Aquatic research and water protection: ongoing challenges

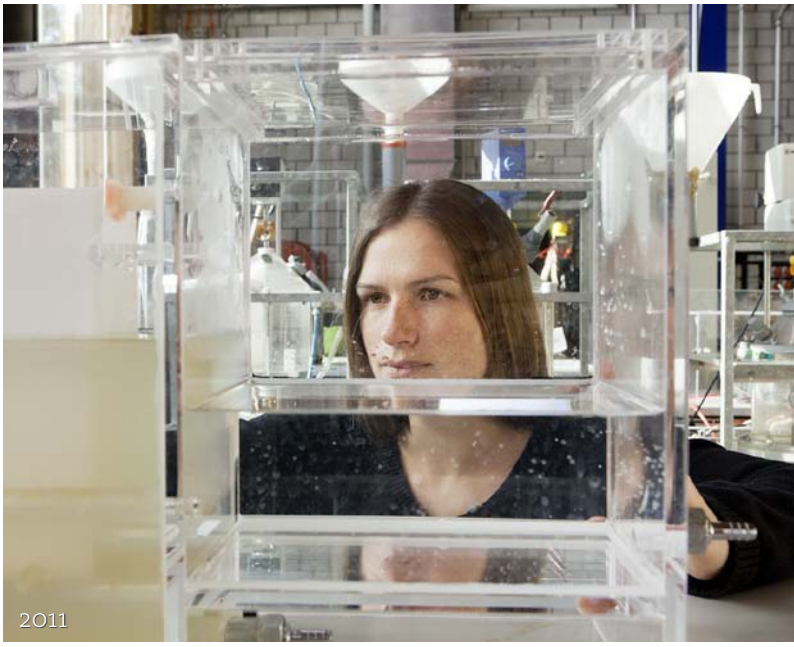
The history of Eawag reflects an increasingly integrated approach to water protection: It has come to involve not just the improvement of treatment methods for wastewater and drinking water, but early detection of problems and prevention; not just the management of emergencies, but efforts to understand fundamental processes; not just a national focus, but an international perspective. Even after 75 years of research, teaching and consulting, the protection of water resources remains an ongoing challenge.

In the early 20th century, discharges of untreated or only mechanically treated wastewater from growing urban areas, as well as industrial effluents, meant that the condition of Swiss rivers and lakes was increasingly dire. Fishermen in particular began to protest about this state of affairs, calling on the federal authorities to take action against water pollution.

Lack of wastewater experts in Switzerland. Before the Second World War, hardly any professionals in Switzerland specialized in the planning and construction of wastewater treatment plants. The few experts available came from Germany. On 1 January 1936, the Federal Council therefore established the ETH Advisory Centre for Wastewater Treatment and Drinking Water Supply. The Hygiene Institute (led by Willy von Gonzenbach; see Box on page 5) and the Hydrological Engineering Test Facility (established in 1930 and headed by Eugen Meyer-Peter) formed the basis of the new institution. It initially employed one chemist, one engineer and one biologist.

As well as providing advisory services for cantonal and communal authorities, it focused on research and education in the field of wastewater systems and on monitoring water quality so as to gauge the effectiveness of the new systems. As early as 1938, the Advisory Centre established a test facility on the site of the Zurich municipal wastewater treatment plant at Werdhölzli, where treatment processes could be developed and studies carried out on the self-cleansing capacity of surface waters. The facility was

Eawag laboratory and experimental set-ups: measurement of radioactivity in river water samples (left) and testing a plastic membrane used to remove viruses and bacteria from drinking water without the need for chemicals or a pump (right).



Stefan Kubli

relocated to the nearby Tüffenwies site in 1950, and to the Dübendorf site in 2001. Eawag's early studies were concerned not only with biological wastewater treatment, but also with methods of drinking water disinfection which could offer an alternative to chlorination – e.g. involving ozone, silver or UV radiation.

The beginnings of an integrated approach. In 1946, the Advisory Centre – now employing 24 people – became a fully-fledged institute, known as Eawag (i.e. the Federal Institute of Water Supply, Wastewater Treatment and Water Pollution Control). Alongside the Biology and Chemistry departments, Groundwater Geology and Civil Engineering departments were established. The first Director, serving until 1952, was Ulrich A. Corti, a chemist and active ornithologist. Although Eawag focused on practical wastewater treatment requirements at the cantonal and communal level, Corti was already developing long-term, ecological concepts and wrote papers on the function of surface waters as habitats. However, the value of this work was only recognized much later.

Venturing into politics. In 1952, Otto Jaag, who lectured in Hydrobiology and Limnology as well as Cryptogamic Botany at the ETH Zurich, was appointed as Director of Eawag. Jaag had already displayed a deep personal commitment to the introduction of a constitutional article on water pollution control. This article was approved in a popular vote in 1953, with no less than 81.4 per cent in favour. The high level of public support for water protection was largely due to Otto Jaag's promotion of the cause.

His advocacy was not misplaced, as growing consumption of energy and resources after the Second World War had left its mark on natural waters. Environmental protection agencies did not yet exist. In 1960, barely 10 per cent of the population had a connection to a centralized wastewater treatment plant. Riverbanks were used as dumps, and swimming in lakes was often prohibited. Jaag saw that the Water Protection Act lacked teeth and pressed for a revision – in particular, for a more active policy on subsidies. A revision (with a new article on subsidies) was passed in 1962, and a new Act in 1971 paved the way for expansion of the sewer network and treatment infrastructure. Today, around 97 per cent of all wastewater in Switzerland is treated at modern plants.

WWTPs alone insufficient. A similar "enforcement vacuum" arose after new water protection provisions – based not least on work carried out by Eawag – had been adopted in an Ordinance (1975) and an Act (1991), calling for careful use of water resources and ecologically adequate residual flows. While it was thus recognized at the federal level that wastewater treatment plants and reasonably clean water are not in themselves sufficient for integrated water protection, quantitative protection measures (including river restoration) and efforts to increase residual flows proceeded at a slow pace.

With the latest revision of the Water Protection Act, which came into force at the beginning of 2011, this should now change. More funding is to be made available, and the cantons are legally required to allow rivers more space so as to permit near-natural development, as far as possible, and to assure flood protection. Here, too, Eawag has supplied scientific foundations, arguments and tools, with research projects on integrated watershed management (e.g. Rhône/Thur, 2005), river assessment methods (Modular Stepwise Procedure, from 1981), or the mitigation of diffuse pollution.

Contract research and consulting. Up until the 1960s, much of Eawag's work was carried out for third parties, especially cantons and communes. In 1970, 37 per cent of the total expenditures of around CHF 3.4 million was covered by income from contract work. In his annual reports, Jaag regularly complained that staff were overstretched by commitments of this kind: "As regards the extent of the institute's activities, it may be noted that this year all

A mirror of water protection in Switzerland

The creation of Eawag has a complex prehistory, reflecting the development of water protection in Switzerland. The end of the 19th century saw a rapid expansion of knowledge about the origins and spread of diseases. In 1894, the Institute of Hygiene and Bacteriology was established at the ETH Zurich by Otto Roth, a student of Robert Koch (who discovered the tubercle bacillus). At that time, the main concern was "protection of human labour against environmental hazards, accidents and acute or chronic poisoning at the workplace". But Willy von Gonzenbach, who took over from Roth in 1920, recognized the risks posed to the environment and human health by the pollution of lakes and rivers. In 1887, moreover, a Limnology Committee had been set up by the Swiss Scientific Society to study lakes, including their functioning and flora and fauna.

The occurrence of epidemics in Switzerland was prevented by the tapping of spring and ground water and the introduction of treatment steps involving sand filtration and, from 1910, also chlorine disinfection. But mains water supplies and new sanitary installations led to a sharp increase in water consumption, and the problem of disposal became more acute. Separate collection of faecal waste in buckets was therefore gradually replaced by waterborne sewage systems. While this neatly solved hygiene problems in urban areas, it also exacerbated visible pollution of surface waters, since wastewater was discharged into rivers untreated or, later, at best after mechanical treatment.

employees have again been continuously stretched to the limit, and indeed that some of them have struggled to complete their assignments on schedule with the necessary care."

By 2010, "miscellaneous revenues" accounted for only a small percentage of total expenditures of around CHF 60 million. Contract work is now only undertaken if the associated research questions are of interest to Eawag. At the same time, research-project funding of around CHF 15 million was obtained from second-party and third-party sources (e. g. EU research programmes or foundations).

Commitment to developing countries. Under Jaag, in addition to the time-consuming contract work, basic research was of course also carried out – for example, on lake eutrophication, chemical and biological processes in groundwater, the self-cleansing capacity of surface waters, or the dimensioning of biological treatment plants. Scientific activities were further strengthened in 1960, when Eawag took over the Hydrobiological Laboratory at Kastanienbaum from the Lucerne Scientific Society (see Box on page 7). In 1968, the WHO International Reference Centre for Waste Disposal was also established at Eawag; in 1992, this became the Department of Water and Sanitation in Developing Countries (Sandec).

In 1970, after various abortive planning efforts and a great deal of toing and froing – Eawag staff worked at up to seven different sites on the Zurich campus, as well as at the Kastanienbaum centre and the Tüffenwies test facility – the new office and laboratory building at Dübendorf was inaugurated. The institute now comprised 8 departments, with 110 employees. Biology, Chemistry, Geology and Civil Engineering had been supplemented by the following departments: Limnology (1952), Solid Wastes (1955), Radiology (1956) and Fishery Sciences (1969). Also in 1970, Eawag became an affiliated institute of the ETH Zurich; in 1993, it attained independence (within the ETH Domain) as the Swiss Federal Institute of Aquatic Science and Technology.

Closer ties with the ETH Zurich. Despite Eawag's new status as an affiliated institute, Werner Stumm – a chemist, who became Director in 1970 – sought to establish closer ties with the ETH and other higher education institutions. In 1979, he launched a postgraduate course in Urban Water Management and Water Pollution Control, and in 1987 he helped to develop an Environmental Sciences course. Stumm reinvigorated the institute by actively recruiting a new generation of scientists.

This group of young scientists included the physicist Dieter Imboden, who is now President of the National Research Council. Imboden – like Ueli Bundi (see interview on page 10) – identifies as one of the key success factors for Eawag in the post-1970 period the fact that it concentrated on multidisciplinary understanding of systems and processes, rather than allowing research

Experimental systems: at the Zurich Tüffenwies site (left), with artificial channels for biological self-cleansing of rivers, and at the Dübendorf testing facility (right), for sludge treatment designed to improve nitrogen removal and reduce energy at WWTPs.

Stefan Kubli

Monika Estermann

The lakeside laboratory at Kastanienbaum before it was taken over by Eawag (left) and a microcosm system used for long-term experiments in evolutionary biology (right).

Kastanienbaum: from lakeside laboratory to Centre for Ecology, Evolution and Biogeochemistry

In 1916, with support from private benefactors, the Lucerne Scientific Society established the Hydrobiological Laboratory at Kastanienbaum on Lake Lucerne. The key figures in this enterprise were the physician Fritz Schwyzer and the high school teacher Hans Bachmann, who chaired the Swiss Scientific Society's Hydrobiology Committee until 1940. The small laboratory was used by specialists from Switzerland and abroad for studies and courses on the chemistry, plankton, aquatic plants and fish of Lake Lucerne and other waterbodies.

In 1920, on the basis of work carried out at Kastanienbaum, the *Schweizerische Zeitschrift für Hydrologie* was launched, which in 1989 was renamed *Aquatic Sciences* – a renowned journal still published today with significant input from Eawag. Since 1960, the Limnology Research Centre (FZL) has been run by Eawag. The facilities available were expanded by the purchase of the "Seeheim" property in 1968 and the construction of a new building in 1976. Today, over 100 people work at Kastanienbaum, and the FZL has become the Centre for Ecology, Evolution and Biogeochemistry (CEEB).

Research at "KB" (as the site is known internally) has always focused on chemical, physical and biological processes in Lake Lucerne and other Swiss lakes. There have been major studies on the importance of the nutrients phosphorus and nitrogen and transformation processes for lake eutrophication. Investigations of plankton, sediments and soil organisms documented the progressive degradation of the lake in the 1960s and 1970s – but also its recovery following the introduction of ring sewerage systems and phosphorus elimination at treatment plants. Multidisciplinary projects studied the function of complex environmental systems, e. g. the benefits of artificial mixing for lake remediation, or the impacts of heavy metals.

In fisheries biology, the emphasis has shifted away from lake management for yield maximization towards efforts to preserve species and habitat diversity in all types of natural waters. The focus is no longer on acute fish kills (as in the 1970s), but on the adaptability of species and ecosystems in a changing environment, and the rise and fall of species in evolutionary processes.

questions to be dictated by specific problems. This approach was supported by mathematical models, which – thanks to increasingly powerful IT systems – permit ever-more precise analyses and predictions, e. g. of internal mixing processes in lakes.

Imboden also cites Eawag's outstanding analytical capacity, which frequently made it possible to detect and explain problems caused by new substances. Another hallmark of Stumm's directorship was growing internationalization, a development which opened up career opportunities for Eawag staff all over the world. This international network, which has been continuously expanded, also facilitated research collaborations in areas where Eawag has less in-house expertise – e. g. efficient use of water in agriculture, impacts of climate change, or treatment of industrial effluents.

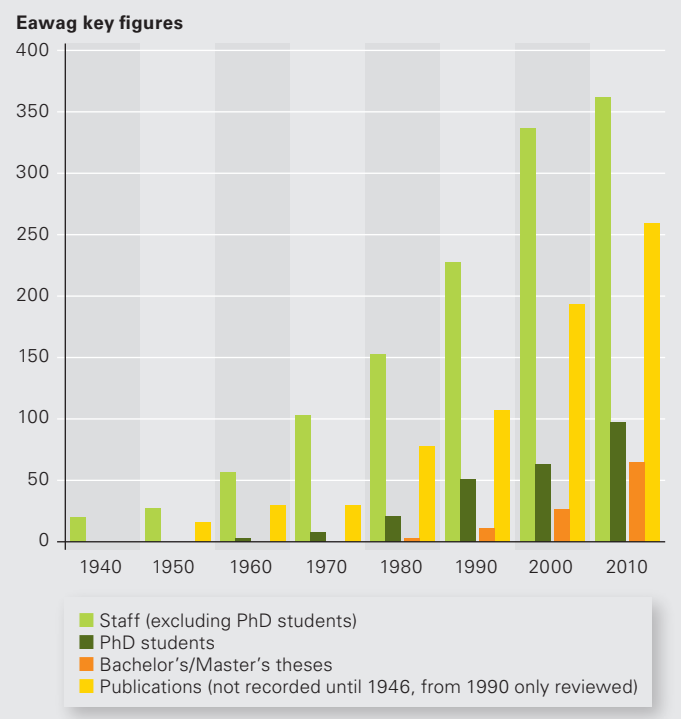
As well as solid wastes, Eawag began to take an interest in other sources of pollution which cannot be readily monitored,

Professors based at Eawag (all ETH Zurich, unless otherwise indicated, for adjunct professors see page 13)

	Served at Eawag	Chair
Willy von Gonzenbach	1936–1945	Hygiene and Bacteriology
Eugen Meyer-Peter	1936–1945	Hydraulic Engineering
Otto Jaag	1952–1970	Hydrobiology, Wastewater Treatment and Water Pollution Control
Arnold Hörler	1954–1968	Sewerage, Wastewater Treatment and Sanitary Engineering
Karl Wuhrmann	1946–1980	Microbiology
Rudolf Braun	1955–1983	Waste Management
Kurt Grob	1974–1985	High-Resolution Gas Chromatography (Kantonsschule Zurich)
Werner Stumm	1952–1992	Water Pollution Control
Heinz Ambühl	1952–1994	Hydrobiology (Associate Professor)
Jürg Hoigné	1974–1995	Aquatic Chemistry
Richard Heierli	1968–1970	Sanitary Engineering (Associate Professor)
Geoffrey Hamer	1980–1992	Technical Biology
Peter Baccini	1974–2004	Resource and Waste Management
James Ward	1995–2002	Aquatic Ecology
Dieter Imboden	1988–1999	Environmental Physics
René Schwarzenbach	1977–2004	Environmental Chemistry
Alexander Zehnder	1992–2004	Environmental Biotechnology
Willi Gujer	1992–2011	Urban Water Management
Bernhard Wehrli	Since 1988	Aquatic Chemistry
Urs von Gunten	Since 1989	Drinking Water Treatment (EPFL) and adjunct professor (ETHZ)
Jukka Jokela	Since 2005	Aquatic Ecology
Ole Seehausen	Since 2005	Aquatic Ecology and Evolution (Berne University)
Martin Ackermann	Since 2006	Molecular Microbial Ecology (Associate Professor)
Janet Hering	Since 2007	Environmental Biogeochemistry (ETH Zurich), Environmental Chemistry (EPFL)
Eberhard Morgenroth	Since 2009	Urban Water Management

such as road and roof runoff, combined sewer overflow emissions or agricultural pesticides.

More engagement with society and industry. In 1992, the biochemist Alexander Zehnder became Director of Eawag. Recognizing that pressures on the environment are largely determined by social processes, he set up a Human Ecology group to supplement the institute's scientific and engineering activities. The ability to understand or even control social processes is essential for the transition to more environmentally sound forms of life and economic activity. Accordingly, a department for Innovation Research in Utility Sectors (Cirus) was established in 2005. Under Zehnder, sustainability and a transdisciplinary approach



A total of 458 people (including 26 apprentices) currently occupy 413 full-time equivalent positions; the proportion of women is 48.4 per cent.

were promoted, and a number of major projects were pursued in cooperation with partners from government, the private sector and academia. These included Greenhydro (environmentally sound hydropower, completed in 2000), Fischnetz (declining fish yields in Switzerland, 2003), Rhône/Thur (sustainable river management, 2005) and Novaquatis (urine source separation, 2006).

When Zehnder was appointed President of the ETH Board in the summer of 2004, his deputy Ueli Bundi (a rural engineer) became Director ad interim. Bundi emphasized in particular Eawag's role in bridging the gap between academic research and practice. In 2004, in partnership with the Swiss Fishery Association and the Federal Office for the Environment, Eawag set up the Swiss Fishery Advice Centre (FIBER). 2007 saw the launch of the "Water Agenda 21" initiative to promote a more integrated approach to water management issues in Switzerland. Bundi also supported preparatory work for the new Centre for Applied Ecotoxicology. Together with Roland Schertenleib and the team of architects from Bob Gysin & Partner, Bundi was one of the fathers of the new Eawag/Empa building Forum Chriesbach, which won several awards for innovative design and sustainability.

No contradiction between cutting-edge research and applications. Since being appointed Director in 2007, Janet Hering has intensified Eawag's cooperation with the EPF Lausanne and the ETH Zurich. As an ETH Board member representing the four research institutes (until 2010), she saw how important it was for Eawag to excel in research (as well as maintaining close contacts with water professionals) if it is not to be eclipsed by the much

Collecting plankton samples on Lake Lucerne (left) and surveying structural diversity on the Sense as part of the river assessment procedure developed by Eawag (right).

larger institutes of technology. Evolutionary aquatic ecology, analysis and ecotoxicology of micropollutants and transformation products, and the removal of these substances from wastewater are all gaps which Eawag is ideally positioned to fill.

The example of micropollutants also demonstrates that cutting-edge research and real-life application concepts can, and indeed must, be pursued concurrently. Eawag's work thus laid the foundations for the preparation in 2010 of an amendment to the Water Protection Ordinance, which provides for the removal of micropollutants at selected wastewater treatment plants.

Cleantech: a fitting aspiration. In the context of Cleantech, Eawag's commitment to the safety of water resources (in the interests of human health) and the protection of natural waters (in the interests of ecosystem health) is becoming increasingly important. For example, current wastewater treatment projects are no longer exclusively concerned with eliminating, as far as possible, all pollutants and nutrients; instead, the goal is to do so in such a way as to minimize energy consumption and emissions, while recovering valuable resources (see the article on page 30).

In addition, Eawag projects have always sought to ensure that the solution of one problem does not generate new ones. For example, when a ban on phosphates in detergents was being considered in the 1980s, Eawag researchers evaluated the phosphate substitutes EDTA and NTA. Other cases in point are the efforts to avoid potentially hazardous chloramines in drinking water disinfection or, more recently, to replace animal experiments in ecotoxicology by using passive samplers or computer models.

The findings of pioneering research of this kind can always be fed into consulting activities, since the private sector often lacks the necessary expertise, equipment, time and financial resources. In recent years, these activities have been further strengthened with the development and expansion of the Centre for Applied Ecotoxicology (together with the EPFL) and the establishment of the Competence Centre for Drinking Water (CCDW). ○ ○ ○

Further information:

www.eawag.ch/about/75jahre/index_EN

Bryner A., Nast M. (2011): Eawag: past, present and future 1936–2011 (trilingual brochure), Eawag.

Archive of annual reports from 1946 at: www.lib4ri.ch/institutional-bibliography/eawag/eawag-annual-reports.html

Perret P. (2001): Beitrag zur Geschichte der Gewässerforschung in der Schweiz, http://chy.scnatweb.ch/downloads/GeschichteGewasserforschungCH.pdf

Mitteilungen der Eawag Nr. 22, 1986 (50th anniversary publication).

Boller M. (2005): Eawag – Forschung im Dienste des Wassers (anniversary 1946–2006 publication), Gas, Wasser, Abwasser (GWA) *3,* 191–202.

Müller R. (1997): Ein Blick zurück – Das Eawag-Forschungszentrum für Limnologie in Kastanienbaum, Eawag.