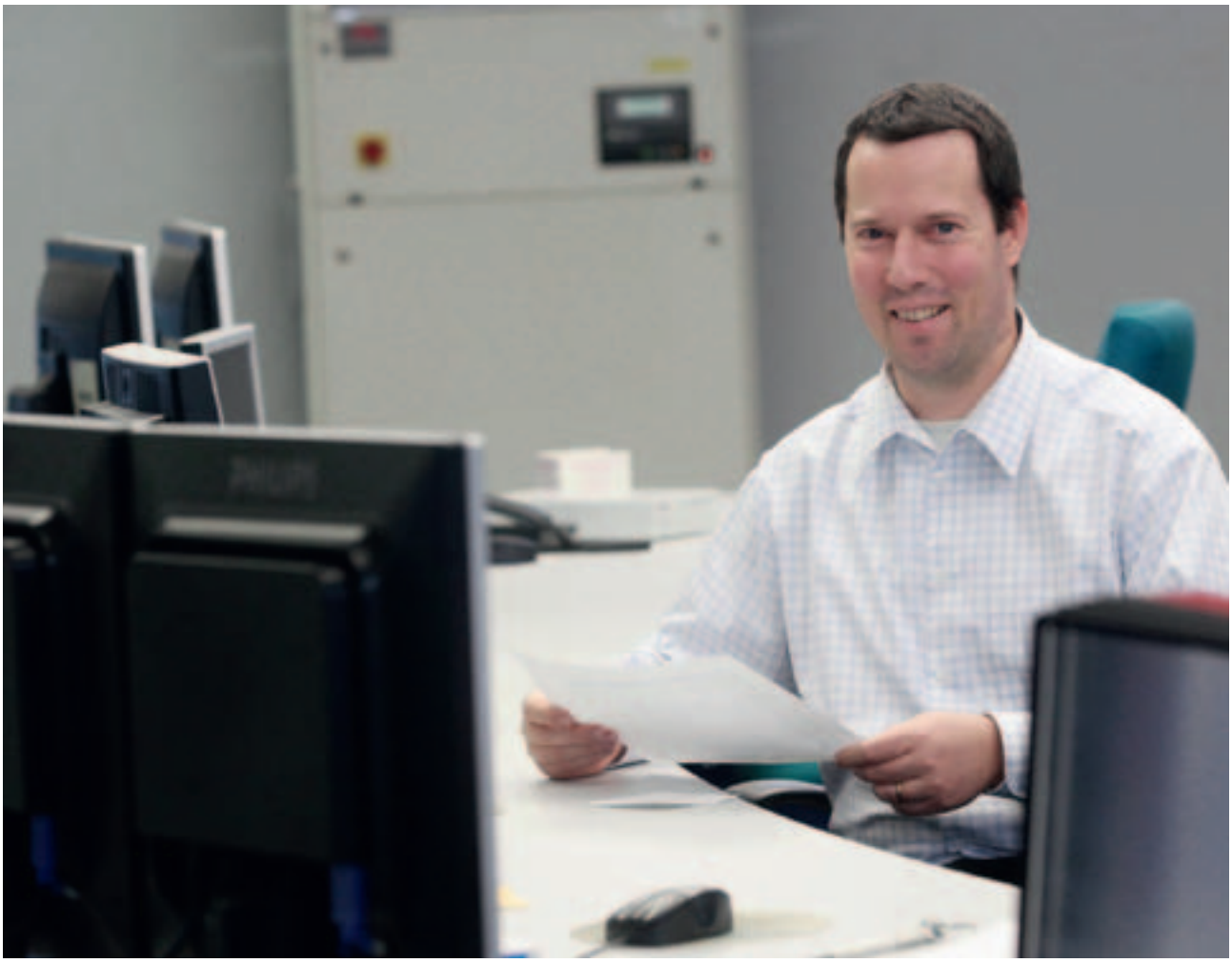
Profiles of Eawag alumni



az Solothurner Zeitung

OLIVER SCHMIDT: ENSURING SAFE DRINKING WATER SUPPLIES

"As long as water keeps flowing from the tap, hardly anyone's aware of exactly what's required to make that happen," says environmental scientist Oliver Schmidt. Since 2011, Schmidt, now 40, has been Director of the Untere Langete water utility (WUL) in Langenthal (Canton Bern): in this capacity, he is responsible for ensuring the provision of safe water supplies to the population of the eleven communes which make up the WUL communal association. In fact, water is his natural element: as a swimmer in the past and now also as a sailor, he has always been attracted to it. At Eawag in 1998, Schmidt studied an underwater landslide (known as a turbidite) which had occurred in Lake Brienz in 1996. Looking back, he sees this as a valuable time: "As well as learning a lot from a professional viewpoint, I acquired some important soft skills." Not least, he recalls, he built up a network of contacts – people he has encountered from time to time in his subsequent career.

After a stint in development cooperation, Schmidt worked as an environmental officer for the Biberist paper mill and then joined the management of the Borregaard cellulose plant. When the latter closed down, Schmidt set up his own business. Today, as well as running the WUL, he continues to work 50 per cent for his own company, providing support on urban water management projects for communal authorities and associations. One's career path is determined by a lot of unpredictable factors, he reflects, but he has always found opportunities to do what interests him: "One day, I'll be dealing with investments of 13 million Swiss francs to secure drinking water supplies for the next 80 years, and the next I'll be discussing the details of pump dimensions. That's what I enjoy about my work – the wide range of activities it involves."

Peter Penicka

HELGE DAEBEL: GREASING THE WHEELS OF INNOVATION

Critical analysis was something Helge Daebel learnt at Eawag, he says – as well as an understanding of technical questions, perseverance and social skills. And he still finds those skills useful today in his dealings with start-ups, for example: "Entrepreneurs can sometimes be a little unconventional!" Daebel, who trained as a civil and environmental engineer, now works as an Investment Director with Emerald Technology Ventures. The venture capital funds managed by this firm invest in young start-ups offering innovative technologies in cleantech sectors such as water. At the same time, Daebel provides practical support for the industrial partners. "Both entrepreneurs and investors are fascinating to work with," he says.

At Eawag, Daebel wrote his doctoral dissertation on uncertainties in the modelling of urban wastewater systems. The fact that he ended up in the investment sector was initially a matter of chance: "But with hindsight, it was definitely the right decision." Thanks to his experience as a researcher, he adopts a critical approach to projects and sometimes draws on earlier contacts to analyse complex technical matters. A successful formula: one start-up whose technology simplifies the inspection of costly drinking and wastewater pipes is now listed on the stock exchange. Another portfolio company, which manufactures ultrafiltration membranes, has been acquired by BASF. And what does Daebel enjoy most about his work? "Helping to keep the wheels of innovation turning."

AGNES MONTANGERO: STRENGTHENING LOCAL ORGANIZATIONS

The idea of working in development cooperation had always appealed to Agnes Montangero – currently Water & Infrastructure Team Leader at Helvetas – "But often you'd hear about projects that weren't sustainable." However, in 1998, having graduated as an environmental engineer, Montangero joined the Department of Water and Sanitation in Developing Countries (Sandec). Here, she was introduced to a way of working which she found compelling: "Rather than imposing solutions from the outside, you need to strengthen local organizations on the ground." This is the approach she has continued to pursue since she left Eawag. She first worked for SKAT, an organization promoting sustainable development (including water supplies and sanitation) in developing countries, before joining Helvetas in 2010. She is now responsible for around 40 projects in the areas of water, sanitation and irrigation. "My work is varied, and I'm able to adopt a broad perspective, also covering cultural and psychological aspects." There is a lot to be done: "Although access to water has improved substantially in recent years, it remains unevenly distributed." In addition, numerous sources of contamination still lie between water resources and users. "Sometimes I get impatient about the slow pace of our progress," she admits. "But then I remember how much I also benefit from working with the people on the ground. I can learn a great deal from the different way in which they approach things."

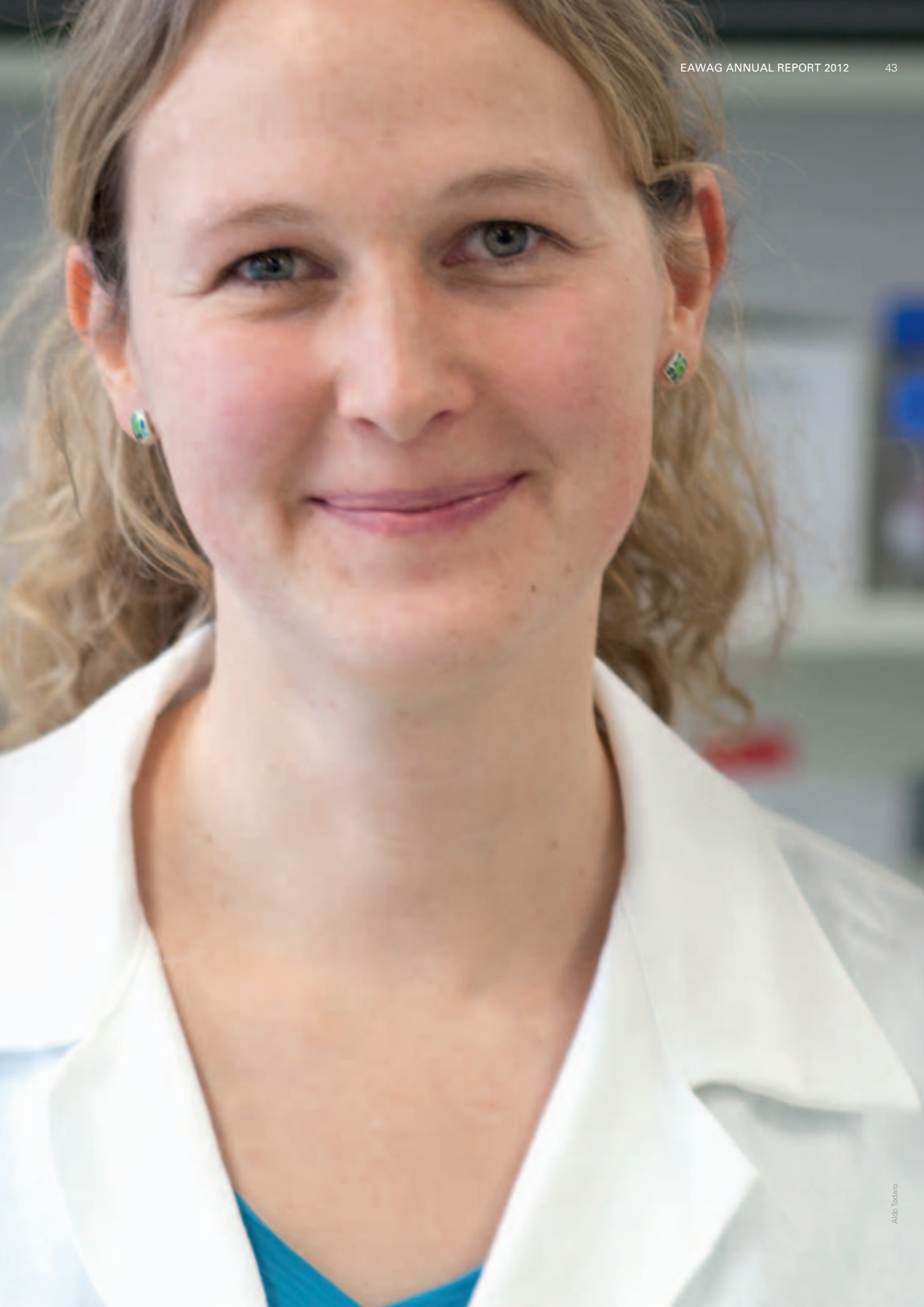
Peter Penicka

Consulting

The 2011 revision of the Water Protection Act has a variety of implications for Switzerland's cantons. Firstly, they are required to implement river restoration measures in the coming years; secondly, wastewater treatment plants are to be upgraded to protect surface waters. In view of the planned phase-out of nuclear energy, there is also growing pressure to further expand the use of hydropower. Given these challenges, Eawag launched the strategic programme Swiss rivers in 2012. This initiative is designed to fill significant gaps in scientific knowledge and support the development of sustainable solutions for the use of water resources. The relationships built up with water professionals over many years provided a sound basis for the initiation of this research programme.

Cornelia Kienle: Developing improved environmental tests

"Endocrine disruptors can have adverse impacts on organisms at concentrations which in some cases are not even chemically detectable," says ecotoxicologist Cornelia Kienle. For this reason, she has been working on the development and wider dissemination of bioassays at the Eawag/EPFL Ecotox Centre since it was first set up almost five years ago. These include not only in vitro assays (e. g. based on yeast cells and human cell lines) but also in vivo assays involving organisms such as the water flea or fish eggs. These assays are much more sensitive than chemical tests and can also be used to evaluate mixtures of substances. But, as Kienle points out, "Despite their advantages, bioassays are barely established in the conventional assessment of surface waters." She and her colleagues are therefore developing a module which cantonal water protection authorities will ultimately be able to use for ecotoxicological assessment of rivers. In future, bioassays are also to be used to determine the effectiveness of filtration for micropollutant removal at wastewater treatment plants. One aspect of Kienle's work which she particularly enjoys is the opportunity for regular contacts with the public and journalists – e.g. after the 2010 Gulf of Mexico oil spill. "We're also happy to advise consumers on everyday questions, such as the possible effects of herbicide use near ponds or the elimination of cosmetics ingredients at wastewater treatment plants."



Aldo Todaro

Bacteria from the tap

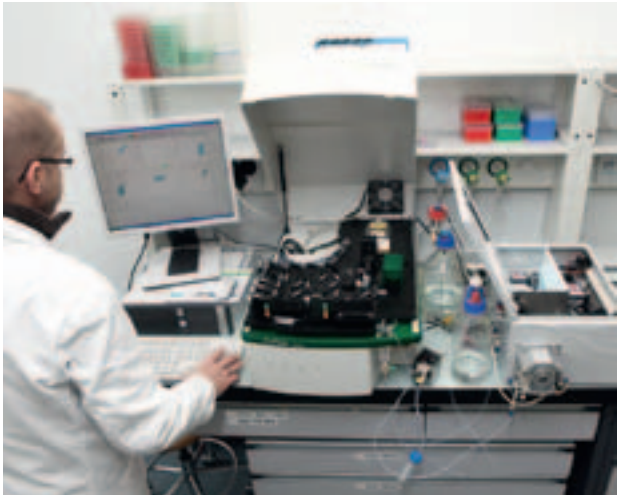
Chemical compounds released from certain plastic pipes can promote bacterial growth and adversely affect drinking water quality. The suitability of materials for water contact can be assessed with a new analytical procedure.

Drinking water is not sterile as it passes through public distribution systems – and still less so when it comes out of the tap. In fact, it contains large numbers of microorganisms. In the vast majority of cases, however, such bacteria are harmless and even desirable, according to Stefan Koetzsch of the Environmental Microbiology department: "They normally ensure that the water is microbiologically stable, preventing the proliferation of pathogens."

But in certain plastic water pipes, including those generally used in household installations, the balance of the natural microbial community can be disturbed. Chemical substances – e.g. additives such as plasticizers or stabilizers – can be released from the plastic material in a process known as migration. Typically, the substances released are organic carbon compounds, which serve as nutrients and thus promote the growth of microorganisms in water. These changes can impair the odour and taste of drinking water and may even pose risks to health.

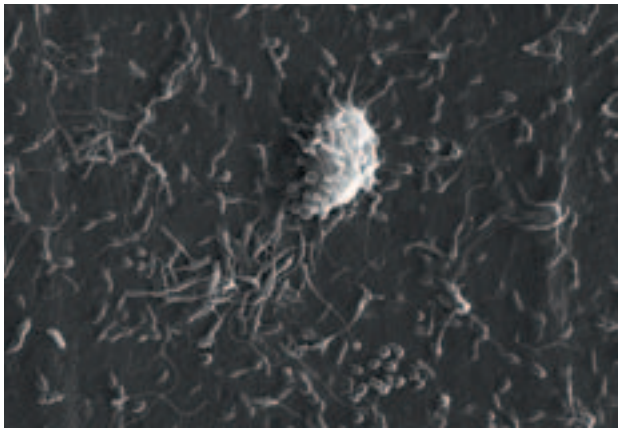
Materials of concern

In order to assess the suitability of plastic materials for water contact applications, Koetzsch and his colleagues have developed a combination of methods known as "BioMig". Various tests are used to determine the amount of organic carbon leaching into water from plastic samples, and to what extent these compounds support the growth of microorganisms. Koetzsch explains: "With BioMig, we can estimate the influence of particular plastics on chemical and microbiological drinking water quality."



Gesa Lüchinger

Flow cytometry is used to determine microbial cell concentrations and community composition in water supplies.



Klaus Marquardt

Biofilm on a plastic surface: certain materials can promote bacterial growth in distribution systems.

The environmental microbiologists applied the BioMig procedure to test three widely used piping materials approved for drinking water contact – radiation cross-linked polyethylene (PE-Xc), peroxide cross-linked polyethylene (PE-Xa) and epoxy resin, which is frequently used in repair work as a lining for metal pipes. To analyse migration behaviour, samples of the materials were placed in water and the leaching of organic carbon compounds was measured over several cycles. The best-performing material was PE-Xc, from which on average a total of 1 milligram of carbon per litre was released. In addition, this was almost completely degraded by microorganisms. Next came epoxy resin, with 1.3 milligrams per litre; here, too, the carbon was almost completely degraded. The highest migration of carbon – 7.4 milligrams per litre – was observed with PE-Xa; here, the degradation rate was less than 5 per cent. Koetzsch comments: "High migration combined with limited biodegradation is problematic, as it's not clear precisely what carbon compounds enter the water and are then ingested by consumers."

Strong bacterial growth

In a further test, the potential of the plastic materials for biofilm formation was evaluated: samples were left in the same water for 2 weeks and bacterial growth was measured. Microorganisms proliferated on each of the three materials tested, with the number of bacterial cells per square centimetre ranging from 30 million (PE-Xc) to 50 million (epoxy resin).

Comparable results were obtained when bacterial growth was measured in simulated and real-life household installations. In the plumbing system of a new residential building in Winterthur, bacterial cell counts in stagnant water (i. e. water residing in pipes for 15 hours without flushing) were found to be up to 100 times higher than in the local water supply. After flushing, levels returned to normal. The composition of the microbial community was also altered in stagnant water.

According to Koetzsch, a safety limit for bacterial cell concentrations in water has not been defined. He also points out that the absolute concentrations are not of crucial importance: "Treated lake water can easily contain 100,000 bacterial cells per millilitre because it's richer in nutrients than, for example, groundwater." What is of greater concern than high, but stable, cell concentrations, in his view, is an abrupt rise in these levels within a distribution system. For this may indicate a disturbance of the microbiological equilibrium, possibly associated with the proliferation of pathogenic organisms.

Koetzsch emphasizes: "Even though it contains microorganisms, drinking water in Switzerland is generally of very high quality." Public water supplies are well monitored and microbiologically stable. This means that drinking water harbours an unvarying population of harmless bacteria. By feeding on organic matter, these bacteria prevent the spread of any pathogenic organisms which may enter the water supply as a result of contamination.

Tighter plumbing regulations

Koetzsch does, however, have one reservation with regard to the quality of drinking water – the "last mile" of the distribution system, which is the responsibility of individual property owners. As he points out, while industrial standards exist for manufacturers concerning the quality and migration potential of plastic piping, they are not legally binding: "Controls go no further than each household's water meter. So, as a rule, nobody can guarantee the quality of drinking water in buildings."

Koetzsch would like to see greater attention paid to the issues of migration and bacterial growth in the plumbing sector. He believes that action is required, for example, with regard to the pressure tests specified for newly installed water pipes. Here, water contaminated with unwanted microorganisms can easily enter a household system. Koetzsch calls on the plumbing sector to place greater emphasis on hygiene and to use membrane filters to retain microorganisms in pressure testing: "Because if unwanted, possibly pathogenic, organisms get into a system at the outset, they find excellent conditions for growth in the new plastic pipes leaching organic carbon."

Koetzsch also suggests that, prior to first use, new pipes should be flushed several times with hot, chlorinated water. The effects of this procedure would be twofold: any microbiological contaminants could be removed, and some of the organic carbon which tends to leach from new pipes (migration being much reduced after the first few months) could be flushed out of the system at this stage.

Flow cytometry method in the Swiss Food Compendium

The flow cytometry-based method developed by Eawag for the analysis of drinking water has been included in the Swiss Food Compendium. This publication, overseen by the Federal Office of Public Health, is an official compilation of recommended and mandatory analytical methods used for quality control of foodstuffs, additives and articles of daily use. In the assessment of the microbiological quality and safety of drinking water, flow cytometry provides much more realistic results than the legally specified heterotrophic plate count (HPC) method. HPC can only detect bacterial cells which grow on solid nutrient media (agar plates) – around one per cent of all the microorganisms present in a water sample. In addition, flow cytometry is much quicker than the conventional method: results are available after a quarter of an hour, whereas HPC analysis can take several days or even weeks, depending on the individual pathogen.
In the analytical procedure known as "BioMig", flow cytometry is used to determine microbial cell counts and community composition in distribution systems.

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Taking the pulse of our lakes

Integrated protection of Switzerland's lakes calls for a detailed knowledge of their physical, biological and chemical condition. A new procedure based on decision-theoretical methods should facilitate standardized assessment of lakes.

On Lake Brienz, 53 per cent of the lakeshore zone is subject to human influences and no longer near-natural. This was one of the findings of surveys carried out by Eawag scientists in an effort to document fish biodiversity in Swiss lakes ("Projet Lac"). On the six lakes studied to date, between 40 and 50 per cent of the shorelines show structural modifications. But the 2011 revision of the Water Protection Act specifies that lakes and rivers are to be restored to a near-natural state. By the end of 2018, cantons are to prepare strategic plans for the rehabilitation of their lakeshores. However, such planning requires a detailed knowledge of the current state of waterbodies and of the factors influencing their condition. This in turn calls for suitable methods of recording and assessing the relevant aspects.

Need for ecological assessment of lakes

No comprehensive, standardized procedure for the assessment of standing waters has been available to date. The development of such a procedure requires scientific and methodological expertise, knowledge of legal regulations and practical experience. At the request of the Federal Office for the Environment (FOEN), a working group was therefore established for this purpose, bringing together Eawag researchers and representatives of cantonal agencies and the FOEN. In this process, the experts were guided by the existing Modular Stepwise Procedure for the assessment of watercourses, jointly developed by Eawag, the FOEN, cantonal water protection authorities and consultancies. The Modular Stepwise Procedure covers every level of organization of rivers and streams – from morphology and hydrology through animal and plant life to water quality. Assessments are performed on different scales, involving surveys of a region/canton, an entire surface water system, or a particular reach (stream section). Project leader Jacqueline Schlosser of the Systems Analysis, Integrated Assessment and Modelling department explains: "For the type of integrated protection stipulated by the law, we also need a modular system to facilitate comprehensive surveys of the physical, chemical and biological condition of lakes."

Stefan Kubli

The development of a morphology module for assessing the condition of lakeshores is seen as a priority.

KKL Lucerne

Ongoing remedial work should minimize inputs of copper from the roof of the Culture and Convention Centre (KKL) into Lake Lucerne.

For the assessment procedure, the scientists used analytical methods drawn from decision theory. The overall goal of a near-natural condition of the lake ecosystem is thus hierarchically structured into more concrete sub-goals. The near-natural condition of the lake is first divided into a near natural physical, biological and chemical condition, and these three areas are then further subdivided. For example, the biological condition is determined by the vegetation and by the communities of plankton, macroinvertebrates and fish. Additional sub-levels may be defined, with the lowest level comprising measurable parameters – e. g. the number of macroinvertebrate species and their biomass – which can be used to quantify the degree to which the corresponding goal has been attained. This involves comparison with reference values based on near-natural waters. Using mathematical methods, the divergence of the actual from the target state can be quantified. "This means we can assess conditions at the various hierarchical levels and, if necessary, assign them to certain quality classes," says Schlosser. Thus, Lake A might be rated as "unsatisfactory" for the condition of its macroinvertebrates, while Lake B could be classified as "excellent".

Planning of the first modules

For the federal and cantonal authorities, now that the procedural framework for lake assessment has been defined, the next step is the elaboration of individual modules. Though guidelines have been prepared by the working group, the development of individual assessment modules is a time-consuming process. Given that lakeshore rehabilitation measures are to be planned by the cantons within the next few years, the experts regard the preparation of a lakeshore morphology module as top priority. Also of high priority is the assessment of nutrient conditions. This is to be followed by a module to assess lake condition through fish – which are valuable indicators of the ecological status of lakes – since only limited long-term data are currently available. It should be possible to apply each of the lake assessment modules independently of the others, as is the case with the modules from the Modular Stepwise Procedure for watercourses.

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KKL: Prevention is better than cure

The roof of the Culture and Convention Centre Lucerne (KKL) is clad with copper sheeting, which covers an area of 9,400 square metres. The lakeside complex – designed by the architects Nouvel and Cattani and opened in 1998 – is now one of the city's best-known landmarks. But, as Empa demonstrated in 2005, around 11 kilograms of copper per year is leached from the roof into the lake. In 2002, Eawag had already detected elevated concentrations of copper – up to 700 milligrams per kilogram of sediment – close to the point where roofwater enters the lake from the KKL (copper is toxic to microorganisms, plants and fish, even at low concentrations). The same year, in consultation with Eawag, the Swiss Water Association (VSA) issued guidelines stating that rainwater from copper roofs with an area of more than 500 square metres is considered to be highly contaminated. Accordingly, in 2006, the Lucerne Environment Office requested the KKL to examine how copper could be removed from the roof runoff. As work was already due to be carried out on the roof of the KKL for other reasons (e. g. to repair a number of leaks), it was decided that a protective polyurethane coating should be applied. The remedial work – described as proportionate by the KKL Lucerne itself – is still underway. Experiments have shown that the coating can reduce the leaching of copper by up to 98 per cent. But researchers will continue to provide support: monitoring of roofwater discharged into the lake, together with weathering and impact tests, should ensure early detection of any reduction in effectiveness or degradation of the coating.

Assessing the toxicity of mixtures

Existing methods for assessing the toxicity of mixtures of chemicals in surface waters are inadequate. The Eawag/EPF Lausanne Ecotox Centre has helped to develop a decision tree which can be used to identify mixtures of ecotoxicological concern.

Large numbers of chemicals used in households end up in surface waters. Mixtures of substances can have toxic effects even if the individual components are unproblematic.

Aquatic organisms are continuously exposed to a wide variety of chemical cocktails. Traditionally, however, ecotoxicologists have assessed the state of surface waters on the basis of individual substances: observed environmental concentrations are compared with reference values (i. e. levels not considered to pose a risk), which are known as environmental quality standards. In the regulatory approval process, it is also assumed that chemicals in the environment act independently of each other. But researchers and regulators have repeatedly raised the question of whether significant hazards will not be overlooked if attention is confined to individual substances. In recent years, numerous studies have shown that mixtures of substances can have toxic effects even if all the components are present in concentrations which, independently, are of no concern. This is because, with a common mode of action or the same target organ, substances may have additive effects. Scientists have therefore begun to seek effective methods whereby such combined effects can be taken into account in environmental risk assessment and in the approval of chemicals.

Identifying mixtures of concern

In Switzerland, over 50 different substances can sometimes occur simultaneously in wastewater treatment plant (WWTP) effluents and in surface waters. According to Marion Junghans of the Eawag/EPFL Ecotox Centre, "It's virtually impossible to assess in detail the toxicity of all the mixtures found. Often, information is also lacking on the toxicity and mode of action of individual substances." But to what extent are toxic effects overlooked if known compounds are only assessed on the basis of their individual toxicity? And how can the mixtures of greatest concern be identified, so that risk reduction efforts

can be appropriately focused? To address these questions, the Ecotox Centre collaborated with the US company Dow Chemical and other partners.

The research team developed a method that makes it possible to identify mixtures with problematic effects in surface waters. In this method, an elaborate decision tree is used to estimate ecotoxicological risks in a series of steps. The first step involves determining whether one or more individual substances exceed the respective reference values. If this is the case, action would need to be taken with regard to these individual substances, but no further investigation of the mixture would be required. Otherwise, the toxicity of the mixture also needs to be estimated. Here, the individual substances are pragmatically assumed to show similar toxicological behaviour. In addition, the assessment focuses on those substances which – because of their effects or concentrations – dominate the toxicity of the mixture. If combined exposures to these substances are problematic, appropriate action would again need to be taken.

Method successfully applied

Marion Junghans and Petra Kunz of the Ecotox Centre, together with other members of the research team, used the method to assess the risks to human health and the environment of 559 chemically analysed mixtures from various WWTP effluents and surface waters across Europe. It was found that less than 2 per cent of the mixtures studied were of concern for human health, but problematic ecotoxicological effects could not be ruled out in 81 per cent of cases. Junghans says: "This means that health and ecological effects always need to be separately assessed." In 68 per cent of the mixtures of ecotoxicological concern, one or more of the chemicals exceeded their reference values and were responsible for the majority of the predicted toxicity. The risks associated with these mixtures could thus be determined in an individual substance assessment.

In 12 per cent of cases, however, the mixture was of ecotoxicological concern even though the individual components were not. Junghans emphasizes: "This is the critical group, as the toxicity of these mixtures would not be identified using a chemical-by-chemical approach. So risk assessment should focus on this group." Detailed toxicity data and mode of action information is thus only required for these substances – a reasonably limited number of metals, pharmaceuticals, hormones, pesticides and flame retardants – in order to accurately predict the toxicity of mixtures. Junghans concludes: "The decision tree has proved to be a helpful tool which can be applied to a wide variety of mixtures." It allows mixtures to be adequately evaluated on the basis of readily available information, such as concentrations and reference values. "Consequently, more resource-intensive data collection and analyses can be reserved for those cases where they're really needed."

The Ecotox Centre

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

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Alpine hut wastewater treatment

In the Swiss Alpine Club's new mountain hut built at the foot of Monte Rosa, the wastewater treatment system was pushed to its limits by the flood of visitors. At the request of the SAC, optimization measures were developed by Eawag process engineers. The redesigned system can now meet the high demands.

The outstanding architecture and high-tech design of the SAC's new, futuristic mountain hut at the foot of Monte Rosa, which was opened in 2010, raised high expectations among users. But in the Monte Rosa hut's first year of operation, visitors and maintenance staff were less than impressed to find that the treated wastewater used for toilet flushing was heavily discoloured and strong-smelling. The wastewater treatment system simply could not cope, as visitor numbers were much higher than had been anticipated. The SAC therefore asked Eawag to investigate how the capacity of the system – located in the basement – could be increased. As no more room was available, the experts from the Process Engineering department recommended that the treatment area should be expanded by integrating an existing buffer tank into the system. This would require a variety of technical alterations.

More bacteria, better performance

The engineers who had installed the system began the alteration work in June 2011, with the effects being continuously monitored by the Eawag scientists. The aim was not only to ensure appropriate wastewater quality but also to keep energy consumption as low as possible – despite increased treatment – and to reduce the need for maintenance.

The buffer tank had originally been designed to store wastewater arising at peak times, such as weekends and early mornings. The idea had been to maximize energy efficiency by running the system primarily when the largest amount of (on-site) solar power was produced. However, because visitor numbers were also high during the week, the system had to be operated continuously. In the redesigned system, therefore, the buffer tank was used for the first treatment step, which meant that two tanks were now available for the second step. Thanks to this increase in volume, the quantities of bacteria responsible for treatment also increased, leading in turn to improved performance.

Max Maurer

Limited space was available in the Monte Rosa hut, not just for Eawag researchers but also for expansion of the wastewater treatment system.

The redesign made it possible to eliminate certain sources of energy consumption: for example, a stirring mechanism was dispensed with in the first treatment step. The existing ultraviolet lamp was replaced with an ozonation unit to improve colour removal. Eawag process engineer Eberhard Morgenroth explains: "If the water is less discoloured, we would expect multiple flushing of toilets to be reduced, and so less wastewater will be generated overall." Additional adjustments were made to reduce the amount of maintenance required.

Lower energy consumption

After the system had been reconfigured, the process was optimized by the team, in collaboration with hut staff. The main objective was to achieve the desired treatment performance with the lowest possible energy consumption. One important factor was the length of time for which the treatment tank was aerated (this could be limited). Energy is also saved by operating the ozonation unit only as needed. Thanks to these and other minor adjustments, energy consumption is now actually lower than it was before. The performance of the redesigned system is consistently high, and unpleasant odours and discoloration have been minimized.

However, as the Eawag process engineers point out, the solution adopted for the Monte Rosa mountain hut cannot necessarily be applied to other decentralized treatment systems in the Alps. "Each site calls for an individual approach," says Morgenroth. He adds: "Sophisticated technology like this would not be an option for the majority of huts." What is needed above all, in his view, are low-tech methods offering robust performance and requiring minimal maintenance.

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Wastewater: planning for the future

The development of wastewater management in Switzerland has been a success story. Now, strategic decisions need to be taken to ensure that this remains the case. The future challenges and uncertainties facing this sector are examined in a new report – "Wastewater Management 2025".

Thanks to sound planning and investment, Switzerland now has a wastewater management system which provides high-quality services nationwide. The estimated value of this infrastructure is around CHF 120 billion. In addition, the annual costs of operation, maintenance and construction amount to CHF 3.2 billion. Max Maurer, head of the Urban Water Management department, says: "Switzerland has achieved a great deal in this sector; now, the right strategic decisions need to be taken so that this excellent public service will be fit for the future." The question of how today's wastewater management sector can respond to expected developments is addressed in a report entitled "Wastewater Management 2025 in Switzerland", prepared by Maurer and his colleagues on behalf of the Federal Office for the Environment. This wide-ranging report reviews existing knowledge and identifies significant gaps in our knowledge.

BilderBox

Switzerland's public sewer network has a total length of around 49,000 kilometres.

Fragmented organizational structures

Maurer explains: "Our wastewater infrastructure does not need to be rebuilt, but preserved, optimized and adapted to changing conditions." Infrastructure management will thus play a key role in the future. According to the report, the organization of the wastewater sector is currently fragmented and strongly influenced by the political structures of local authorities and associations, which makes professional management difficult. The authors therefore expect that the wastewater sector will increasingly be organized in larger regional structures. This would be in line with the trend towards integrated watershed management, i. e. an integrated approach to water supply, urban drainage, wastewater treatment and water protection.

Today, most wastewater in Switzerland is conveyed to treatment plants by combined sewers, mainly comprising domestic and industrial wastewater and stormwater. Each year, treatment plants handle a total of almost 1.7 billion cubic metres of wastewater. By 2060, the population is expected to grow to around 9 million, which will also lead to increased volumes of wastewater. However, the pattern will not be uniform, as the population is expected to grow mainly in urban centres, while declining in rural areas. The authors of the report believe that decentralized wastewater treatment facilities could become established in less densely populated regions, which would substantially reduce the costs associated with wastewater transport. The provision of sewer networks accounts for 90 per cent of investments in the wastewater sector.

Factoring in uncertainties

Wastewater volumes could also increase as a result of climate change. Climate models predict that heavy rainfall will become more frequent in Switzerland, and rainfall volumes influence the dimensioning of sewers. But, as Maurer notes, "We know very little about the impacts of climate change, which makes planning extremely difficult." It is, however, essential to take such uncertainties into account in the decision-making process.

The authors conclude that, overall, wastewater management costs and charges are likely to rise in the future. The increases will be due not only to adaptations to population growth and climate change but also to, for example, the need for renovation and upgrades to permit the removal of micropollutants. In addition, the costs of waste management operations are not fully covered in many areas at present. Maurer says: "On the basis of our review, we now need to work together with operators and owners to develop sustainable solutions for the future."

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Improving hygiene promotion

Regular handwashing can help to prevent the spread of cholera in a disaster area. But how can people be persuaded to adopt appropriate hygiene behaviour? A study in Haiti showed that not all hygiene promotion measures have the desired effects.

In response to the devastating earthquake which struck Haiti in January 2010 and the severe outbreak of cholera later that year, the international aid agency Oxfam initiated a variety of activities designed to improve hygiene behaviour among the local population. Via public health campaigns and information events, people in affected areas were to be encouraged to wash their hands with soap after using the toilet and before handling food. The aim of these promotion activities was to help to contain the cholera epidemic.

Wide variety of activities

In a study commissioned by Oxfam America, Hans-Joachim Mosler and Nadja Contzen of Eawag's Environmental Social Sciences department evaluated the effectiveness of the various promotion measures and investigated the main psychological factors influencing hygiene behaviour among the population. For this purpose, in the early summer of 2011, structured interviews were conducted in more than 800 households and the results were statistically analysed. To ensure

Hans-Joachim Mosler

Posters like this displayed in Haiti did not seem to increase the frequency of handwashing.

that the sample was representative of the whole community, households in both urban and rural areas were included in the survey.

Measures found to be particularly effective were, for example, radio spots, information disseminated by friends or neighbours and hygiene theatre. The frequency of faeces- and food-related handwashing was also increased by the distribution of materials with instructions and demonstrations. Radio programmes in which listeners' questions were answered by experts were likewise found to be effective. According to Mosler, "The positive impact was stronger if these measures were combined."

At the same time, certain activities were found to be ineffective or even counterproductive. Educational stickers, posters and paintings displayed at key locations had a negative impact, as did hygiene songs performed at meetings or broadcast on the radio. Another striking finding was that special hygiene days or home visits carried out by aid workers tended to have a negative impact on hygiene behaviour.

Why these promotion activities, in particular, had unfavourable effects should now be studied in more detail. As Mosler points out, "Because our investigation was a cross-sectional study – documenting hygiene behaviour at a given point in time – our findings do not reveal causal relationships. However, the responses clearly indicate areas where there is a potential for improvement."

Health knowledge is not sufficient

But what psychological factors ultimately determine whether people wash their hands with soap? The findings of the study confirm that – like other types of human behaviour – hygiene is influenced by a number of different factors. It would appear that what is decisive is not how well-informed people are about infection risks and health-related aspects of handwashing. Instead, it is primarily the social norms prevailing in the community and individual attitudes to handwashing which determine whether or not recommendations are complied with. Other key factors are individuals' readiness and confidence in their ability to adopt and maintain a change in their hygiene behaviour. Mosler explains: "Our results show that knowledge of the risks is not in itself sufficient. To be effective, prevention efforts need to do more than just communicate knowledge."

Elizabeth Stevens, Oxfam America

Handwashing can help to prevent the spread of cholera.

Additional research will now be carried out to investigate how behaviour is affected by specific measures. Mosler says: "It's important to find out what psychological factors can be influenced by particular types of promotion activities. Once these links have been established, the available resources can be deployed more effectively."

Contact: hans-joachim.mosler@eawag.ch

Aldo Todaro

Eawag in 2012

In 2012, Eawag defined its research priorities for the next few years and began to implement activities in these areas. This included not only the launching of major programmes such as EcoImpact or Swiss rivers, but also key management decisions. Recognition for practice-oriented research came in the form of awards and professorial appointments. Eawag engaged in partnerships at the national and international level and initiated scientific discussions with representatives from the spheres of practice and academia. High-ranking international delegations visiting Eawag appreciated the opportunity for direct contacts with scientists – such exchanges are fundamental to applied water research efforts.

Salome Mwaiko: A passion for lab management

Biologist Salome Mwaiko relishes the challenges of working as a lab manager: "One week all the experiments will run smoothly – the next, you'll do exactly the same thing, but nothing will work as planned!". She is proud of the results obtained in her molecular genetics lab, part of the Fish Ecology and Evolution department at Kastanienbaum. This lab studies the ecology, evolution and biodiversity of aquatic organisms – especially fish – from lakes and rivers in Switzerland and East Africa, using molecular genetic and other methods. Mwaiko says: "Each method requires different equipment, which needs to be permanently available and functional." As well as managing and maintaining the equipment, she provides technical training for new staff, assists with fieldwork, curates the immense data archive and is responsible for the constantly growing collection of preserved fish. These relics of earlier research have been kept as reference specimens since 1993. At present, Mwaiko's lab is used by around twenty people, although no more than a handful are usually present at any one time. The lab manager also provides moral support: "If something goes wrong, I reassure them that it's perfectly normal and happens to everyone." Salome Mwaiko has thus contributed to the success of numerous research projects – and at the same time has learnt a lot from all the scientists working at her lab. "I never get bored here," she adds with a smile.

Broad dialogue

ETH Water Talks

At the Water Talks hosted by the ETH Zurich, Eawag Director Janet Hering, together with Nestlé Chairman Peter Brabeck and Peter Niggli of Alliance Sud, addressed the question "What is the value of water?". In front of an audience of over 600 people, the panellists discussed the responsibilities of the private sector, governments and research for providing access to safe drinking water.

International presence

Last year, Eawag was not only represented at scientific conferences and workshops. The activities of the Sodis Reference Centre were also presented for a week at the Expo 2012 world fair in Yeosu (South Korea). Here, visitors had an opportunity to hear at first hand how sunlight is used to disinfect water in developing countries.

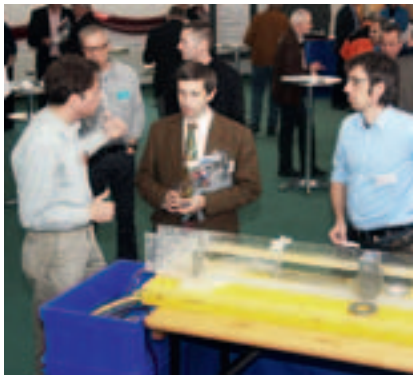
Präsenz Schweiz

Students at the world fair learned how the Sodis method works.

A number of Eawag scientists were present at the 6th World Water Forum in Marseilles. This event attracted 35,000 participants – including policymakers and civil society representatives – from almost 180 countries. As well as giving presentations, delegates from Eawag used a mock-up of an Indian slum to demonstrate in an unconventional manner what the development of appropriate sanitation solutions involves.

Contacts with stakeholders

As exchanges with practice are vital for Eawag, close contacts with professionals from the Swiss water sector were maintained throughout 2012. In March, for example, Eawag was represented at the Bern Water Day.



Andri Bryner

Ecotox Centre staff talking to delegates at the Bern Water Day event.

In October, a workshop on aquatic invasive species, organized by the Aquatic Ecology department, was attended by 40 experts from the federal and cantonal authorities, environmental consultancies and research. At this event, measures were defined to ensure a more coordinated approach, laying the foundations for improved collaboration in this area. Another forum for interaction between scientists and stakeholders was a symposium held in November on applied evolutionary ecology. Here, the aim was to discuss how research in this field can contribute to solving pressing environmental problems in aquatic ecosystems.

In June, Eawag's Info Day was held in the Auditorium Maximum at the ETH Zurich. This event focused on Switzerland's surface waters, which provide not only ecological but also significant economic services. The question of what is required if the functions of aquatic ecosystems are to be preserved in the face of growing pressures was discussed by more than 300 delegates from academia and practice.

Peter Penicka

Eawag's annual Info Day provides an opportunity for dialogue with water professionals.

www.eawag.ch/lehre/infotag/2012

Venue for Nano Authorities Dialogue

In May 2012, Eawag hosted the 6th International Nano Authorities Dialogue, attended by representatives of government departments, authorities, enterprises, research institutions and the media from Austria, Germany, Liechtenstein and Switzerland. The topic of the two-day conference was the communication of scientific information and dialogue with the public and other stakeholders (business, academia, policymakers). At the event, Eawag researchers presented the latest findings on nanomaterials in aquatic ecosystems.

Conference on 3Rs in ecotoxicology

The 1st European Conference on the Replacement, Reduction and Refinement of Animal Experiments in Ecotoxicology was held at Eawag in June. This Euroecotox network event was organized by the Environmental Toxicology department.

Addressing practical issues

In 2012, Eawag was able to contribute directly to the improved management of practical problems in the water sector. A method developed by Eawag for the determination of bacterial cell counts in drinking water was included in the Swiss Food Compendium by the Federal Office of Public Health. This analytical method, based on flow cytometry, makes it possible to detect and respond to changes in microbiological water quality within a matter of minutes.

A longer-term issue is the safeguarding of Switzerland's water resources. In response to Parliament's call for a national water management strategy, Eawag has set up a working group to coordinate

internal activities and provide expert support for the Federal Office for the Environment.

Eawag's expertise is also in demand at the international level. For example, global risk maps showing the probability of groundwater contamination with arsenic or fluoride – prepared as part of the Water Resource Quality project – were included in the UNICEF/WHO report on "Drinking Water Equity, Safety and Sustainability". The risk maps help planners to decide where groundwater resources can be used without endangering public health.

Eawag

Risk maps help to identify sites where groundwater is contaminated with arsenic or fluoride.

Strategic partnerships

In 2012, the Sodis Reference Centre signed an agreement on collaboration with the development organization Helvetas. This partnership combines Eawag's research expertise and knowledge of the implementation of solar water disinfection in drinking water projects with the broad experience of Helvetas in development cooperation. Helvetas will integrate the Sodis method into its drinking water projects, while Eawag will provide support in the form of research, technical advice and international advocacy efforts.

Lilia Rojas

In Bolivia youngsters are already familiar with the Sodis method of disinfecting drinking water.

The Department of Water and Sanitation in Developing Countries (Sandec) seeks to promote sustainable solutions through participatory processes. Since 2012, the WHO Collaborating Centre for Sanitation and Water in Developing Countries has been based at Eawag. This increases the visibility of Sandec's activities and facilitates access for researchers to a worldwide network of experts.

In February 2012, the Swiss Water Partnership (SWP) was launched in Bern – in the presence of the SDC Director-General – by representatives of 45 organizations from the Federal Administration, the scientific and research communities, the private sector and aid agencies. The SWP aims to strengthen the international profile of the Swiss water sector and to create synergies between its members' activities. Christian Zurbrügg and Eberhard Morgenroth of Eawag are members of the Steering Board. In February 2013, an event was held at Eawag to celebrate the SWP's first anniversary.

Awards

UN prize for Sodis

In 2012, the UN "Water for Life" Best Practices Award went to Fundación Sodis in Bolivia. This non-profit organization, founded by Eawag and the Swiss Agency for Development and Cooperation in 2001, promotes water and sanitation solutions in Latin America. Over the years, it has provided training on solar water disinfection (Sodis) for more than 1.2 million people, and it now also addresses hygiene and environmental sanitation issues.

Life's work honoured

At a ceremony held in Chur in November, Martin Wegelin was awarded the Dr J.E. Brandenberger Foundation Prize (worth CHF 200,000) for his pioneering work on solar water disinfection (Sodis). Wegelin – who worked at Eawag for 25 years – led the team which studied the principle of using sunlight to purify contaminated water in PET bottles, and implemented the method in practice. The Eawag team demonstrated that pathogenic microorganisms are inactivated by the sun's ultraviolet radiation and explored how the Sodis method can be most effectively disseminated.

www.sodis.ch

Award from University of KwaZulu-Natal

Eawag received an award from the School of Engineering at the University of KwaZulu-Natal (UKZN) in recognition of its support for the training of engineers. The UKZN is a key partner in Eawag's Vuna project, which is concerned with the recovery of nutrients from urine in the Durban region.

Bastian Etter

Valuable nutrients can be recovered from urine.

Recognition award for toilet

In the Bill & Melinda Gates Foundation's Reinvent the Toilet Challenge, a team of Eawag researchers – together with an Austrian firm – received a special recognition award for outstanding design. The competition called on participants to develop a next-generation toilet providing a hygienic, dignified and environmentally sound sanitation solution at a cost of less than five cents per user per day. The USD 40,000 prize money is to be invested in the development and construction of a prototype (see also page 26).

www.eawag.ch/rttc

Infrastructure

Renovation completed at Kastanienbaum

In August, scientific staff and those responsible for facility management celebrated the opening of the freshly renovated laboratory building at the Kastanienbaum site. Over a two-year period, it had been progressively modernized and optimized to meet today's needs. One of the main innovations is a ventilation system which uses lake water cooling to ensure pleasant temperatures in the summer and, via heat recovery in the winter, should contribute to a dramatic reduction in energy consumption.

Eawag

Renovation of the laboratory building at the Kastanienbaum site was completed in 2012.

Expansion of Dübendorf testing facility

Planning for the expansion of the 30-year-old testing facility at the Dübendorf site began in 2012. The new aquatic testing centre will have greater capacity for experimental installations in the areas of ecology and ecotoxicology, and also for field tests. Building work begins in 2013.

Eco-management

New photovoltaic system

Eawag is committed to the use of renewable sources of energy. At the end of 2012, it increased its solar power generation capacity from 0.25 to around 0.5 terajoules per year by installing a new photovoltaic system on the roof of the renovated office building at Dübendorf. No solar power is fed into the grid, as it is all used internally. Storage is not required since electricity is also needed for laboratory facilities outside working hours. The system's output is continuously displayed on monitors. The rest of Eawag's electricity requirements (around 10 terajoules a year in total) are supplied almost entirely by certified green power ("naturemade star"). The criteria specified for the hydropower element of the Swiss ecolabel are based on Eawag research.

Restoration on our doorstep

Eawag has initiated a restoration project on the Chriesbach in Dübendorf. In autumn 2012, work began on the lower stretch of the stream. In addition to habitat enhancement measures and improved public accessibility, an open-air laboratory is to be established near Eawag's headquarters, allowing the Chriesbach to be used for teaching and research. The project is being managed by the Canton Zurich Office for Waste, Water, Energy and Air (AWEL), with Eawag being responsible for scientific support and also conducting a monitoring programme. Funding is being provided by the federal and cantonal government, the "naturmade star" fund of the Zurich Electric Utility, Dübendorf and Eawag.

Support for cycling

Another key sustainability issue is mobility. Here, public transport connections and promotion of bike use are top priorities. Charges levied for air travel were used to finance the complete renovation of bicycle storage facilities at the Kastanienbaum site. Modern shelters were installed, providing protection against the weather, and decals were applied to the roofs to prevent bird strikes.

www.eawag.ch/about/nachhaltig

Andri Bryner

Work has begun on restoring the degraded Chriesbach stream.

Equal opportunities

Coaching for postdocs

In autumn 2012, seven Eawag postdocs (most of them female) took the opportunity to discuss questions relating to career development and everyday work with the aid of a professional coach. This half-day event was appreciated by the participants, as it helped them to clarify their ideas about the next steps in their careers. It was run by Monika Clausen, a trainer and facilitator working in the area of organizational and team development.

Peter Penicka

A coach facilitated postdocs' discussion of work and career-related issues.

The feedback on the creative and dynamic programme was positive. In particular, participants welcomed the opportunity to get to know each other and to explore research-related themes across institutional boundaries. Also valuable were discussions of the problems arising in daily work and the strategies adopted to deal with them.

Women's lunch with Empa

In September, almost 40 staff met to revive the tradition of an Empa/Eawag women's lunch – after a gap of over nine years. Clearly, there is still a demand for a women's network allowing experiences to be shared and new contacts to be

made. The event generated a lot of positive feedback and will now be held on a regular basis again.

Institution & personnel

Basel University professorship

In September, Hong Yang was appointed Associate Professor of Sustainable Water Use at the University of Basel. Hong Yang, who has worked at Eawag in Dübendorf since 1999, is head of the Water, Environment and Food Security research group. Her research focuses on the impacts of growing water scarcity and food trade on global food security. Hong Yang is well known for her studies of "virtual water", a concept to which she has given wide currency. Since 2006, she has been teaching at the University of Basel, offering courses on the globalization of water resources.

Martina Bauchrowitz

Hong Yang: New Associate Professor of Sustainable Water Use at University of Basel.

Max Maurer appointed ETH Professor

In September, Max Maurer – head of the Urban Water Management department – was appointed Full Professor of Urban Water Systems at the ETH Zurich. The appointment of this renowned scientist to the Department of Civil, Environmental and Geomatic Engineering further strengthens Eawag's close cooperation with the ETH in research and teaching. At present, Maurer is particularly interested in the engineering potential of innovative approaches to urban water management and innovative management and planning procedures for water infrastructure.

Carsten Schubert new head of Surface Waters

In September 2012, Carsten Schubert took over from Alfred Wüest as head of the Surface Waters department. Schubert joined Eawag 10 years ago, having previously worked at the Max Planck Institute for Marine Microbiology in Bremen. His research group studies biogeochemical processes such as the microbial degradation of organic compounds in lake water and sediments.

Peter Penicka

Carsten Schubert: the new head of the Surface Waters department.

Retirement of Thomas Egli

Thomas Egli retired at the end of August. A microbiologist, he joined the wastewater department of Eawag in the 1980s. More recently, he played a leading role in the development of a method of drinking water analysis based on flow cytometry (a technique originally used in medicine). His career was crowned by the inclusion of this method in the Swiss Food Compendium in 2012 (see also page 45).

Tom Kawara

Thomas Egli: formerly ETH Titular Professor and head of Environmental Microbiology.

New research chair in limnology

A chair for the study of lake ecosystems has been established by the EPFL, Eawag and Ferring Pharmaceuticals. In December, the Margaretha Kamprad Chair in Limnology and Environmental Science was inaugurated at the EPFL in the presence of Ferring Chairman Frederik Paulsen and Ikea founder Ingvar Kamprad. The chair is held by Alfred Wüest of Eawag, an internationally renowned expert on aquatic physics.

New member of Eawag Directorate

In May, Hansruedi Siegrist was appointed as a member of the Directorate. Siegrist has held various positions at Eawag since 1986, most recently serving as head of the Process Engineering department (up to the end of 2011). He has also been a lecturer at the EPF Lausanne and the ETH Zurich since 1989, and an Adjunct Professor at the ETH Zurich since 2002.

New member of Advisory Board

In 2012, Anton Kilchmann, Director of the Swiss Gas and Water Industry Association (SVGW), joined the Advisory Board of Eawag. The SVGW is the Swiss gas and water sector's professional body, promoting high-quality, sustainable supplies of natural gas and drinking water. It has represented the interests of gas and water suppliers for 140 years. Eawag has a long history of close collaboration with the SVGW in the areas of drinking water and wastewater.

www.eawag.ch/about/organisation

New department of Environmental Social Sciences

In September, a new research department – Environmental Social Sciences (ESS) – was established at Eawag. It is to focus on three fundamental topics: individual behaviour and decision-making with regard to environmental and health problems; the role of institutions, networks and governance structures in regulating and addressing environmental

problems; and sustainability-oriented socio-technical transformation processes in industry. ESS research should thus contribute to improved understanding, assessment and management of water-related problems. Its activities are divided into five competence clusters – Environmental Innovation, Decision Analysis, Environmental and Health Psychology, Environmental Economics and Policy Analysis.

www.eawag.ch/forschung/ess

ETH domain

Fostering young researchers

At a career planning event held jointly by Eawag and Empa, 44 postdocs from the two institutions had an opportunity to meet and compare notes. Information was provided on courses and coaching/mentoring in the ETH domain, and participants also discussed individual success factors and objectives for career development in academia or industry.

New Empa/Eawag guest apartments

In October, new accommodation came on stream in Dübendorf for guests of Eawag and Empa. Apartments and single rooms for short- or medium-term occupation are now available for a total of 116 guests of the two institutions. The apartments are in the Neugut residential complex (Wincasa AG) close to the Eawag/Empa campus. The new development comprises 192 apartments, which are mostly occupied by private tenants. Eawag and Empa are jointly renting 40 apartments, an office, basement and storage rooms, as well as a limited number of parking spaces, which are sublet and managed by the Empa/Eawag accommodation service. The two institutions helped to ensure that the entire development would conform to the Minergie standard. It is conveniently situated for public transport (and also for private vehicle users) and lies close to the Swiss International School Zurich.

Peter Penicka

Rik Eggen (Eawag) and Roland Knechtle (Empa) are pleased with the new guest apartments.

Joint appearance at cleantech event

In March, for the first time, all six institutions of the ETH Domain were represented at a single exhibition stand. They teamed up to present new technologies and approaches at the Cleantec City fair in Bern. Eawag researchers demonstrated the principle of nutrient recycling with the aid of a urine reactor. The stand generated a lot of interest among visitors and also attracted the attention of the media.

Bern Expo

Kai Udert explains nutrient recovery to parliamentarians at the Cleantec City event.

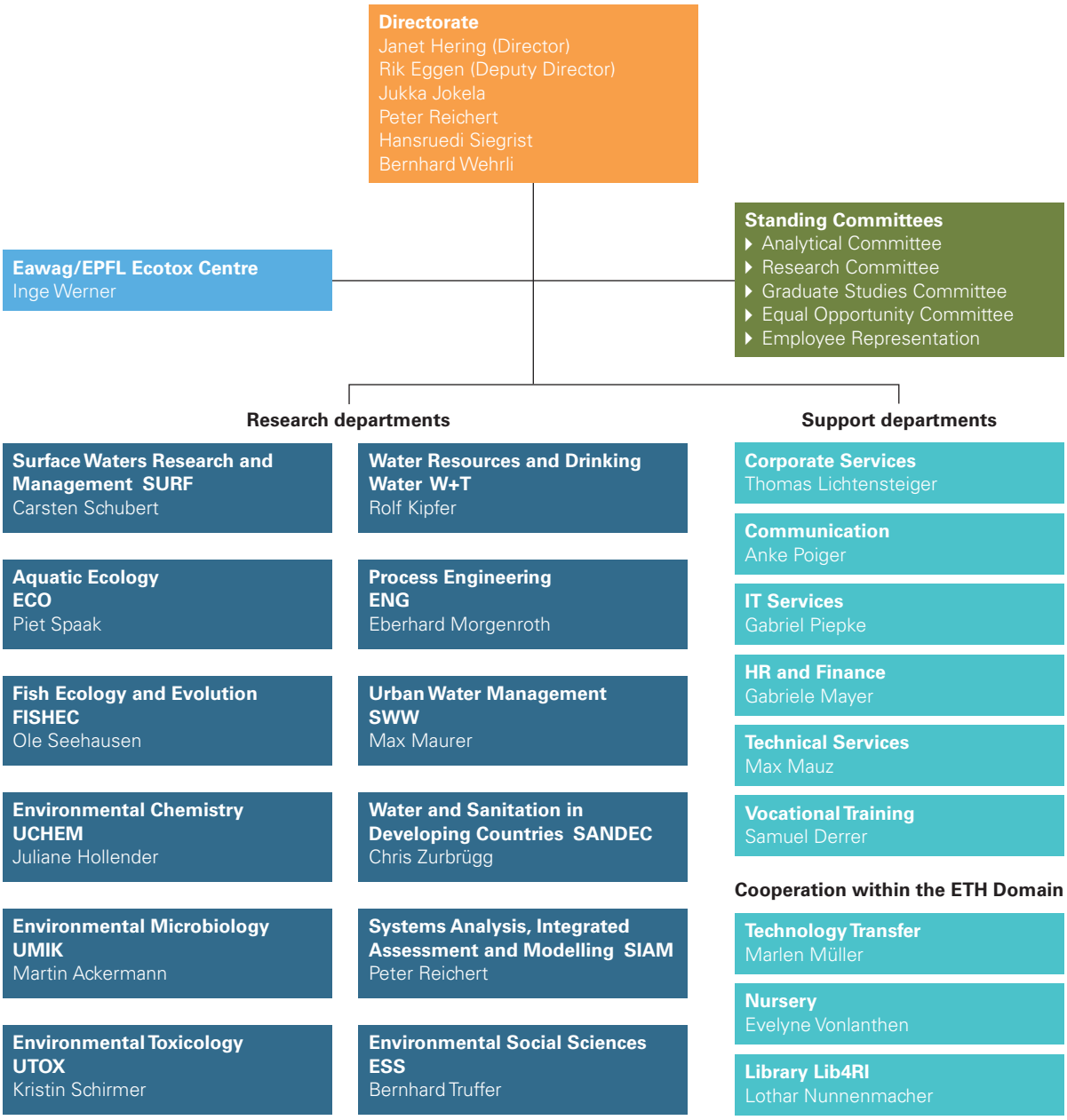
Collaboration on IT projects

In spring 2012, the directorates of Empa and Eawag jointly decided to replace the ageing telephone system with a new communication solution. The two institutions plan to introduce internet-based telephony. The results of a pilot phase at Empa and Eawag were positive and, from 2013, the system is to be rolled out to all Empa and Eawag sites. The two IT departments are collaborating closely on this project. The main benefits of the new system arise from integration with the existing Office environment. Telephony is location-independent, and staff will be able to use numerous additional functions such as video-conferencing and messaging services.

Two-way back-ups

Empa and Eawag have launched a shared virtual server and storage platform, permitting synchronous mirroring of data between the two institutions' data centres at Dübendorf. As well as higher capacity and performance, this system provides greater flexibility, data security and availability. Even in the event of total failure of one of the two data centres, the latest data is available at the other centre and the most important virtual servers can be restarted there. The high degree of virtualization reduces the need for server hardware and thus saves energy. In addition, maintenance is simplified thanks to the merging and standardization of systems.

Organisation



Advisory Board

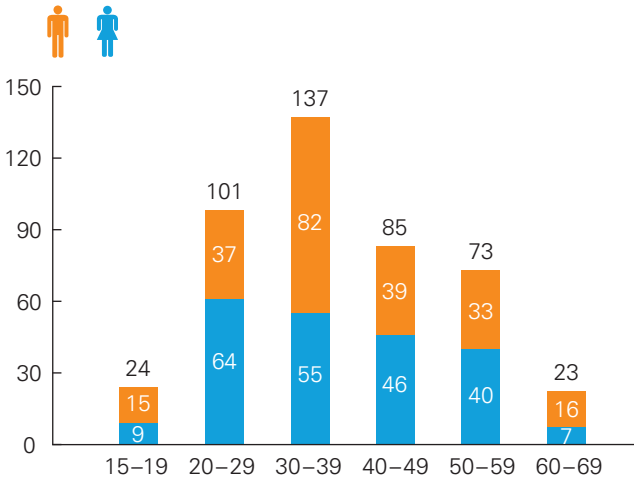
Ursula Brunner (Chair), ettlersuter law firm, Zurich
Claus Conzelmann, Vice President for Safety, Health and Environmental Sustainability, Nestlé Group
Günter Fritz, Head of Environment, Health and Safety, BASF Schweiz AG
Urs Gantner, Head of Research and Extension Unit, Federal Office for Agriculture, Bern
Heinz Habegger, Head of Water and Waste Management Office (AWA), Canton Bern
Peter Hunziker, Director, Hunziker Betatech AG, Winterthur
Anton Kilchmann, Director, Swiss Gas and Water Industry Association, Zurich
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, Consultant, Von Sury Consulting, Solothurn
Thomas Weibel, National Councillor, Green Liberal Party, Canton Zurich

People

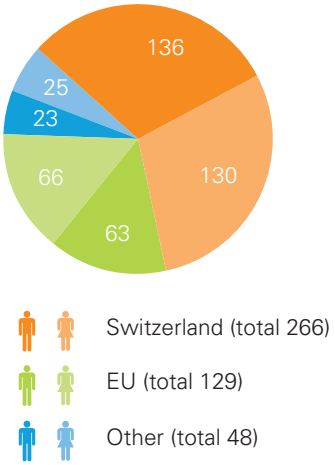
	No. of people	No. of women	No. of non-Swiss	Full-time equivalents
Professors[1]	26	7	11	26.0
Scientific staff	160	66	82	145.7
PhD students	96	45	65	92.5
Technical staff	82	40	12	69.8
Administrative staff	67	56	10	51.9
Apprentices	24	9	2	24.0
Total	**455**	**223**	**182**	**409.9**
Affiliated staff (Eawag-Empa nursery)	14	13	0	13.6
Trainees	47	22	29	47.0

[1] including 12 not directly employed by Eawag

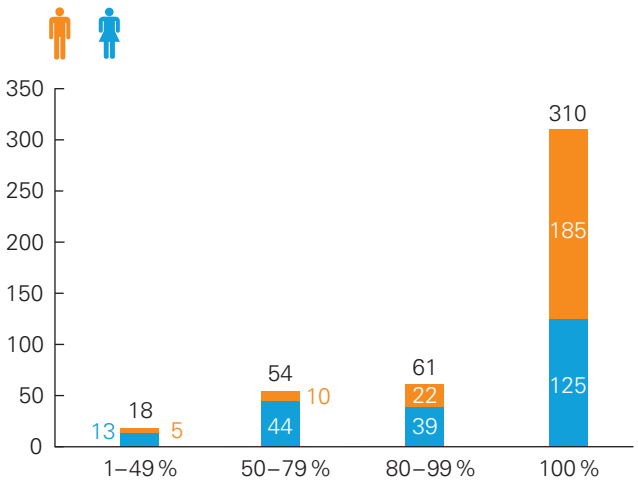
Age structure



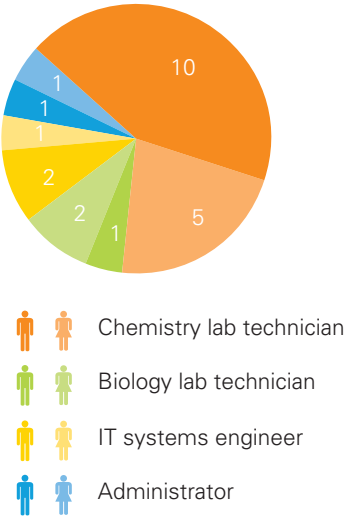
Origin



Percentage employment

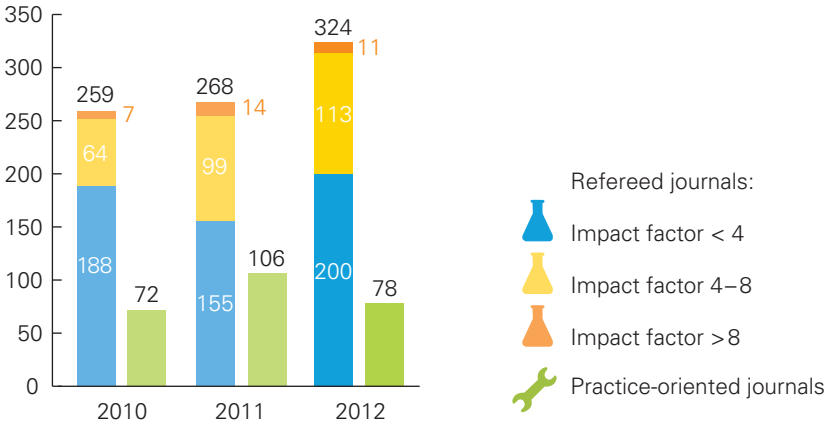


Apprentices

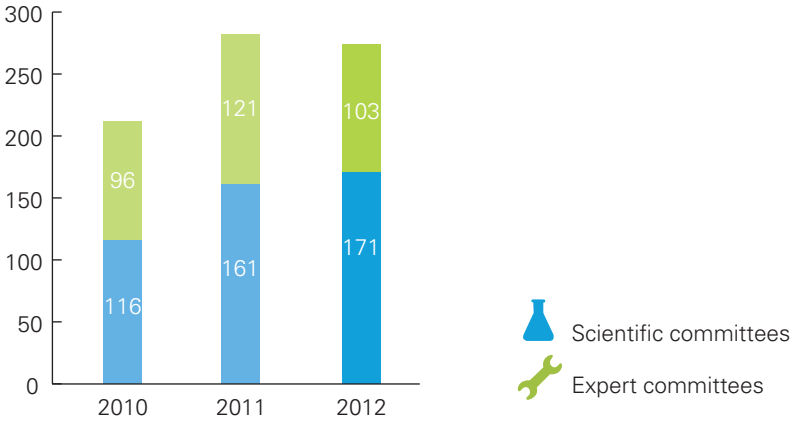


Activities

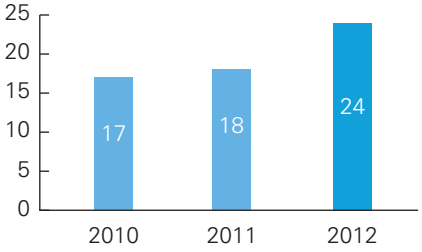
Publications



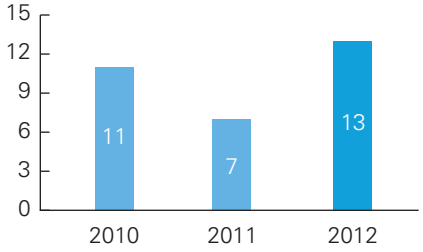
Committee memberships



Organised conferences



Awards



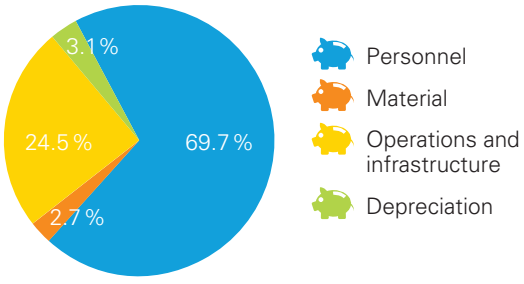
Finances

Financial statement	2010	2011	2012
Personnel	41,923,339	44,425,613	44,710,054
Materials	2,990,640	5,347,807	1,741,239
Operating and infrastructural expenses	14,920,290	14,856,606	15,686,077
Depreciation	2,109,090	2,110,493	2,004,570
Provisions	–210,058	–140,318	1,093,985
Expenditure	**61,733,302**	**66,600,200**	**65,235,925**
Federal government funding	54,239,254	55,251,566	54,933,096
Third-party resources (incl. changes in inventories)	14,246,016	14,274,585	16,220,891
Miscellaneous revenue	1,717,018	2,127,238	721,656
Income	**70,202,289**	**71,653,389**	**71,875,643**
Result	**8,468,987**	**5,053,189**	**6,639,718**

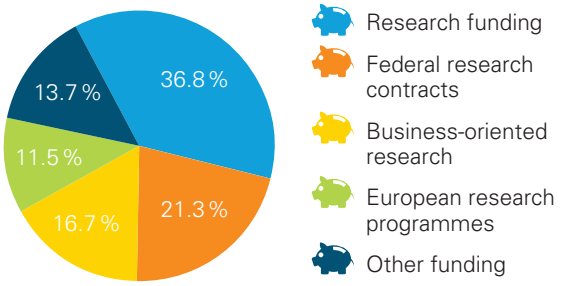
Investments	6,181,458	5,030,479	4,710,682
Real estate	3,121,000	2,723,000	2,278,386
Movables	3,006,300	1,820,471	2,386,126
IT	54,158	487,008	46,170

all figures in CHF

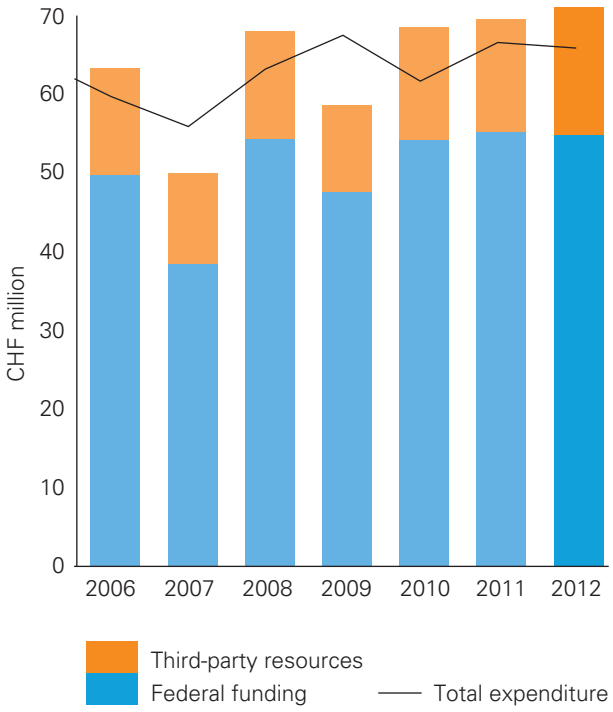
Breakdown of expenditure 2012



Third-party resources 2012



Development 2006 – 2012



The Annual Report 2012 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.

The Annual Report is also available in German.

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