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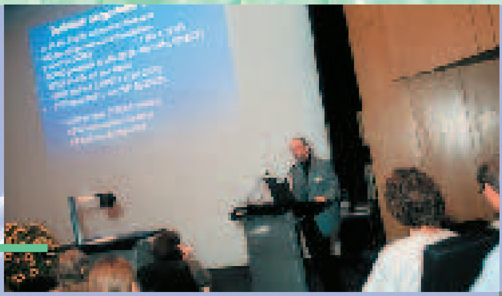
Risk Factors in Water



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Risk Factors in Water

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Editorial

Hans-Peter Kohler is head of the group "Environmental Biochemistry" in the department "Environmental Microbiology and Molecular Ecotoxicology".

In 1962, the American biologist and author Rachel Carson condemned the pollution of surface waters and ground water by pesticides as an unacceptable risk. Her book "Silent Spring" gave major impetus, leading to an increased public concern for clean water and air and unpolluted soil. This pressure led, among other things, to the formation of the Environmental Protection Agency (EPA) in the USA in 1970. In Switzerland, an environmental protection article was added to the federal constitution in 1971 and carried by a clear majority of the votes. The foundation for comprehensive environmental legislation was lain. The quality of streams and lakes has improved significantly since then, in part due to technical advancements, more stringent environmental laws, and changes in the behavior of the public. Many of the prominent environmental problems of the "early days" may be considered solved. Despite this fact, the topic "Risk Factors in Water" is still relevant, even 40 years later.

Problems surfacing today are far more difficult to understand and deal with the increase of female characteristics in male aquatic organisms, the development of resistance to antibiotics, and the occurrence of chronic poisoning by drinking water containing arsenic. At the EAWAG Information Day 2001 dealing with "Risk Factors in Water", it was evident that today's water pollution problems are complex and multi-dimensional. Everyday activities of our civilization cause a large number of the chemicals to be released into our waters. Pharmaceuticals and hormones are increasingly of concern. They are typically present in very low concentrations, but can still have undesirable consequences. Our wastewater treatment plants are not designed to eliminate such "micro-pollutants".

Risk analysis of chemicals are based, in part, on the assessment of negative effects on aquatic organisms. It is impractical, however, to test for all possible effects on all possible organisms. We must, therefore, set reasonable priorities. Furthermore, how do we act if a chemical has a negative effect on only one of a hundred organisms tested, for example, the water snail? How do we weigh and assess this result? In a strictly statistical analysis, the snail would "disappear" in the error bar since 99% of the organisms were unaffected. Where do we draw the line? How important is the snail? This example illustrates that in the area of risk analysis we have a great need for scientific and political tools.

The Swiss National Science Foundation has recognized the critical nature of this situation and has initiated two national research programs[1]: the NRP 49, "Antibiotic Resistance", and NRP 50, "Endocrine disrupters: Relevance to Humans, Animals and Ecosystems". Both programs focus on the correlation between micro-pollutants in the environment and negative environmental impacts, as well as on ways to mitigate the effects and the risks. EAWAG has several groups involved in multiple projects within these national research programs.

H.P. Kohler

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[1] For more information, see:
www.snf.ch/en/rep/nat/nat_nrp_49.asp
www.snf.ch/en/rep/nat/nat_nrp_50.asp

Dealing with Risk Factors

Modern society has become dependent on a wide range of chemicals; however, it was not until the second half of the 20th century that we acknowledged that many of these compounds cause severe environmental and health problems. An early response was to assess the environmental risk associated with selected chemicals; depending on the results, various countries subsequently introduced regulations governing their use. Today, there is a consensus that, at least in principle, all chemicals that are in use must be evaluated. Unfortunately, the number of chemicals to be tested is enormous. Therefore, appropriate prioritization procedures are employed that identify particularly dangerous substances, which may then be subjected to more extensive risk assessment. In recent years, an increasing effort has been made to solve chemical pollution problems on an international level.

In 1775, the English physician Sir Percival Pott documented in his book "Surgical Observations" an increased incidence of skin cancer among London's chimney sweeps. He identified the problem as a professional disease, probably caused by frequent exposure to soot. The responsible substance in soot, benz(a)pyrene, was only identified another 150 years later. Benz(a)pyrene belongs to the so-called polycyclic aromatic hydrocarbons (PAH).

In the early 1970s, the chemists Crutzen, Molina and Rowland warned against the use of chlorofluorocarbons, more commonly known as "freons" and mostly used as propellants and coolants. They predicted that these chemicals might damage the ozone layer in the stratosphere. In 1985, the so-called "ozone hole" over the Antarctic was observed for the first time. Only two years later, a worldwide ban on freons was established by the Montreal Protocol. Since then, a number of other ozone-depleting chemicals have been added to the international agreement. In 1995, Crutzen, Molina and Rowland received the Nobel Prize in chemistry for their pioneering work in environmental risk assessment.

Benz(a)pyrene and freons are examples of chemicals occuring as environmental risk factors that were recognized early on (Tab. 1). The goal of this article is to summarize the policies that currently deal with chemical contaminants. It will be described how the environmental risk of an individual chemical is assessed, how prioritization procedures are used to screen large numbers of chemicals in order to identify substances that warrant immediate ban or use restrictions, and how environmental protection policies tackle the problem of chemical pollutants.

Industrially produced chemicals

- **18 million substances are listed and described in the "Chemical Abstracts".**
- **400 million tons of chemicals were produced worldwide in 2000. For comparison, the total production in 1930 was 1 million tons.**
- **100,000 chemicals were listed with the EU in 1981 (old chemicals).**
- **2,700 chemicals have been reported to the EU since 1981 (new chemicals).**
- **30,000 chemicals are on the market in quantities over 1 ton.**
- **5,000 chemicals are being produced in quantities over 100 tons.**
- **720 chemicals were newly listed under the Swiss Ordinance on Environmental Pollutants between 1988 and 2000.**
- **8,700 different food additives are known.**
- **3,300 substances are being used as drugs or in human medicine.**

Categories of Risk Factors

Our modern civilization produces approximately 100,000 chemicals in various quantities (see box). During manufacturing, use and/or disposal, a portion of these substances are released into the environment. In addition to these artificial risks, there are natural risks, such as arsenic in drinking water or the presence of various pathogenic microorganisms.

Table 1 tries to differentiate the environmental risk factors that are known to date into 15 categories; some factors may be assigned to more than one category. How and where a particular chemical is used determines the path by which it is introduced into the environment. Obviously, the contanminants' chemical and physical properties are important determinants for their behaviour and fate in the environment. Effects of acute releases into the environment, due to catastrophes or accidents, are often the most devastating and also the most obvious. More difficult to recognize are environmental impacts caused by chronic inputs.

Assessment of Environmental Risks and Establishment of Limite Values

In order to assess the environmental risk of a particular substance, we need to know both how it enters the environment and how it behaves after its release. In addition, we need to assess its effects on a range of different organisms. The primary tools are exposure analysis and effect assessment (Fig. 1).

Exposure analysis identifies potential pathways for a chemical to reach the environment, estimates quantities that could be released, and predicts the behavior of the chemical in the environment based on its chemical and physical properties. Important parameters in exposure analysis are PEC

Category	Example: chemical, source
I. Early recognized chemicals	Polycyclic aromatic hydrocarbons (PAH), chlorofluorocarbons (CFC, freons)
II. Acutely released chemicals	Dioxins (Seveso, 1978), radioactivity (Tschernobyl, 1986), agrochemicals (Schweizerhalle/Rhine, 1986), oil tanker accidents (e.g., Torrey Canyon, Amoco Cadiz)
III. Chemicals with detectable chronic effects	Branched alkylbenzenesulfonates, anionic surfactants in detergents (foam formation), phosphates in detergents (eutrophication of surface waters)
IV. Chemicals that are accumulated in biological systems	DDT, polychlorinated biphenyls (PCB), persistent organic pollutants (POP), heavy metals (lead, cadmium, mercury)
V. Chemicals for specific applications	Detergents, pesticides, herbicides, concrete admixtures, anti-fouling agents (organotin compounds)
VI. Substitute chemicals	Linear alkylbenzenesulfonates (LAS), nitrilotriacetate (NTA), Zeolite A, organophosphorus insecticides
VII. Intermediates of biological transformation (metabolites)	Methylmercury, nitrosamines, nonylphenol
VIII. Analytical side results (ghost peaks)	PCB, perchloroethylene, clofibric acid
IX. Product impurities	Polychlorinated dibenzodioxins and dibenzofurans
X. Side products in water technology	Chlorophenols, trihalomethanes, haloacetic acid, nitrosodimethylamine (NDMA), bromate
XI. Late recognized chemicals	Arsenic (see articles by M. Berg, p. 12; and H.-R. Pfeifer and J. Zobrist, p. 15)
XII. Erroneously assessed chemicals	Methyl-tert-butylether (MTBE, see article by T. Schmidt, p. 18)
XIII. Chemicals that are difficult to assess	Hormonally active compounds (bisphenol A, β-estradiol, see article by M. Suter, p. 24), drugs
XIV. Emerging contaminants	Antibiotics (see article by C. McArdell, p. 21), brominated flame retardants, fluorinated sulfonate surfactants
XV. Recurrent risk factors	Sewage sludge (see article by P. Stadelmann, p. 9), pathogens in drinking water (see article by W. Köster, p. 26)

Tab. 1: Classification of environmental risk factors in 15 categories.

values (predicted environmental concentration) and MEC values (measured environmental concentration). MEC values are often difficult or expensive to obtain and are only available for a relatively small number of chemicals.

The purpose of effect assessment is to determine the potential harmful effects of a chemical as a function of its concentration, i.e., to determine the dose-response curve. This information is used to determine a PNEC value (predicted no effect concentration), a threshold value representing the smallest concentration at which an effect can be observed. In the subsequent risk assessment, PEC and MEC are compared to the PNEC. If environmental concentrations are higher than the PNEC, mitigation measures need to be considered.

Policies on Priority Pollutants

In principle, the environmental risk should be determined for each chemical compound that is in use. But because of the enormous number of contaminants, this is impossible. The strategy, therefore, is to identify the important chemicals out of the multitude and to thoroughly examine those that are selected. One such prioritization scheme was developed as part of the OSPAR convention on the protection of marine ecosystems (see article by H.-J. Poremski and S. Wiandt, p. 6).

The American National Academy of Sciences [1] has proposed another prioritization procedure. This method focuses on identifying the most important chemical and biological contaminants in drinking water. In the USA, the Environmental Protection Agency is required by law to publish an updated candidate contaminant list every five years (Fig. 2). In a first step, potential pollutants are classified as belonging to one of four compound categories (Fig. 3). Chemicals that fall into areas I–IV go on a list of provisional candidate contaminants. In a second step, the hazard level for each of these compounds is assessed, leading to the identification of the final list of candidate contaminants. The hazard potential is determined by a mathematical model as well as by "expert judgement".

Concerted Actions on the International Level

In the past, individual countries mostly performed their own risk assessment and issued their own regulations on the use of chemicals. Examples include the Swiss Ordinance on Chemicals Hazardous to the Environment and the list of priority pollutants in drinking water in the USA.

However, since our knowledge of risk factors is far from complete, and sources and effects of chemicals can be separated temporally and spatially, international cooperation is essential. The OECD has been engaged in risk assessment and risk management of chemicals for more than 40 years. Their central task is the development of internationally accepted testing methods. Countries bordering on the North Atlantic joined together in the OSPAR Com-

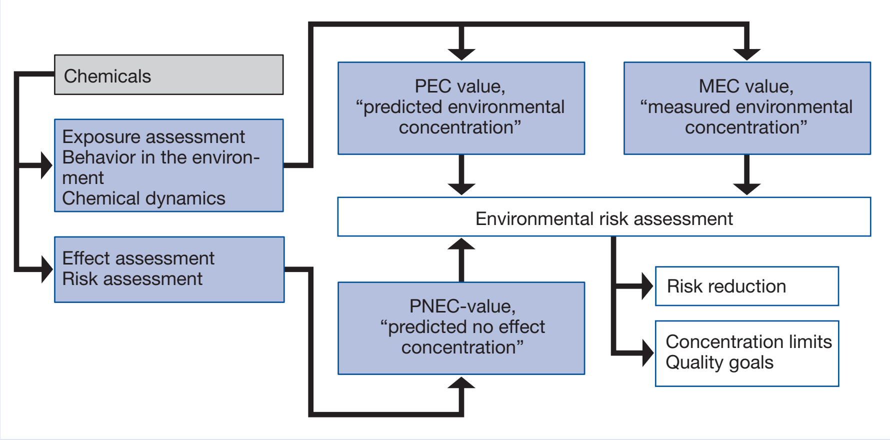

Fig. 1: Environmental risk assessment of chemicals.

mission in order to work jointly towards the protection of the oceans. With the Convention of Sintra (1997), OSPAR set the important goal of stopping the discharge of hazardous substances into the North Sea and the Baltic Sea within one generation.

Since the 1990s, the European Union (EU) has also become increasingly active. The European Office on Chemicals, for example, located in Ispra, Italy, is under the auspices of the EU and is maintaining a database on chemicals and coordinating risk assessments. At the beginning of the new millennium, the EU has also produced two key documents: the Water Framework Directive [2] and the White Paper on the Strategy for a Future Chemicals Policy [3]. The Water Framework Directive aims at protecting inland waters without stopping at national borders. In January 2001, the EU presented as a supplement to the Water Framework Directive, a list of 32 priority pollutants which are gradually to be taken out of circulation and of which 11 substances are particularly hazardous.

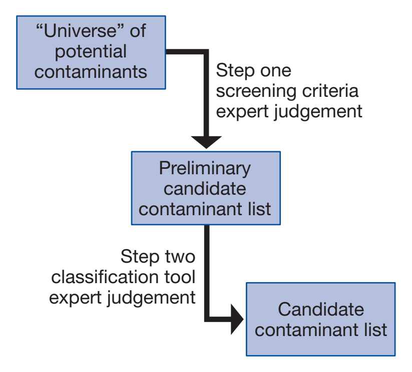

Fig. 2: Prioritization concept for drinking water contaminants in the USA [1].

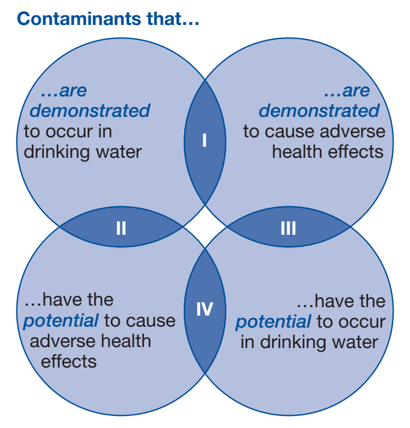

Fig. 3: Step one of the prioritization scheme for drinking water contaminants in the USA [1].

Future EU Chemicals Policies

The primary goal of the EU White Paper on the Strategy for a Future Chemicals Policy in February 2001 is to protect human health and the environment [3]. The basic concept is to identify the most dangerous chemicals – carcinogens, chemicals that accumulate in the environment, and chemicals that interfere with reproduction – and to withdraw them from the market, replacing them with safer compounds. The guiding rule is the precautionary principle: Action should be taken as soon as a certain level of risk has been exceeded, even if the exact cause-effect relationship has not been documented in detail. A key element in the EU policy on chemicals is to develop a transparent evaluation system. The so-called REACH system has three major components: **R**egistration, **E**valuation and **A**uthorization of **CH**emicals:

- *Registration* of basic information on approximately 30,000 old and new chemicals that are produced in quantities larger than 1 ton;
- *Evaluation* of the potential risk for all substances produced in quantities larger than 100 tons, or for chemicals produced in smaller quantities if there is an increased level of concern;
- *Authorization* of substances with certain hazardous properties, i.e., CMR substances (carcinogenic, mutagenic or reprotoxic substances) and POP (persistent organic pollutants).

Another important element of the EU policy is a reversal of the burden-of-proof. In the future, it will be up to industry – not the government – to provide information on the environmental risks associated with chemicals that are to be imported or produced. It will be the task of government agencies to evaluate the data provided by industry, to ensure that adequate test protocols were used and to decide on further steps to be taken.

Switzerland has recently adopted a new Law on Chemicals, which is planned to be in force starting in 2005. The goal is to achieve better coordination with laws in the European Union [4].

Holistic Concept

An integrated approach to assessing and mitigating environmental pollution problems is a major challenge for science, government agencies, the chemical industry as well as non-governmental environmental protection groups and consumer organizations. In addition to the scientific and technical aspects, we also have to give some consideration to socio-economic aspects, such as consumer acceptance or economic acceptability of substitute chemicals. From an environmental protection perspective, however, the risk-based assessment must have priority over socio-economic aspects. The guiding principle of chemicals policy has to be sustainable development, where the negative impacts of chemicals are kept at an acceptable level such that future generations can live in an intact environment and have healthy water resources. Good efforts are already under way, but we have to make improvements in a number of areas; early recognition of problem chemicals being a particularly important one. For optimal protection, we have to apply the precautionary principle; unfortunately, this principle was not adhered to in the case of freons. Humans will eventually have to accept the fact that it is ultimately impossible to reliably and conclusively determine the risk associated with any particular chemical.

Walter Giger, chemist and professor for environmental chemistry at ETH Zurich and the University of Karlsruhe, head of the department "Chemical Pollutants" at EAWAG. Research area: Occurrence and behavior of chemical pollutants in waste water, surface waters and drinking water.

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The OSPAR Strategy against the Introduction of Hazardous Substances into the Marine Environment

In 1998, the contracting parties to the OSPAR Convention for the "Protection of the Marine Environment of the North East Atlantic" agreed on a strategy to make every effort to cease discharges, emissions and losses of hazardous substances to the marine environment. Its objective is to prevent pollution of the maritime area by continuously reducing and eliminating discharges, emissions and losses of hazardous substances within one generation. The OSPAR working group DYNAMEC has subsequently developed a transparent and methodically-reliable procedure for the identification and prioritisation of hazardous substances. Accordingly, the OSPAR Commission has so far agreed to include 42 hazardous substances on the OSPAR List of Chemicals for Priority Action.

Marine ecosystems function as sinks for substances emitted and discharged by atmosphere and rivers. Among these are numerous hazardous substances. Their degradation during transport is very slow and some can be detected nowadays in substantial concentrations in the marine environment, especially if they accumulate in organisms and in the food chain. As a counter measure, the governments of states bordering the North-East Atlantic have therefore agreed in Sintra (Portugal) on a strategy within the framework of the OSPAR Convention on the cessation of discharges, emissions and losses of hazardous substances to the maritime area [1, 2]. By the year 2020, i.e. within one generation (about 25 years), discharges, emissions, and losses of hazardous substances shall be reduced. The objective is to achieve concentrations near background values for naturally occurring substances, and concentrations close to zero for man-made synthetic substances. Hazardous substances are defined as [2]:

- PBT-substances, which are **p**ersistent, liable to **b**ioaccumulate and **t**oxic; or
- substances requiring a similar approach, even if they do not meet all the criteria for the three PBT properties, e.g. heavy metals and substances that interfere with the hormonal systems of humans and animals, i.e., endocrine disrupters.

The OSPAR Strategy

The strategy comprises the following elements:

- the development of a dynamic procedure for the selection and prioritisation of hazardous substances;
- the establishment of a priority list of hazardous substances;
- the development of assessment tools for hazardous substances in the marine environment;
- the elaboration of criteria and methods for the identification and the development of less hazardous and environmentally sound products and substitutes;
- the development of appropriate measures to reduce hazardous substances and an assessment of the advantages, disadvantages and effectiveness of such measures;
- a broad social involvement of groups and organisations concerned;
- the implementation of adopted measures and reporting.

Selection and Prioritisation Method

The method for selection and prioritisation of hazardous substances was developed by the OSPAR working group DYNAMEC and comprises of basically three steps [3, 4]:

- initial selection,
- establishment of a ranking list for potentially hazardous substances,
- final selection of the chemicals for priority action.

The flow chart in figure 1 gives an overview of the main steps in this process.

Initial selection of hazardous substances

As starting point for the selection of hazardous substances, available databases of substances were consulted. These comprised a Nordic Substance Database with 18,000 registered substances, the QSAR database of the Danish Environmental Agency with 166,000 entries and the Dutch BKH/Haskoning database with 180,000 entries. Based on the PBT selection criteria (Tab. 1), a preliminary list of relevant substances was established. At the same time,

Category	**Limiting values used**		
	Persistence	**Bioaccumulation**	**Toxicity**
Initial selection	Half life >50 days or measured/estimated biodegradation	log K_{OW} ≥4 or bioconcentration factor ≥500	*Aquatic Organisms:* acute LC_{50} or EC_{50} ≤1 mg/l, NOEC ≤0.1 mg/l *Mammals:* Carcinogenic, mutagenic, toxic to reproduction or chronically toxic
Final selection	Non-biodegradable	log K_{OW} 5 or bioconcentration factor ≥5000	*Aquatic Organisms:* acute LC_{50} or EC_{50} ≤0.01 mg/l, NOEC ≤0.01 mg/l *Mammals:* same criteria as in initial selection

Tab. 1: Selection criteria of the initial and final selection.
K_{OW} = 1-octanol/water partition coefficient;
LC = lethal concentration, EC = effect concentration, index 50 = 50% of the organisms studied are affected;
NOEC = no observed effect concentration.

the "safety net procedure" was used to screen substances for hazardous properties not selected by the PBT criteria set. Substances thus determined to be of similar concern were also added to this preliminary list [4].

In a further evaluation step, experts scrutinised the individual entries on the list for plausibility and concluded on the preliminary selection list of approx. 400 substances of possible concern (Fig. 1). To complete the subsequent prioritisation, data profiles have been established.

Prioritisation of Pollutants on the Basis of their Hazard and Risk

Prioritisation aims at determining the relative hazard and risk of the 400 selected substances, which lead to their ranking according to their potential hazard and risk. The COMMPS-method (Combined modelling and monitoring priority settings) was applied. This method was developed [5] by the Fraunhofer Institute Schmallenberg within the scope of the preparatory work to the Water Framework Directive of the European Union (EU), and is currently used as standard methodology within the EU. It includes both a modelling approach, originally developed for the "European Union Risk Ranking"-methodology (EURAM) [6, 7], and a monitoring approach to statistically evaluate measured data and calculate the relative priority ranking for each individual substance. To calculate the priority ranking, an algorithm is used to classify the substances according to their persistency, bioaccumulation and (eco)toxicity.

Within the context of the OSPAR work, the COMMPS method was modified for specific marine environmental conditions and the selection was adapted to substance-based data and model parameters [8, 9]. For example, when modelling the exposure range, the loads of substances discharged into the marine waters (water column + sediment) were considered. Both direct (toxicity) and indirect (bioaccumulation) effects on marine organisms were taken into account when calculating the range of effects. Compared with the limnic model, more attention was given to the indirect effects, as retention and exposure times of hazardous substances are significantly higher in marine ecosystems. The ranking, however, also took into account effects of so-called CMR substances (**c**arcinogenic, **m**utagenic, toxic to the **r**eproductive system) on human health. CMR substances can, for example, enter into the human body through consumption of contaminated seafood. Furthermore, increased consideration was given to persistence in the calculation of the overall ranking score, and the differentiation of biodegradation was spread in the scaling.

Four ranking lists were established on the basis of the results of these calculations:

- the *ranking list Water I* is based on measured environmental concentrations and effect data,
- the *ranking list Water II* is based on modelled data and effect data,
- the *ranking list Sediment I* is based on measured environmental concentrations and effect data,
- the *ranking list Sediment II* is based on modelled data and effect data.

Of the total of 400 substances on the preliminary selection list, only approximately 200 could be placed on one of the four ranking lists. Since the remaining 200 substances exhibit substantial gaps pertaining to effects, measured concentrations and discharge quantities, calculation of their relative risks and ranking was not possible. As soon as the data gaps are filled, these substances will be ranked according to the DYNAMEC method.

Final Selection

To facilitate the approach, a shorter sub-list was created containing a maximum of 80

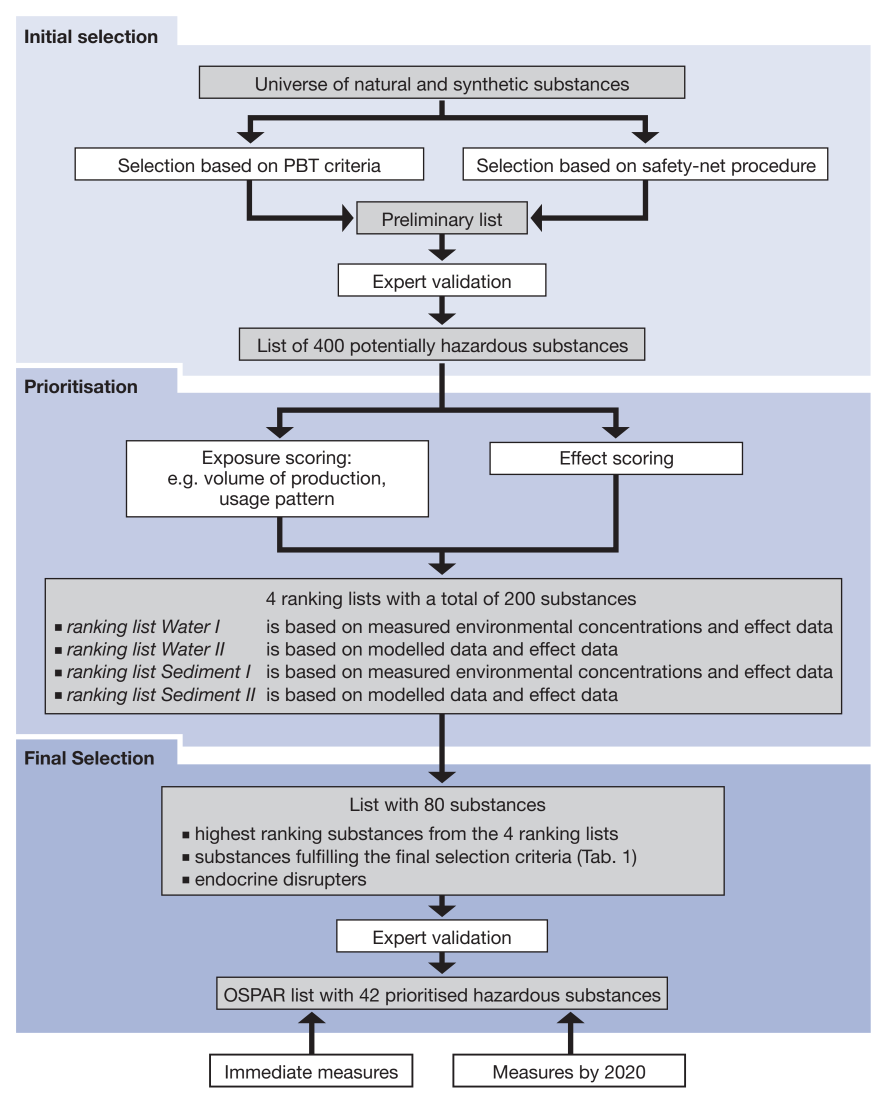

Fig. 1: Flow chart of the OSPAR method for the selection and prioritisation of hazardous substances developed by the OSPAR working group DYNAMEC.


Greenpeace/Greig

OSPAR strategy: Cease the introduction of hazardous substances by 2020.

substances. This list includes substances of the four lists with the highest ranking scores, substances which fulfil the stringent final selection criteria (Tab. 1) and endocrine active substances. In a further round of expert revisions, the list was completed, containing a total of 42 priority hazardous substances, which the OSPAR Commission adopted as OSPAR List of Chemicals for Priority Action [10].

For these substances, so-called OSPAR lead countries will compile background documents including risk assessment [11], substance and application characteristics, sources of emissions, as well as suggestions for reduction measures and possibilities for substitution.

Legal Implementation of Measures

For EU Member States being Contracting Party to the OSPAR Convention as well, the implementation of OSPAR measures takes place within the context of the relevant EU Directives. An important legal basis is provided by the EU Water Framework Directive, which came into effect in December 2000 and should be implemented similar to the OSPAR strategy by the year 2020. The Water Framework Directive lists 32 priority chemicals. According to Article 16 of the Directive, quality standards have to be developed for these substances. Some of these substances are also found on the OSPAR List of Chemicals for Priority Action. As for the OSPAR substances, concentration levels of close to zero or background levels are required by the year 2020, the development of quality standards can in these cases only be regarded as intermediate objectives.

Implementation of these measures can include extensive discharge limits for point sources of pollution and restrictive internal market regulations for diffuse sources. Both types of emission sources will be addressed by the application of best available techniques (BAT) and best environmental practice (BEP), respectively. It can be concluded that the Water Framework Directive offers an overall concept for marine coastal and freshwater waters, thereby also taking into account the protection demands of the oceans with respect to hazardous substances discharged by water from land-based sources.

Prospects

The OSPAR Strategy on the cessation of discharges, emissions and losses of hazardous substances to the marine environment pursues the challenging goal of eliminating such inputs by the year 2020 [12]. This requires great efforts from OSPAR Contracting Parties but also from social groups, companies and organisations involved. Therefore, it was of primarily importance to develop an indisputable method for the selection and prioritisation of hazardous substances. The working group DYNAMEC has successfully elaborated a transparent and methodically reliable procedure. The OSPAR List of Chemicals for Priority Action was therefore accepted by all stakeholders involved, and the implementation of the OSPAR Objective can take place effectively.


Heinz-Jochen Poremski, Scientific Director at the German Federal Environmental Agency, Berlin.


Suzanne Wiandt, Deputy Secretary at the OSPAR Commission, London.

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Sewage Sludge: Fertilizer or Waste?

The use of sewage sludge as an agricultural fertilizer is at the center of an intense debate. The primary benefit of using sewage sludge as a fertilizer is the recycling of valuable plant nutrients from the consumer back into the agricultural system. But this benefit is offset by the risk posed by the introduction into the environment of potentially harmful chemicals contained in the sewage sludge. The benefits and the risks must be weighed against one another. In the short term, we should use only the highest quality sewage sludge; in the long term, we need to develop systems and techniques that satisfy criteria for both sustainability (nutrient recycling) and precaution (environmental protection).

Sewage sludge is produced by centralized wastewater treatment plants and is classified as a waste fertilizer (see box) according to the Swiss Regulations on Chemicals (StoV) and the Regulations on Fertilizers (DüBV). In 1999, the 979 wastewater treatment plants in Switzerland produced a total of 209 000 tons of sewage sludge (dry weight), 40 % of which was used in agriculture (Tab. 1). The bulk of the remaining sludge was used for fuel in industrial furnaces designed for sludge incineration, in cement production, and in waste incineration plants. A small portion of sewage sludge was once deposited in landfills, but this practice was banned in 2000. Utilization and disposal methods for sewage sludge vary strongly among the cantons: in JU, GL, FR, TG and UR, almost the entire volume of sewage sludge is used in agriculture, while GE, BS and AI used virtually none of their sewage sludge as fertilizer.

Sewage Sludge Contains Both Nutrients and Pollutants

Despite the fact that most European countries use at least some portion of their sewage sludge as agricultural fertilizer, this practice is presently the topic of an intense debate. On one hand, the recycling of nutrients contained in sewage sludge satisfies the sustainability principle; on the other hand, sewage sludge may contain a number of undesirable chemicals so that its use as a fertilizer poses a risk to both the environment and human health, thereby contradicting the principle of precaution. It is our task to weigh the benefits against the risks.

Benefits of Sewage Sludge Utilization

Source of Nutrients, Fertilizer: On a dry weight basis, sewage sludge contains on average 45 % organic matter, 5.8 % calcium, 4.4 % nitrogen, 2.7 % phosphorus, 0.5 % magnesium and 0.3 % potassium. In addition, it usually contains sulfur and trace elements like cobalt, copper, molybdenum, nickel and zinc. Compared to the total amount of nutrients from farm manure and mineral fertilizers (see box), the contribution from sewage sludge is relatively small (Tab. 2). It counts only for 7.1 % of phosphorus, 2 % of nitrogen, and 0.1 % of potassium from the totally deposited amount of fertilizer [1]. Omitting nutrient input from internal farm sources (dung, manure, etc.) and considering only the nutrient input from external sources (deposition, mineral fertilizers, animal feed), however, sewage sludge may account for as much as 34 % of the phosphorus and 9 % of the nitrogen output from

Fertilizers are nutrients for plants. There are three groups of fertilizers:

1. **Waste fertilizers**
    - **Sewage sludge: product of wastewater treatment**
    - **Compost: decayed plant and animal material**
    - **Undecayed plant material, e.g., waste from apple juice production**
    - **Products from mineral or animal waste, e.g., horn chips, ground leather**
2. **Farm manure: e.g., liquid manure, solid manure, manure drainage, silo drainage**
3. **Mineral fertilizers: mostly chemical products**

	Nutrient load in 1000 t		
	N	**P**	**K**
Farm manure	128	20.5	162
Mineral fertilizer	53	7.4	27
Sewage sludge	**3.7**	**2.2**	**0.25**
Compost	2.9	0.74	1.8
Other wastes	1.5	0.57	1.5
Total	**189**	**31.4**	**192**

Tab. 2: Comparison of nutrient loads from different fertilizers in Switzerland for the year 1999.

	1974	**1980**	**1984**	**1989**	**1994**	**1999**
Number of communal WWTP's	430	710	855	930	977	979
Population served (%)	46	70	81	88	91	95
Total sewage sludge production (1000 t dry matter)	90	170	176	213	211	209
Amount used in agriculture (%)	80	65	50	50	55	40

Tab. 1: Number of wastewater treatment plants (WWTP's), population served, total production and agriculturally utilized sewage sludge volumes for Switzerland.

agricultural production (plant and animal products) [2, 3].

Preservation of Global Nutrient Reserves: According to current estimates, phosphate mineral deposits accessible by current technologies (12 billion tons of ore) will be depleted within the next 80 years. Additional phosphate reserves, estimated at approximately twice that volume, are at the bottom of the oceans or contain heavy metals and can, therefore, be utilized only to a limited degree or at a high cost. The situation is less critical for nitrogen and also the potassium reserves should last for the next 300 years [1].

Improvement of Soil Characteristics: The introduction of organic matter and lime improves the physical, chemical and biological properties of the soils when fertilized with sewage sludge. Field studies have documented an increase in humus content, soil pH, biological activity (soil respiration, nitrogen mineralization, enzymatic activity) and microbial biomass. These improvements were found down to a 1 m depth [4]. The increased soil pH has a secondary effect on adsorbed and dissolved heavy metals in the soil: an increase in soil pH reduces the amount of dissolved (i.e., bioavailable) heavy metals in the soil, with the result that plants on soils fertilized with sewage sludge exhibit lower cadmium and nickel concentrations than plants grown on unfertilized soils or soils amended with liquid manure (Stadelmann et al. 1988, cited in [1]).

Benefits to the National Economy: Fertilization with sewage sludge (at 1999 levels) can save fertilizer and nutrient costs of 7 million CHF per year. In addition, the use of sewage sludge in agriculture saves approximately 34 million CHF annually of incineration costs [1].

Risks in the Use of Sewage Sludge

General Risks: Long-term use or inappropriate application of sewage sludge can lead to contamination of surface waters (due to run-off or erosion), ground and spring water. Contaminants may also accumulate in the soil, which leads to reductions in soil fertility (reduction of diversity and activity of soil organisms), crop quality, and crop yield. At the same time, contaminants may enter the food chain and cause negative effects on the health of livestock and humans [1].

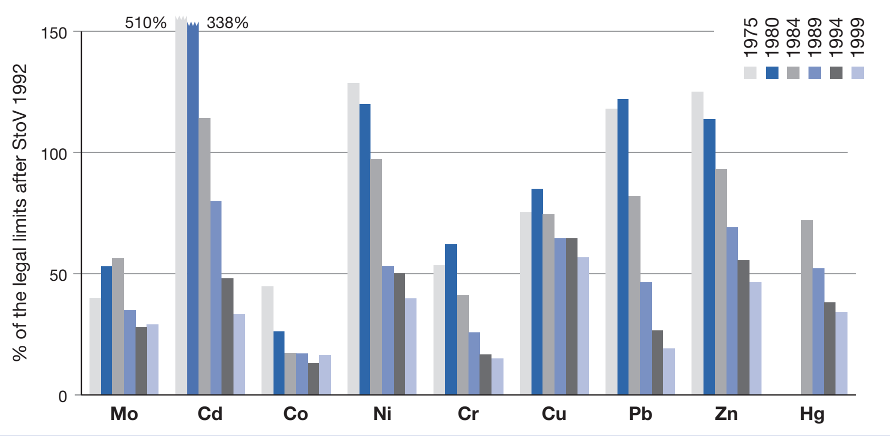

Fig. 1: Average utilization of heavy metal limits for sewage sludge in Switzerland, according to the Regulations on Chemicals (StoV 1992) (after Külling 2001, cited in [1]).

Heavy Metals: Repeated fertilization with sewage sludge causes heavy metals to accumulate in the soil. Increased levels of dissolved heavy metals (e.g., cadmium, zinc, copper) result in a reduction in biological activity in the soils [5], lower crop yields, and increased heavy metal concentrations in the crops. The threat from heavy metals to livestock and human health, however, is generally considered to be minimal [1]. Since 1975, heavy metal concentrations have been generally dropping. The quality of the sewage sludge used in agriculture has never been as good as it is currently, and contamination levels are clearly below the levels set by the StoV (Fig. 1). This is reflected in improved heavy metal-nutrient values (HMN) and heavy metal-phosphate values (HMP), two parameters that are commonly used in Switzerland to assess and compare the quality of different sewage sludges (Tab. 3) [1]. The lower the two values, the higher the quality of the sewage sludge.

	1975	1980	1984	1989	1994	1999	AG^{99}
Total of heavy metals	378	653	534	467	375	321	140
HMN	6.39	4.43	1.99	1.44	1.15	0.96	0.85
HMP	21.46	11.78	4.48	4.27	3.26	2.68	2.37

Tab. 3: Heavy metal loads in sewage sludge (t/year) and heavy metal-nutrient (HMN) and heavy metal-phosphorus (HMP) values for Switzerland [1]. AG^{99}: Metal load introduced into agriculture via sewage sludge for 1999.

Organic Contaminants: Sewage sludge may contain a number of organic contaminants (see box), mostly in the range of µg/kg dry weight [1]. The organic compounds can vary over a wide range in their chemical characteristics, i.e., persistent, lipophilic, toxic or carcinogenic properties. Persistent compounds, such as PCBs, can accumulate in agricultural systems and food chains (Fig. 2). Most organic contaminants show only minor toxicity towards plants and usually are absorbed by the plant to a negligible degree. If the plant takes up the contaminant, it is often at least partially degraded during the plant's metabolism. The problem for livestock and humans, however, is the surface contamination of meadows, pastures and soil surfaces as a result of sewage sludge application. If dairy cows, for example, ingest plants and soil particles that are contaminated on their surfaces, the contaminants may end up in the milk and, therefore, in the food chain. For this reason, Germany, Sweden and Norway have strict bans on the use of sewage sludge in feed crops.

The dominant organic contaminants in sewage sludge are:

- **chlorinated aliphatic and aromatic hydrocarbons**
- **chlorophenols**
- **polycyclic aromatic hydrocarbons (PAHs)**
- **polychlorinated biphenyls (PCBs)**
- **polychlorinated dibenzodioxines and dibenzofuranes (PCDD/F)**
- **di(2-ethylhexylphthalate) (DEHP)**
- **organotin compounds (TBT)**
- **tensides and tenside metabolites (LAS, NP)**
- **bisphenol A**
- **chlorparaffines**
- **polybrominated diphenylethers (PBDE)**
- **polychlorinated naphthalene (PCN)**
- **organochlorine pesticides**
- **musk compounds and drugs (including antibiotics and hormones)**

Pathogens: Sewage sludge is a potential carrier of a number of pathogens, such as bacteria (e.g., *Salmonella*), viruses (e.g., Hepatitis B), protozoa (e.g., Entamoebae) and roundworms (e.g., *Ascaris*) [1]. If sewage sludge is sanitized, for example by heat, the number of pathogens can be significantly

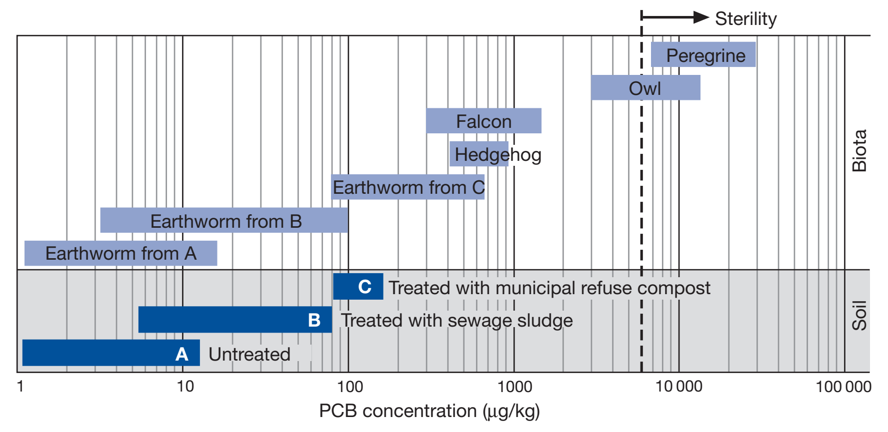

Fig. 2: Accumulation of PCBs in agroecosystems in Switzerland (after Tarradellas et al. 1985, and Becker van Slooten 2001, cited in [1]). PCB concentrations in soils are based on dry weight, in animals on wet weight.

reduced. The use of heat-treated sewage sludge as a fertilizer in agriculture, therefore, poses a very low risk to human and animal health.

BSE and GMO: Only a minimal fraction of infectious material (e.g., BSE infectious particles) is found in the waste water, provided that appropriate methods of slaughtering and meat processing are used, good hygiene is practiced, and all solid materials from filtration and floatation processes in meat processing plants that could pose a risk are collected. Sewage sludge, therefore, presents a minimal contamination risk for BSE. In the case of genetically modified microorganisms (GMOs), spreading of these organisms via sewage sludge is possible, in principle, particularly in sewage sludge that has not been sanitized [1].

Sewage Sludge is Only One of Several Risk Sources

Chemical pollutants, pathogens and GMOs are released into the environment also by processes other than those related to sewage sludge. Only about 12% of the heavy metals in Switzerland are released into the soil from sewage sludge; 38% come from farm manure, 25% from atmospheric deposition, 14% from mineral fertilizers, 6% from fungicides, 4% from compost and 1% from ash (wood burning) [1]. The situation is similar for many organic contaminants. For PCBs, for example, annual amounts released into agricultural soil are estimated at about 1000 kg from deposition, 70 kg from farm manure, 8 kg from sewage sludge, and 3 kg from compost [1]. In a rough evaluation of the total risk by multi-criteria analysis [1] assessing nutrient stock (availability), soil structure, heavy metal content, organic contaminant concentrations, pathogens, BSE, GMOs, disposal costs and marketing/image, sewage sludge was rated the worst. Better ratings were given to wood ash, waste from lumber processing, farm manure, compost, waste from food processing and mineral fertilizers. What is generally acknowledged, however, is that any use of fertilizer carries certain risks.

What Has to Be Done?

Generally, we cannot evaluate the benefits and risks of using sewage sludge as a fertilizer isolated from other aspects. First, we need to reduce the contaminant load in sewage sludge; secondly, we need to improve both the methodology and practicability of risk management.

In the short to mid-term, we need targeted measures to minimize risks and optimize benefits, such as:

- solid waste separation in meat processing (BSE risk), improved monitoring of hygiene and targeted selection of sewage sludges with low HMN and HMP values;
- prevention/reduction of the ingestion of sewage sludge by livestock on pastures;
- introduction of additional criteria in the Regulations on Fertilizers (DüBV) for organic contaminants and re-evaluation of current limits for heavy metal concentrations and recommended fertilizer volumes as set in the Regulations on Chemicals (StoV);
- phasing out of sewage sludge applications in agriculture in case of a ban (grassland before arable crops).

The long-term goal in the context of a closed agricultural system and resource management is to recycle nutrients from human waste and other usable sources. We need to put increased effort into the conceptual development of alternative sewage systems that allow us to separate domestic waste water, industrial process water and run-off. We also need to advance technologies dealing with the extraction of nutrients from waste water and sewage sludge.

Nature does not produce waste, but only valuable nutrients that need to be utilized. Expressions such as waste, waste water and waste heat are out of place. Our primary goal should be to simultaneously satisfy the principles of sustainability and precaution.

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Arsenic in Drinking Water – Vietnam, New Focus of Attention

In some countries, arsenic is the most important chemical pollutant in ground water and drinking water. The Bengal Delta region is particularly affected as 35 million people have been drinking arsenic-rich water for the past 20–30 years, of which one million are currently suffering from chronic arsenic poisoning. In the Red River Delta around the Vietnamese capital of Hanoi, EAWAG researchers have recently identified another highly arsenic contaminated groundwater area. In some locations, the contamination in Vietnam exceeds the standard value of 10 µg arsenic per liter recommended by the World Health Organization (WHO) 300 times. Measures to mitigate the arsenic problem include not only the development of low-cost arsenic detection and easy to use arsenic removal methods, but also dissemination of information to professionals and consulting services to public authorities.

Recently, news about arsenic contaminated drinking water has hit the headlines. Chronic levels of 50 µg arsenic per liter can already cause health problems after 10–15 years of exposure. The development of the disease is strongly dependent on the exposure time and the resulting arsenic accumulation in the body. The first symptoms of the disease are characterized by a noticeable skin pigmentation which can lead to skin cancer (Fig. 1 on page 13). The subsequent health problems are affections of the cardiovascular and nervous system. After 15–30 years of exposure, victims often develop lung, kidney or bladder cancer.

The European Union allows a maximum arsenic concentration of 10 µg/l, and the World Health Organization (WHO) recommends the same value as a guideline. However, in many developing countries, but also in Switzerland and in the USA, the drinking water limit for arsenic has been established at 50 µg/l. Efforts are currently being undertaken in the USA to lower the allowable concentration value to 5–10 µg/l in the near future.

Arsenic – A Global Problem

Regions with arsenic-rich drinking water can be found around the globe: Taiwan, Chile, Argentina, Mexico, Ghana, Hungary, Mongolia, India, and Bangladesh are among the most notorious regions [1]. However, larger regions in the USA are also affected. Vulnerable areas in Nepal, Pakistan, Thailand, Laos, Cambodia, and Sumatra have barely or not been examined so far.

To combat serious infectious diseases in Bangladesh, UNICEF promoted the use of abundantly available and germfree ground water at the end of the 1970s. In rural households, the ground water is pumped by small handpumps (see photograph, this page) and consumed as drinking water without further treatment. Since then, this measure has contributed to a significant decrease in infectious diseases and infant mortality. However, the potential high arsenic content in the water was unknown at that time. Only when cases of chronic arsenic poisoning had increasingly been diagnosed by 1989, could the reason be attributed to the arsenic contaminated ground water, where it was found that the local geological and hydrogeological conditions have lead to a reductive dissolution of arsenic-containing sediments.

In Bangladesh, over one million people currently suffer from chronic arsenic poisoning. This tendency is on the increase. The first systematically conducted study on the water quality in Bangladesh revealed that 25% of the population drink water whose arsenic concentration exceeds 50 µg/l [2]. A report published in the WHO bulletin in 2000 stated


Nguyen Viet Thanh, EAWAG

Arsenic-rich ground water in Bangladesh and Vietnam drawn by simple handpumps poses a major health risk. Picture of a groundwater handpump in the backyard of a private household located in a rural area of Vietnam.


www

Fig. 1: Skin cancer is one of the symptoms caused by chronic arsenic poisoning.

that “the contamination of ground water by arsenic in Bangladesh is the largest poisoning of a population in history, with millions of people exposed”.

Natural Occurrence of Arsenic in River Sediments

Arsenic predominantly pollutes the ground water and drinking water through natural processes (see also article by H.-R. Pfeifer and J. Zobrist, p. 15). Weathering of arsenic containing minerals dissolves the arsenic contained in the rock stratum. The dissolved arsenic is, in turn, highly adsorbed to iron (hydr)oxide containing particles that are transported by rivers and deposited mainly in sediments of river deltas. Under oxygen-rich conditions in the ground water arsenic remains fixed in the sediments. However, if the sediments come into contact with oxygen-poor ground water, the arsenic-rich iron (hydr)oxide particles are dissolved by microbial activity and the arsenic is redissolved [3]. This process, which also occurs in the Bengal Delta formed by the Ganges and Brahmaputra rivers, is the cause for the arsenic contamination in Bangladesh and West Bengal (Indian federal state) [4], both located in this delta.

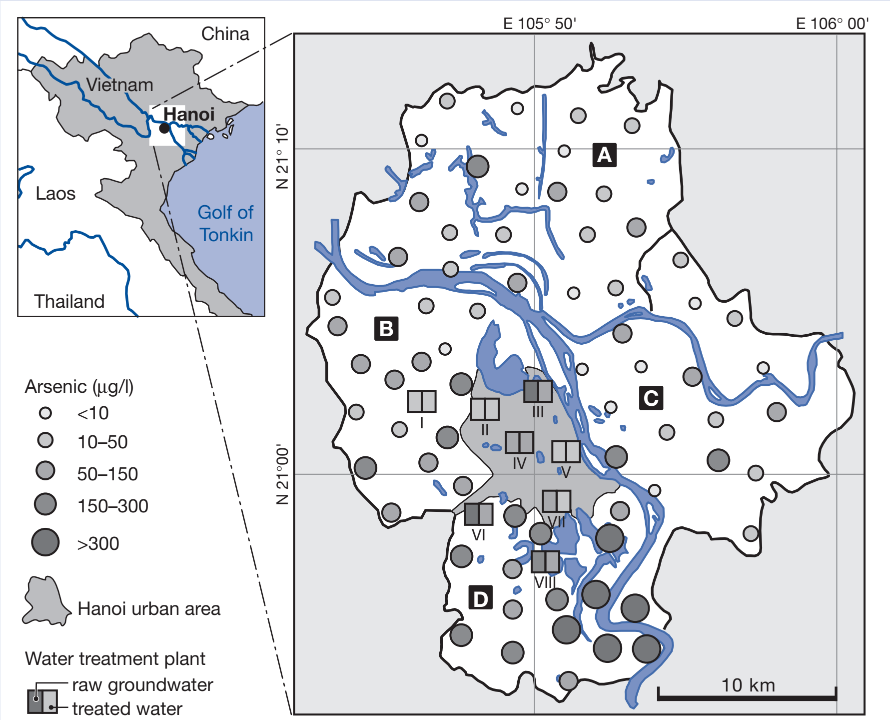

Fig. 2: Arsenic concentrations in groundwater samples from Hanoi and surroundings. 68 samples of randomly selected households were analyzed in the rural districts A–D. In Hanoi city, raw ground water and treated drinking water samples from the eight largest drinking water supplies were analyzed. Measuring campaign: September 1999.

Latest Focus of Attention: The Red River Delta in Vietnam

Since the Red River Delta in the north of Vietnam exhibits similar geological and hydrogeological properties as the Bengal Delta, the EAWAG assumed there would also be higher arsenic contamination of the ground water in this region. Therefore, groundwater samples from Hanoi were analyzed by EAWAG for the first time in 1998 in the frame of a long-term research collaboration between EAWAG and the Vietnamese National University, which is financed by the Swiss Agency for Development and Co-operation (SDC). The presence of critical arsenic concentrations in these samples incited EAWAG to conduct several systematic measuring campaigns from April 1999 through July 2000. The analyzed ground water originated from:

- 68 groundwater handpumps (tubewells) from randomly selected private households in the rural districts A–D around Hanoi,
- raw and treated drinking water from the eight largest drinking water supplies of the city of Hanoi.

Figure 2 illustrates the results of the measuring campaign of September 1999 in the rural districts A–D. The results from the investigated family-based tubewells reveal that 50 % of the samples exceed the Vietnamese guideline value of 50 µg arsenic per liter with an average concentration of all the samples amounting to 159 µg/l. Peak values of 3000 µg arsenic per liter were measured in district D, south of Hanoi. Figure 3 shows as cumulative frequency the results of three measuring campaigns in districts A–D. The situation in district D is particularly alarming: with an average value of 432 µg/l, 90 % of the analyzed samples revealed concentrations of 51–3000 µg/l.

Moreover, the ground water treated for drinking water purposes in the city of Hanoi contains arsenic concentrations of up to 430 µg/l. Although treatment partly eliminates some of the arsenic, concentrations of roughly 90 µg/l arsenic remained in the treated drinking water of four water supplies, and thereby, clearly exceed the drinking water limit (Fig. 4).

The results of the present survey [5–7] confirm our assumption that the 11 million inhabitants of the 11,000 km^2 delta of the Red River are exposed to a risk of chronic arsenic poisoning, yet no disease symptoms have been diagnosed so far. This could possibly be attributed to the fact that in Vietnam, arsenic contaminated ground water has only been used as drinking water for the past 7–8 years. Experience shows that it can take up to 10 years before the first symptoms of arsenic poisoning become apparent. Compared to Bangladesh, one might further speculate that the general nutrition of the Vietnamese population is much better and could have a retarding influence on the outbreak of the disease. Nevertheless, the expected number of cases of the disease occurring in the near future should not be underestimated.

Mitigation Measures

The results obtained clearly reveal that mitigation measures to solve the arsenic problem have to be applied at several levels, as millions of households draw their drinking water from private groundwater wells, but also municipal water supplies are confronted with the same difficulty. Efficient and low-cost arsenic detection and removal methods as well as implementation of a focused information policy are therefore required. With a view to attaining these objectives, EAWAG is participating in an overall project "Sustainable Water Management in Arsenic Contaminated Asian Regions" jointly financed by the Alliance for Global Sustainability.

For a number of years already, several international research teams have been trying to develop inexpensive and simple techniques for arsenic removal from drinking water. EAWAG has developed a low-cost removal technique based on arsenic oxidation and subsequent precipitation using sunlight. This method could be used in households without requiring significant effort (SORAS) [1, 8].

The currently available arsenic measuring methods represent an additional problem. In Bangladesh for example, three million tubewells have to be analyzed due to significant local variations in arsenic concentrations, an undertaking which well exceeds the sample throughput capacity of high-tech laboratory instruments for arsenic analysis. In practice, field test kits for arsenic detection using a wet chemical method have not proved satisfactory so far. EAWAG is, therefore, working on the development of a simple and inexpensive biosensor for quantitative arsenic determination [9].

In addition, both the population and public authorities of the most affected regions must be fully informed about the arsenic problem. EAWAG is actively involved in Vietnam, where it provides scientific and technical consulting services to government authorities and fosters the exchange of ideas and experience with specialists of other research and development organizations.

Additional information on EAWAG's activities in arsenic related research is available at www.eawag.ch/arsenic.

Michael Berg, chemist, is leader of the research group "Contaminant Hydrology" in the department "Water Resources and Drinking Water" at EAWAG as well as manager and scientific consultant of the research cooperation project with the National University in Vietnam. Current research interest: Occurrence and behavior of chemical pollutants in aquatic and terrestrial environments.

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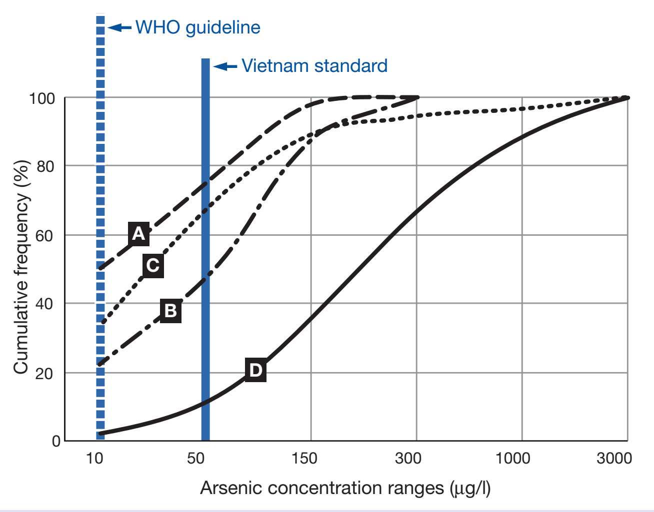


Fig. 3: Cumulative frequencies of the measured arsenic contents in 196 groundwater samples pumped through family-based tubewells in the rural districts A–D around Hanoi. Measuring campaigns: September and December 1999 as well as May 2000.

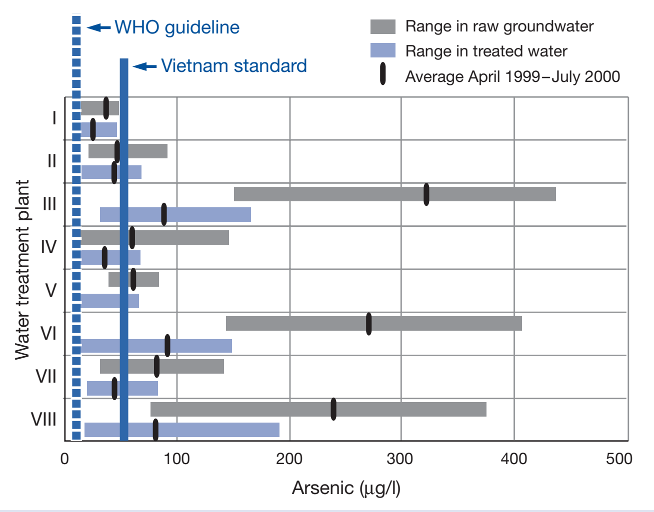


Fig. 4: Arsenic concentrations in raw ground water and treated drinking water from the eight drinking water supplies of Hanoi. Concentration ranges and average values from 7 measuring campaigns (from April 1999 through July 2000, 7x16 samples).

Arsenic in Drinking Water – also a Problem in Switzerland?

In Switzerland, areas with elevated arsenic levels are found primarily in the Jura and in the Alps. Weathering and erosion of rocks containing arsenic releases this element into soils, sediments and natural waters. The national limit for drinking water of 50 µg/l arsenic is not exceeded anywhere in Switzerland; however, in localized areas in the Cantons Ticino, Grisons and Valais, arsenic concentrations in the drinking water are above the level of 10 µg/l recommended by the World Health Organization (WHO).

On average, the earth's crust contains 2 mg arsenic per kg. Compared to the abundance of other elements, such as copper, zinc or lead, this concentration is very low; however, arsenic is rather unevenly distributed, i.e., rocks contain either no or very little arsenic (less than 1 mg As per kg of rock), or high concentrations of 50 mg – 500 g per kg. Zones rich in arsenic are usually well defined but can vary in size. Typically they measure between 1 m and several 100 m in diameter (Fig. 1).

Natural arsenic containing formations are either:

- metal ore deposits that contain large volumes of arsenic containing minerals, such as sulfides, arsenates or more rarely iron oxides;
- extended areas of rocks with elevated arsenic concentrations, usually caused by the presence of iron bearing sulfides or oxides, such as pyrite, goethite or hematite.

In addition to these natural sources, arsenic can be detected in landfills and on industrial sites. Most of these contaminated sites are related to urban gas production, the production of special glass, or extensive pesticide use. Since 1970, however, arsenic is no long used in pesticides.

Release of Arsenic into the Environment

When an arsenic containing material comes in contact with moving water, substantial amounts of arsenic can be released into the environment. If the material is present in deeper formations, arsenic can be brought to the surface by thermal springs. When the arsenic bearing formation is near the surface, weathering and erosion release substantial amounts of arsenic into the environment. Arsenic either accumulates in soils and sediments, or is diluted in natural waters. Streams and glaciers can transport arsenic over distances of several 100 kilometers. In soils, sediments, and relatively stagnant, particle rich waters, arsenic typically binds to iron or aluminum oxyhydroxides and to clay minerals. Under certain conditions it can be remobilized, for example, if the pH increases to above 7.5, or when the absence of oxygen leads to iron reducing conditions [1] (see also article by M. Berg, p. 12).

Arsenic may also be released into the environment by atmospheric transport. One study, for example, documented wind transport of arsenic containing fine dust by chemical analyses of mosses [2]. It is not clear at this point, whether volatile arsenic methyl compounds formed by microorganisms are of any importance in Switzerland.

Natural Arsenic Occurrences in Switzerland

Switzerland has three main areas with elevated natural arsenic concentrations (Fig. 2):

- Northeastern Switzerland, where a number of arsenic containing thermal and mineral springs are located;
- the Jura, with its iron containing limestones and clays;
- the Alps, where arsenic bearing ore deposits and crystalline rock formations can be found. In addition, there are other isolated thermal and mineral springs.

Thermal and mineral springs are fed by surface water that has penetrated the rock formations down to depths of several kilometers. The thermal springs of Baden, Zurzach, Schinznach and Bad Saeckingen in northern Switzerland are typical cases and may contain up to 130 µg arsenic per liter at their source [3]. The arsenic in these springs stems from deep lying granites and schists of the Black Forest massif. Due to treatment of the raw water, guests typically receive water containing less than 1 µg arsenic per liter (Fig. 3). The same can be said for the arsenic containing mineral and thermal springs in Saxon, Leukerbad and St. Moritz in the Alps. The cold mineral springs of Val Sinestra in the lower Engadin, with extremely high arsenic concentrations of up to 3 mg/l, are no longer used.

The Jura has three arsenic bearing and iron rich formations: the brown limestones of the Dogger formation and the yellow limestones of the Cretaceous formation contain between 10 and 20 mg arsenic per kilogram of

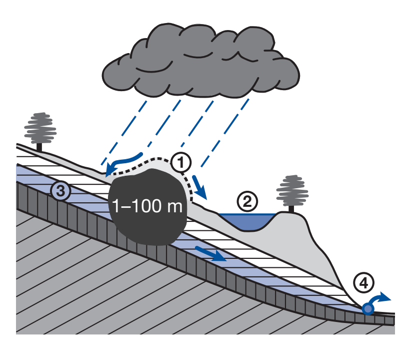


Fig. 1: Weathering of arsenic containing material (silicate rocks, mineral ores, dump sites; black) releases arsenic into (1) soils and sediments, (2) surface waters, (3) ground water, (4) spring water.

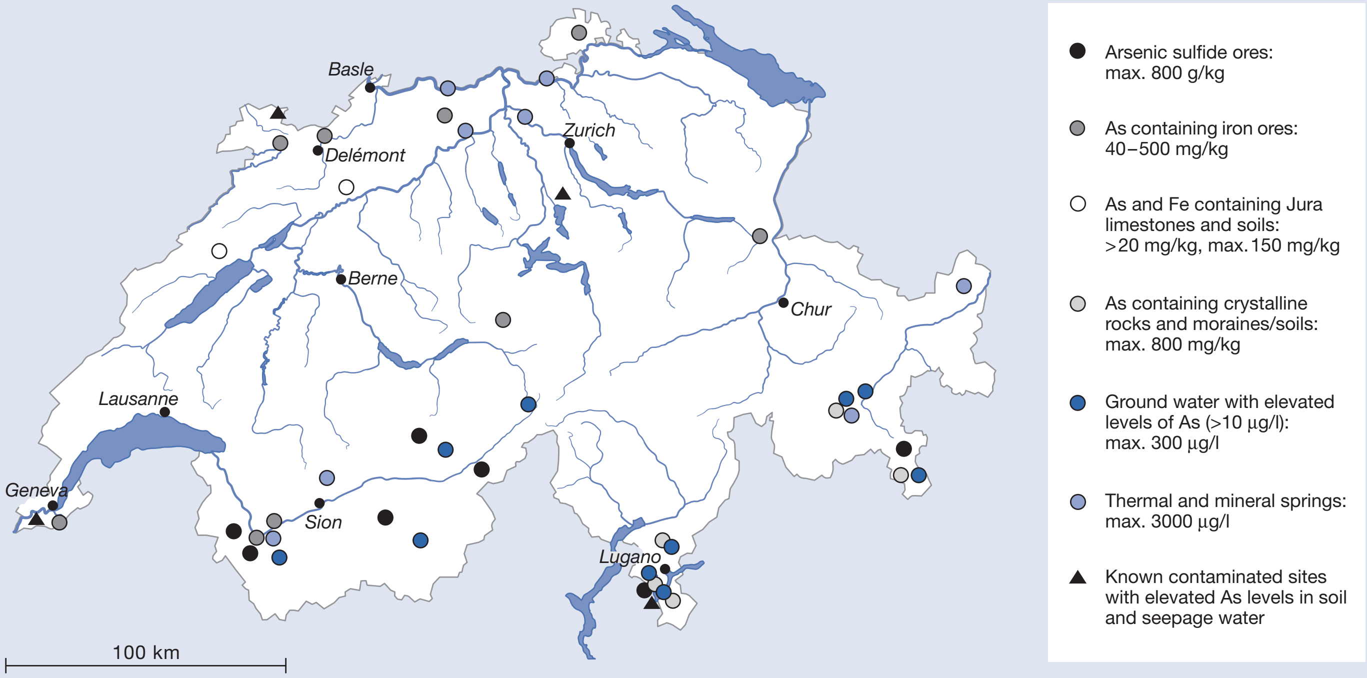


Fig. 2: Areas with elevated levels of arsenic in Switzerland. Elevated arsenic levels in ground water are found primarily in Wallis, Ticino and Grisons.

limestone; however, arsenic is accumulated in the soils during weathering processes and can reach levels of up to 150 mg/kg. These iron rich limestones occur primarily in the Jura mountains of Solothurn, Aargau and Neuenburg. The Bohnerz formation with its iron nodules and red clays is found in restricted areas in the Jura portions of the Cantons Waadt, Jura (Delémont) and Schaffhausen. Bohnerz rocks contain up to 500 mg arsenic per kg of rock. There have not been any investigations as yet on whether arsenic accumulates in the soils of these regions. All of the groundwater and plant samples from Jura analyzed so far have shown very low arsenic concentrations: less than 1 µg arsenic per liter water and no more than 500 µg arsenic per kg dry plant mass. These low values indicate that arsenic is strongly bound to iron phases in the soil.

More heavily impacted areas are in the Swiss Alps, where sulfur and arsenic rich ore deposits or arsenic crystalline silicate rocks are present, such as schists, gneisses and amphibolites. The numerous small ore deposits that were mined in the past, only have a localized impact on the environment. Much more important are situations where arsenic bearing crystalline rocks cover a large surface area, i.e., several 100 km^2. Such areas are found in the Cantons of Wallis, Ticino and Grisons.

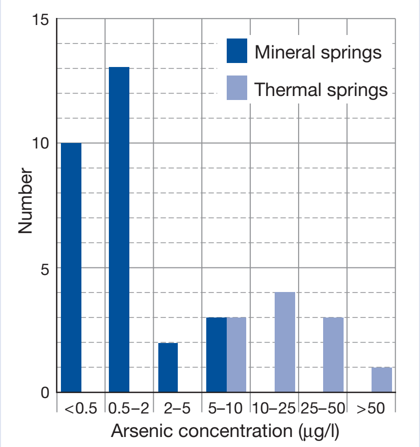
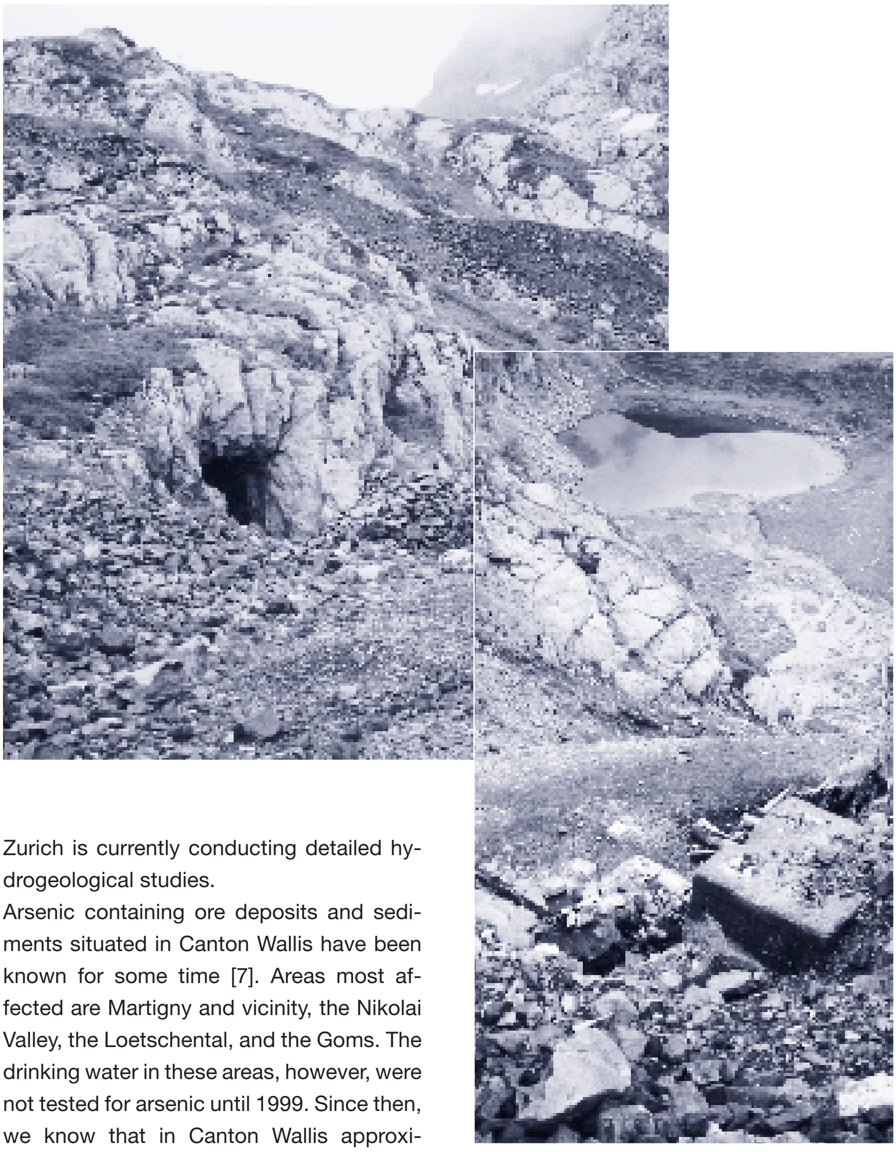


Fig. 3: Arsenic concentrations in utilized thermal and mineral springs [from 3].

Does Drinking Water in Switzerland Contain Arsenic?

In Canton Ticino, environmental impacts of localized arsenic formations have been studied since 1992 [4]. In 1996, all public water supply systems in the Canton were tested for arsenic [5]. The results were rather surprising: water with arsenic concentrations of more than 10 µg/l were found only in the vicinity of Lugano (Sottoceneri), i.e., in Val Isone, in Val Colla, in Malcantone and near Barbengo-Morcote and the adjacent Italian province of Varese. About a dozen communities use drinking water resources that contain between 11 and 50 µg/l arsenic. These values are below the Swiss limit of 50 µg/l arsenic for drinking water, but above the 10 µg/l limit that the WHO recommends. In two cases, however, arsenic concentrations were significantly above both of these limits. Water samples from the Malcantone showed around 80 µg/l, and in neighboring areas in Italy, the concentrations were as high as 300 µg/l. Often the affected spring areas with the contaminated water are at some distance from known ore deposits. This suggests that the arsenic in these areas stems from glacial moraines, river sediments and soils. Weathering and erosion of ore deposits situated further up in the watershed are at the origin of this material, and as a result, arsenic concentrations between 100 and 800 mg/kg can be found. In the area north of Lugano, local pyrite or iron oxide containing gneisses and schists are suspected to be the origin of the arsenic. Impacted areas of the Sottoceneri comprise approximately 500 km^2, affecting about 5000 inhabitants.

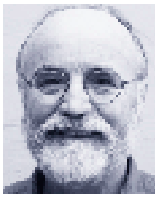
Alarmed by the results found in Canton Ticino, the Canton Grisons decided to test all of the 336 public water supplies in 1998. In 312 drinking water samples, arsenic concentrations were below 10 µg/l, while 21 samples had arsenic concentrations between 10 and 50 µg/l. Three samples exceeded the Swiss limit of 50 µg/l. The maximum concentration found was 170 µg/l [6]. Affected are mainly the Val Poschiavo and two individual springs in the upper Engadin. In Val Poschiavo, the occurrence of arsenic is a regional phenomenon, and the situation is similar to the one in Canton Ticino. The number of people affected is not yet known in detail because a large number of private water supplies are also impacted. ETH



Photos: H.-R. Pfeifer, Lausanne

View looking up to the entry of the abandoned arsenic mine of Salanfe in the lower Wallis, and looking down to Lake Ottans, situated below the mine. Between 1904 and 1928, over 700 tons of arsenic were extracted from this mine, and the soils and the water of the surrounding area are heavily contaminated.

Hans-Rudolf Pfeifer is Professor for Geochemistry and Director of the Geochemical Laboratory in Earth Sciences at the University of Lausanne (Centre d'Analyse Minérale, BFSH 2, 1015 Lausanne). For the last 10 years, Hans-Rudolf Pfeifer has worked on trace element contamination of the environment, in particular arsenic, in water, soils and plants. He is coordinating the interdisciplinary curriculum in Environmental Sciences at the "Ecole Lémanique des Sciences de la Terre et de l'Environnement" in cooperation with the University of Geneva.



Jürg Zobrist, inorganic chemist in the department "Water Resources and Drinking Water" at EAWAG. His research focuses on processes that control the quality of ground water and streams and that are important in the protection of water resources.

Zurich is currently conducting detailed hydrogeological studies.

Arsenic containing ore deposits and sediments situated in Canton Wallis have been known for some time [7]. Areas most affected are Martigny and vicinity, the Nikolai Valley, the Loetschental, and the Goms. The drinking water in these areas, however, were not tested for arsenic until 1999. Since then, we know that in Canton Wallis approximately 14 000 people live in areas where the drinking water contains between 12 and 50 µg/l arsenic [8].

Risks and Possible Remediation

Although detailed studies are not yet available for all of Switzerland's regions, we can assume that health risks related to arsenic come primarily from the consumption of drinking water with elevated arsenic concentrations. In most cases where the Swiss limit of 50 µg/l is exceeded, communities have responded immediately by abandoning that particular spring or by mixing the contaminated water with arsenic free water. There are several localities, however, where long-term solutions have to be found in order to guarantee an adequate drinking water supply for the next 20 to 30 years that is free of arsenic.

In many cases, there are plans to solve the problem by developing new springs and groundwater sources, which is relatively expensive. In some cases, it would be worthwhile considering the use of arsenic removal technologies, such as membrane filtration or iron and aluminum oxide filters. Which solution will ultimately be the appropriate and most cost-effective one, largely depends on whether or not Switzerland will keep its current limit for arsenic in drinking water of 50 µg/l, or will adopt the 10 µg/l limit which has already been applied in the European Union.

In Switzerland there is currently no legal limit for arsenic concentrations in soils. Outside of the areas impacted by arsenic described here, agricultural soils typically contain less than 10 mg arsenic per kg soil [9]. Even in the industrial sites that have been examined so far, arsenic contaminations are lower than those found in areas impacted by naturally occurring arsenic.

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Does the Fuel Oxygenate Methyl-tert-butylether (MTBE) Threaten the Ground Water?

Methyl-tert-butylether (MTBE) is one of the most important synthetic chemical compounds world wide. Although simple partition models reveal that MTBE remains primarily in the atmosphere, there is growing evidence that, similarly to chlorinated solvents, it may pose a threat to ground water. EAWAG is currently investigating immission paths and long-term behavior of this quite mobile and poorly degradable substance.

MTBE is used almost exclusively as antiknock agent in gasoline, and has as such replaced the previously used tetraalkyl lead compounds. Currently, its global use amounts to about 20 million tons annually, of which 60% are used in the USA, 15% in Europe, and still 0.5% in Switzerland [1]. The immense demand in the USA is due to the Clean Air Act amendments from 1990 that require a minimum content of oxygen in gasoline sold in areas with high air pollution levels. There is, however, an ongoing debate on the actual effect of MTBE on the reduction of traffic emissions. In Europe, the MTBE content in gasoline is restricted to 15 vol %. The average MTBE content in the European gasoline pool is 2%, though MTBE use varies considerably between countries and in time (Fig. 1).

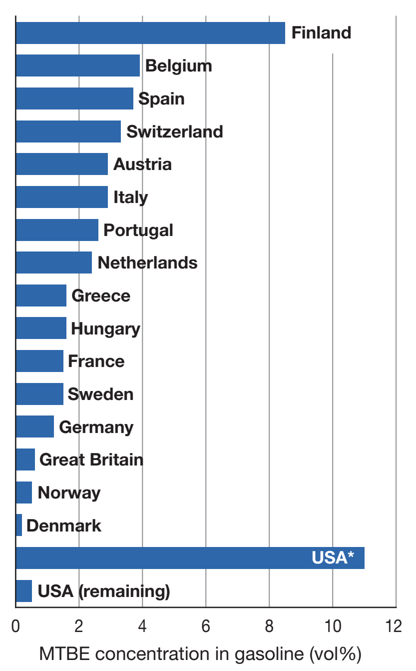

Fig. 1: MTBE is used as an antiknock agent in gasoline. The MTBE content of gasoline, indicated here are mean values from 1996/97, differs substantially among European countries. Furthermore, variations within each country may be of equal magnitude.
*** = Regions in the US where a minimum content of oxygen in gasoline is required to curb traffic emissions.**

MTBE has a negative effect on taste and odor of drinking water even in concentrations as low as 2–50 µg/l. The substance exhibits a low level of acute toxicity, however, some chronic exposure studies with rodents suggest a carcinogenic potential whereas other studies do not. If this implies a potential carcinogenic effect for humans remains unclear at the moment.

Insufficient Risk Analysis – Devastating Consequences for the Environment

Equilibrium partition modeling of the environmental behavior of MTBE [2] reveals that this compound remains almost exclusively in the atmosphere where it decomposes quite rapidly. From this viewpoint, the use of MTBE is considered as noncritical for the environment. However, due to its high water solubility, MTBE is, in fact, quite a problematic compound. Once present in aquatic environments, it is characterized by high mobility and poor biodegradability compared to other gasoline components. American studies have shown that numerous drinking water resources are contaminated with MTBE. As a result, the state of California requires a warning label for gasoline containing MTBE at filling stations, and by 2003 the use of MTBE will be entirely banned from gasoline. Furthermore, a secondary contaminant level of 5 µg MTBE per liter of drinking water was established. Within the last few years, the use of MTBE has also become an important environmental issue in Europe. The present spectrum of opinion ranges from advocating an increased use of MTBE, presented by the German Ministry of the Environment in February 2000, to a total phase-out in Denmark. Moreover, the Minister for Environment and Energy in Denmark calls for a ban of MTBE as gasoline additive within the European Union. European maximum contaminant levels or guideline values for MTBE in ground water or drinking water have not been established so far. Preliminary values in the range from 2 to 30 µg/l have been proposed in Switzerland, Denmark and Germany. Failure of the equilibrium partition models to predict the behavior of MTBE shows striking parallels to chlorinated hydrocarbons such as trichloroethylene. For decades, these compounds range among the most recalcitrant and widespread groundwater contaminants, although they also remain primarily in the atmosphere under equilibrium conditions.

Nonpoint and Point Sources of MTBE

Previous environmental assessments of MTBE did not take into account that MTBE may be introduced into ground water both from diffuse and point sources. Diffuse sources comprise atmospheric washout, road runoff, and infiltration of MTBE-contaminated surface water. Point immissions mostly occur due to accidental releases during transport and storage of gasoline. Industry and authorities in Europe often presume that as a result of the stringent fuel storage guidelines, tank leakages rarely occur in Europe. This view is questioned by an increasing number of reports on point source releases from leakages at gasoline stations and storage facilitites that have led to contamination of ground water with MTBE [1]. Our preliminary estimates reveal

Fig. 2: After the accident of a tank train in Zurich-Affoltern in 1994, about 5 tons of MTBE reached the underground through infiltration of unburned gasoline.

about 20 major annual gasoline releases in Switzerland, and 1000 in the EU [3]. Figure 2 illustrates a point source contamination by MTBE from a tank train spill in Zurich-Affoltern in 1994. High MTBE concentrations can still be measured in the affected aquifer six years after the accident (Fig. 3). Diffuse and point sources typically differ substantially in the degree of contamination. Background concentrations of MTBE in Swiss and European drinking and ground water currently are in the sub µg/l range, with 20 to 30% positive findings in the investigated wells (Fig. 4). Concentrations above 5 µg/l are more likely due to point immissions of MTBE. In the immediate vicinity of point sources, MTBE concentrations may reach the high mg/l range. However, it is still difficult to assess the importance of the various immission paths and future trends of MTBE loads in ground water. EAWAG is working to this end, in collaboration with cantonal authorities and water works.

Long-term Behavior in the Underground

Numerous field studies reveal that MTBE causes larger contaminant plumes than any other gasoline component. However, the degradation processes and rates of MTBE and its metabolites under different (bio)-geochemical conditions are not well understood. Laboratory experiments show that various microorganisms can degrade MTBE under controlled conditions in a rather oxygen-rich environment. However, MTBE degradation at contaminated sites cannot be reliably quantified with a classical mass balance approach. Even at a site with an injection of a defined amount of MTBE, well-known hydrogeological parameters and a dense network of sampling wells, it was not possible to unequivocally determine

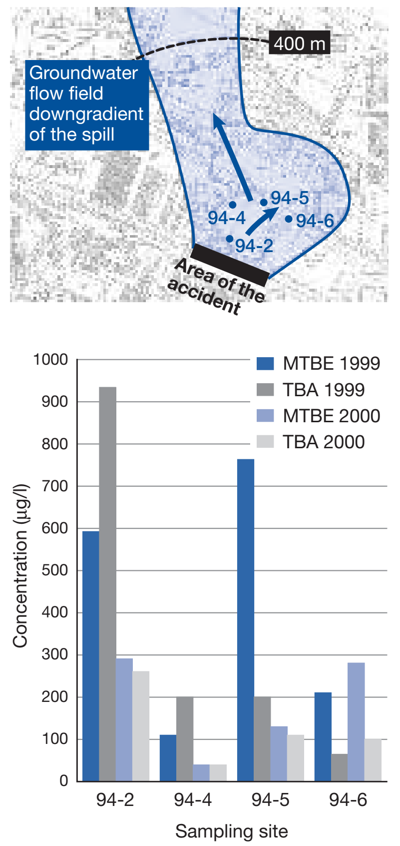

Fig. 3: Measured MTBE and TBA concentration (bottom) at 4 selected sampling sites (top) adjacent to the tank train spill in Zurich-Affoltern in the years 1999 and 2000.
The groundwater flow field downgradient of the spill is marked in light blue and the arrows indicate the groundwater flow direction.

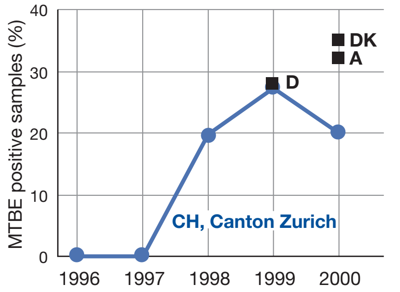

Fig. 4: Frequency of MTBE detection in ground water in the Canton of Zurich during 1996–2000 (blue curve). Comparison with results of one-time monitoring studies in Denmark, Germany and Austria.
Detection limits: CH and D 50 ng/l, A 100 ng/l, DK no indication.

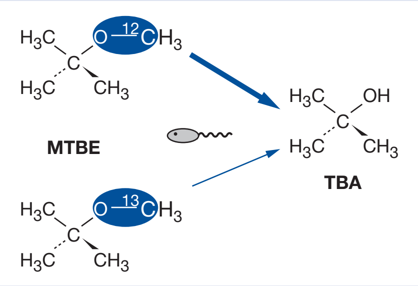

Fig. 5: Faster microbial degradation of MTBE containing ^{12}C isotopes and, thus, enrichment of ^{13}C isotopes in the remaining MTBE fraction.

MTBE biodegradation after a period of eight years [4]. Detection of the primary degradation product of MTBE, tert-butyl alcohol (TBA), must not be taken as a proof of biodegradation since it is also present in gasoline in substantial amounts [5]. The problem of providing evidence of MTBE degradation in gasoline-contaminated subsurface systems ultimately limits the choice of possible remediation techniques. Regarding remediation, a distinction is necessary between active measures where, for example, contaminated ground water is pumped off and treated, and passive measures, which make use of the naturally occurring degradation processes in the subsurface ("natural attenuation"). To test the success of passive remediation measures, appropriate degradation parameters are examined over time. Since such an assessment is not yet possible without ambiguity in the case of MTBE, passive measures for MTBE-contaminated ground water are often not applicable at this point in time.

To obtain a better understanding of the long-term behavior of recalcitrant substances such as MTBE in the underground, EAWAG is applying a new method to determine the isotopic composition of organic pollutants along a contaminant plume [6]. Microbial degradation of MTBE produces the corresponding alcohol TBA via cleavage of the ether bond. In this process, the ether bond is cleaved at varying rates for the two stable isotopes of carbon, ^{12}C or ^{13}C, and leads to an enrichment of the heavier ^{13}C isotope in the remaining MTBE (Fig. 5). This effect has already been substantiated by laboratory experiments [7]. Combination of this method with a determination of the water age along the contaminant plume and subsequent integration of the data obtained into groundwater models will allow a quantitative description of the behavior of recalcitrant contaminants in the underground without the need for error-prone mass balances of pollutants. Preliminary investigations at the contaminated site of Zurich-Affoltern revealed no difference in the carbon-isotope composition of MTBE along the contamination plume, a fact that contradicts the hitherto assumed MTBE degradation at this location. However, this method is still not sensitive enough to carry out extensive field investigations outside the plume center. Therefore, EAWAG is currently developing more efficient enrichment methods, which will precede the measurement of isotope composition.

Extensive Risk Assessment is Compulsory

The problems posed by MTBE exemplify that a sound assessment of environmentally harmful substances should take into account both the partitioning between and the degradation within environmental compartments as well as relevant emission scenarios. Equilibrium partition models implying that MTBE remains in the atmosphere are inappropriate for the assessment. Possible substitutes for MTBE should be evaluated prior to their use to avoid future problems with antiknock agents.

Torsten Schmidt, chemist and scientist in the department "Water Resources and Drinking Water". Research interests: Environmental behavior of gasoline additives and methodological development of compound-specific isotope analysis (CSIA) as a tool in environmental research.

Coauthors:
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Antibiotics – The Flipside of the Coin

Antibiotics that are widely used in human and veterinary medicine are detectable today in Swiss waste waters and surface waters. Studies performed at EAWAG show that there are different pathways by which human and veterinary antibiotics find their way into the aquatic environment: human antibiotics are found in the effluents of wastewater treatment plants and in lower concentrations in surface waters; they are not completely removed during the wastewater treatment process. Veterinary antibiotics, on the other hand, are rarely detected in the wastewater effluent, but can be found in specific surface waters. They are carried with animal excreta and liquid manure from the pastures directly into streams. It is not quite clear yet what effects the antibiotics have on ecosystems and humans – particularly with respect to the spread of antibiotic resistance.

Pharmaceuticals are released into the aquatic environment via human and animal excreta and by improper disposal. There are two different pathways (Fig. 1). Human pharmaceuticals originating from private households and hospitals first reach wastewater treatment plants (WWTPs). The pharmaceuticals are only partially removed by the wastewater treatment process and ultimately reach surface waters. With the application of liquid manure or animal excreta, veterinary pharmaceuticals are spread across fields or pastures from where they are washed directly into streams or infiltrate into the soil and reach the ground water. Most pharmaceuticals are found in natural waters in only very low concentrations. Despite this general finding, the question arises whether these traces of pharmaceuticals pose a risk for aquatic ecosystems. Antibiotics are of particular interest because we do not currently know whether their presence in natural waters contributes to the spread of antibiotic resistance in potentially pathogenic microorganisms.

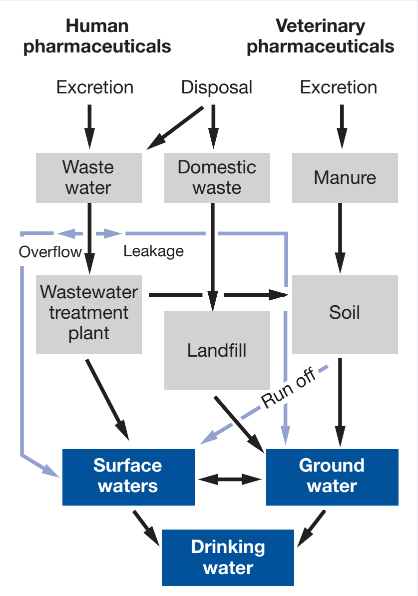

Fig. 1: Human and veterinary pharmaceuticals reach natural waters via different pathways.

Use of Antibiotics in Switzerland

In 1997, approximately 90 tons of antibiotics (including antibacterials like fluoroquinolones and sulfonamides) were used in Switzerland – 38 % in human medicine and 62 % in veterinary medicine [1–3]. In veterinary medicine, antibiotics are used as growth promoters, as prophylactic or therapeutic amendments to animal feed, or for the therapeutic treatment of individual animals. Because of a ban on growth promoters in 1999, they are essentially no longer in use in Switzerland [3]. The volume of antibiotics in feeds has also dropped – by 33 % by the year 2000 – to a level of 17.3 tons annually. Therapeutic use of antibiotics for individual animals, on the other hand, has increased by 27 %, reaching a level of 21.6 tons per year. The volume of antibiotics used annually in human medicine is around 34 tons and has remained fairly constant since 1992. The β-lactam antibiotics which include penicillins and cephalosporins represent the largest fraction of human antibiotics, accounting for approximately 18 tons in 1997. They are followed by 5.5 tons sulfonamides, 4.3 tons macrolides and 3.9 tons fluoroquinolones. Considering the magnitude of these numbers, it is important to know what portion of these antibiotics is actually reaching the environment. A few recent studies in Germany and the U.S. were able to detect antibiotics in surface waters [4–6]. But what is the situation in Switzerland? EAWAG is investigating this question. Since β-lactam antibiotics are chemically unstable, EAWAG has focused on the fate of sulfonamides, macrolides and fluoroquinolones. The study aims at determining environmental pathways for these antibiotics, their mass fluxes, their behavior in wastewater treatment processes and their introduction into natural waters. The first task was to develop analytical techniques for the detection of individual antibiotics.

Sulfonamide and Macrolide Antibiotics

Concentrations of sulfonamide and macrolide antibiotics were determined in 24-hour composite samples from four wastewater treatment plants in Canton Zurich and in random samples from various streams and lakes in the Cantons of Zurich and Lucerne. Antibiotics were enriched by solid phase extraction and analyzed with liquid chromatography directly coupled to mass spectrometry. Figure 2 summarizes the observed concentration ranges. Note that for the veterinary antibiotic sulfamethazine, effluents from WWTPs exhibited lower concentrations than surface waters, indicating that veterinary antibiotics are leached from ani-

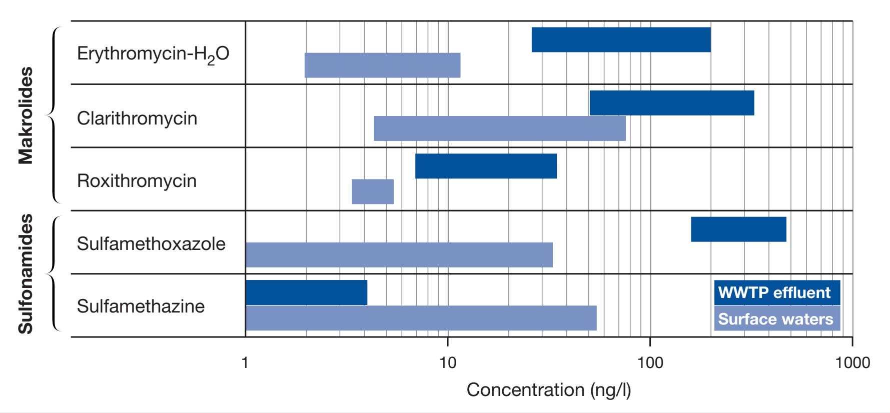

Fig. 2: Sulfonamide and macrolide concentrations in effluents of wastewater treatment plants (WWTPs) and in surface waters of the Cantons Zurich and Lucerne.

mal excreta and are washed directly from the fields into the surface waters. More recent studies performed at EAWAG showed that the antibiotic sulfamethazine could be detected in the liquid manure from selected farms which use this antibiotic as a therapeutic drug for pigs and calves. Sulfamethazine and its metabolite N^4-acetyl-sulfamethazine were found in concentrations of up to 8.7 mg and 2.6 mg, respectively, per kg liquid manure with a dry matter content of 3.3% [7, 8].

In contrast to veterinary antibiotics, antibiotics used in humans showed higher concentrations in the effluents of wastewater treatment plants than in the streams and lakes examined for this study (Fig. 2). The observed concentration differences correspond to dilution factors of 2 to 20. The difference is due to the fact that human antibiotics are first discharged with domestic and hospital waste water into treatment plants; after being partially removed in the WWTP, they are then released into surface waters.

Depending on the catchment area of the wastewater treatment plant, the antibiotic loads can vary dramatically. Daily loads of the macrolide antibiotics erythromycin, clarithromycin and roxithromycin in the effluent of the WWTP Werdhoelzli are 5 to 30 times higher than the loads for these antibiotics in the effluent of the Duebendorf treatment plant. For example, the daily load for clarithromycin at Werdhoelzli was 48 g, while it was only 1.6 g in Duebendorf. This difference can be attributed to the fact that the Werdhoelzli plant serves approximately eight times more people than the Duebendorf plant. Additionally, a large number of commuters work within the catchment area of the Werdhoelzli plant, and most of the hospitals in Zuerich also are located in this area.

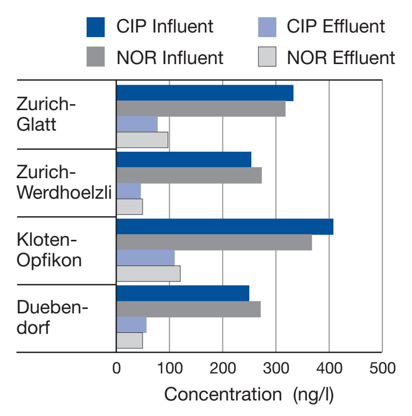

Fig. 3: Concentrations of the fluoroquinolones ciprofloxacin (CIP) and norfloxacin (NOR) in the influent and effluent of wastewater treatment plants in Canton Zurich.

Fluoroquinolone Antibiotics

The two most important fluoroquinolone antibiotics used in human medicine are ciprofloxacin and norfloxacin. In order to follow the fate of these antibiotics, 24-hour composite samples were measured in the influent and effluent of four WWTPs in Canton Zurich [9–11]. Influent samples were taken before the mechanical treatment step; effluent was sampled after biological treatment and filtration. Fluoroquinolones were detected using a new method. After solid phase extraction, they were analyzed by a method coupling liquid chromatography and fluorescence detection. Figure 3 shows that the concentrations of the two fluoroquinolones in the influent are clearly higher than their concentrations in the effluent. Our studies showed that the wastewater treatment plant removes 70–80% of the fluoroquinolones; the remaining 20–30% of the load is discharged into surface waters. In the river Glatt, for example, which receives effluent from several wastewater treatment plants, this leads to ciprofloxacin and norfloxacin concentrations of up to 18 ng/l. Additional investigations on the fate of fluoroquinolones in wastewater treatment plants showed that these compounds were not degraded during the treatment process, but were merely adsorbed to sewage sludge.

Until now, neither fluoroquinolones nor sulfonamides or macrolides have been detected in ground water or drinking water in Switzerland.

EAWAG Projects Investigating the Removal of Antibiotics from Waste Water

Current and future studies at EAWAG are aimed at examining the fate of antibiotics in wastewater treatment plants in more detail and the comparison of different treatment technologies. Within the EU project POSEIDON, different methodologies for the treatment of waste water and drinking water are evaluated with respect to elimination of antibiotics and other pharmaceuticals. Of particular interest is a comparison of newer membrane technologies with conventional activated sludge and fixed bed processes used in wastewater treatment. One advantage of the membrane technology is that higher sludge concentration and sludge age can be achieved. The hope is that microorganisms with slower growth rates can establish themselves in the activated sludge and become specialized in degrading specific contaminants, such as antibiotics. In the interdisciplinary EAWAG project NOVAQUATIS, approaches are explored in which pharmaceuticals or other undesirable compounds are not even released into the wastewater stream, but are collected at the source. In a special no-mix toilet, urine is collected separately, only diluted minimally with flushing water, and then fed into a technical clean-up process.

Risk Assessment

Because of their persistence in water, the assessment of the effects that antibiotics have in the aquatic environment is extremely important. Of particular interest is the


R. Schaffner, EAWAG

Antibiotics, a blessing if used appropriately.

spread of resistance to antibiotics. According to our current knowledge, resistance is transferred to humans primarily in hospitals, but possibly also via foods from animal products [12]. In addition the question arises whether antibiotics can contribute to the spread of resistance at concentrations which are found in the environment. This and other aspects related to the widespread occurrence of antibiotic resistance are addressed in the recently launched National Research Program NRP 49 by the Swiss National Science Foundation.

Another effect that is caused by prolonged use of antibiotics is the increased appearance of allergies, which has been observed over the last several years. Allergic reactions to penicillin, for example, may be caused by repeated contact with antibiotics at relatively low concentrations [13].

An assessment of the ecotoxicological effects of antibiotics present in trace concentrations is extremely difficult at this point in time, mostly because we do not have the data to judge the effects. The EU is currently preparing guidelines for the ecotoxicological risk assessment of human pharmaceuticals that will be part of the approval procedure for new drugs. Such guidelines exist for veterinary pharmaceuticals since 1998.

Targeted Use and Proper Disposal

There is no question that antibiotics are indispensable in the medical treatment of humans and animals. The release of these antibiotics into the environment, however, could be minimized by their targeted use and proper disposal. Antibiotics should only be used if they are really needed – and then at the correct dosage and over a sufficiently long time period. It is therefore most important that physicians and patients are informed about the problems. In veterinary medicine, a first step towards reducing the consumption of antibiotics in Switzerland has already been made with the ban of growth promoters. Serious consideration should also be given to avoiding the use of identical or similar preparations in both humans and animals. There is growing evidence for so-called cross-resistance, where the resistance a microorganism has acquired towards a particular antibiotic can also cause resistance to other antibiotics that are chemically similar or are in the same family as the original antibiotic.

Conclusion: There is a major need for research before we can judge how dangerous the antibiotics are that we release into the environment. We need to know more about how antibiotics behave in the environment, their ecotoxicological effects, to what degree they are eliminated in wastewater and in drinking water plants, and how they behave in sewage sludge and in liquid manure.

Acknowledgement

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Additional information is available at:

- www.eu-poseidon.com
- www.novaquatis.eawag.ch
- www.snf.ch/en/rep/nat/nat_nrp_49.asp
- www.emea.eu.int

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How Does the Pill Affect Fish?

Chemicals with estrogenic effects – so-called environmental hormones – are believed to be responsible for the promotion of female traits in male fish. As part of the EU program COMPREHEND, EAWAG has investigated the effects of wastewater treatment plant effluents on male rainbow trout and found increased levels of vitellogenin. This egg yolk protein precursor is normally found in high concentrations in female fish only. Effluent samples from wastewater treatment plants, which were taken during the fish exposure, underwent chemical ultra-trace analysis and *in vitro* testing for estrogenic activity. In some samples, elevated hormone concentrations could be detected and estrogenic activity could be confirmed.

Environmental chemicals that interfere with hormonal systems of humans or animals are called environmental hormones. Of primary interest are the so-called estrogens that mimic female sex hormones. These include:

- the natural estrogen estradiol and its transformation products, estron and estriol;
- synthetic estrogens, such as ethinylestradiol, the active ingredient commonly found in oral contraceptives;
- high production volume manufactured chemicals that are for instance used in industrial detergents (alkylphenol polyethoxylates and their degradation products) and in plastics (e.g., bisphenol A).

Many of these hormonally active chemicals can be detected in aquatic systems. Natural and synthetic estrogens, for example, are excreted by humans and transported to wastewater treatment plants where they are eliminated to some extent but also partially washed out into surface waters.

Mechanism of Action of Environmental Hormones

In fish, indigenous production of estradiol induces synthesis of the protein vitellogenin in the liver, the precursor of egg yolk proteins that is transported via the blood stream to the oocytes in the ovaries. It is normally only found in large quantities in the blood of sexually mature females. This is why high vitellogenin concentrations discovered in male fish in the UK in the mid-1990s caused some alarm. Fish exhibiting elevated vitellogenin concentrations were from stream sections below wastewater treatment plants; vitellogenin production was attributed to the presence of estrogen-like compounds in the treatment plant effluent. In addition, it was shown that male fish in contaminated waters showed a significant higher incidence of testicles containing female egg cells, a phenomenon called "intersex". This has recently also been observed to occur in whitefish in Lake Thun.

We can only speculate on the effect of estrogen-like chemicals in humans. It has not yet been demonstrated that postulated reductions in sperm count and sperm quality and increases in testicular cancer are linked to the increased occurrence of hormonally active chemicals in the environment.

Over 500 Potential Hormonally Active Chemicals

Over the last few years, high priority programs have been initiated on an international level to identify potential hormonally active chemicals from among the roughly 80,000 chemicals that are currently in use. The EU has recently published a list of 553 chemicals, plus 9 natural and synthetic steroid hormones, that are "suspected to interfere with hormonal systems in humans and animals living in the wild" [1]. Simultaneously, national and international projects, in which EAWAG is a participant, are examining the occurrence of environmental hormones in surface waters and determining their effect on aquatic organisms. National research programs include the National Research Program "NRP 50 – Endocrine Disruptors", started in 2001, and the network project "Fish Decline in Switzerland", which among others examines whether or not hormonally active chemicals are responsible for the observed fish decline in Swiss surface waters. Results presented in this article were obtained under the EU project COMPREHEND (**COM**munity **P**rogram of **R**esearch on **E**nvironmental **H**ormones and **EN**docrine **D**isrupters) that was completed by the end of 2001. The primary goals of COMPREHEND were to examine the presence of hormonally active chemicals in effluents of industrial and communal wastewater treatment plants all over Europe and to develop new detection methods.

Elevated Vitellogenin Concentrations also in Swiss Fish

For a period of two weeks, male rainbow trout were exposed to the effluent of the wastewater treatment plant (WWTP) Rontal in Canton Lucerne. Control fish were held for the same period of time in the stream above the point where the effluent is discharged into the river and in the laboratory. Fish were not fed during their exposure. Figure 1 shows that in control fish, vitellogenin concentrations decreased over the duration of the experiment. This is possibly due to the fish having been fed fish food containing hormonally active chemicals during the acclimatization phase. Fish exposed to the effluent of the WWTP, on the other hand, showed increased levels of vitellogenin, indicating the presence of hormonally active compounds.

Combined Chemical and Biological Analysis

Concurrent with the fish exposure experiments, water samples were taken from the effluent of the WWTP Rontal and examined for the presence of hormonally active chemicals, combining two different analytical tools. Chemical ultra-trace analysis was used to determine concentrations of known environmental hormones in the water samples. Estrogenic activity in the water samples was examined using a biological test system, in this case, a yeast estrogen screen containing a human estrogen receptor and a reporter gene. If hormonally active chemicals are present, they bind to the receptor, activate the reporter gene and can subsequently be detected by a biochemical color reaction. The intensity of the color is a

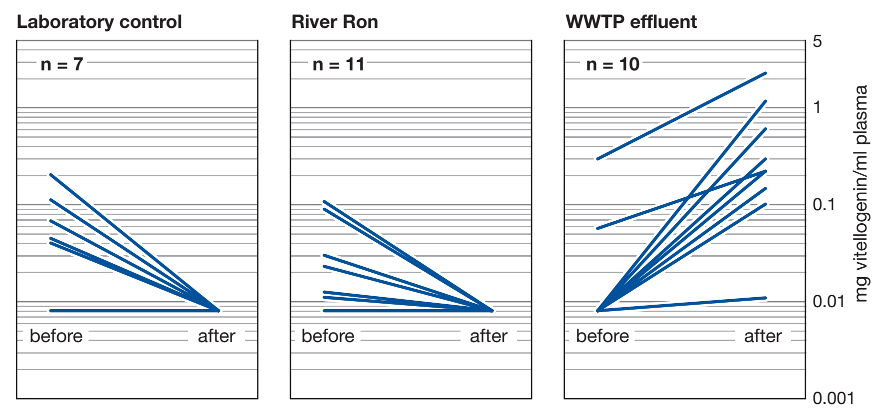

Fig. 1: Vitellogenin induction in individual male rainbow trout (n = number of male fish).

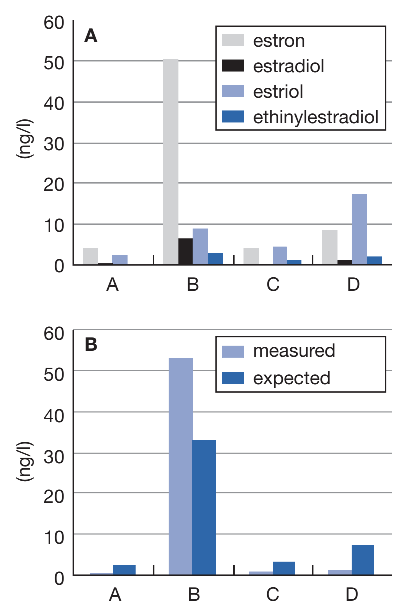

Fig. 2: Analyses of four water samples from the effluent of the WWTP Rontal
(A) Concentrations of natural and synthetic steroid hormones.
(B) Expected and measured estrogenic activities expressed as estradiol equivalents.

measure of the estrogenic activity of the sample and is expressed in estradiol equivalents. Either one of these two methods on its own is insufficient for characterizing a water sample; the combination of the two however, gives us information on actual concentrations of environmental hormones and on the estrogenic activity of a given sample, resulting in a number of advantages:

- a lower probability of false negative results, due to inhibition of the yeast screen;
- identification of water samples in which individual hormonally active components are present below the minimum effect concentration, but show estrogenic activity in combination [2];
- the possibility of identifying unknown environmental hormones in hormonally active samples.

Expected and Measured Concentrations in WWTP Effluent

Assuming a ratio of 1:1 between men and women and that 60 % of the women are menstruating and 0.8 % are pregnant, we can calculate an average excretion of 3.1 µg estradiol per day and person (including men) [3]. Calculating the estradiol discharge for the population served by the WWTP Rontal, and assuming that 50 % of steroid hormones are eliminated in the treatment process, we would expect an average estradiol concentration of 1.6 ng/l in the WWTP effluent. This value compares well with the measured average concentration of 2.0 ng/l estradiol as determined by chemical analysis (Fig. 2A). A similar result was found for ethinylestradiol, where the measured concentration of 1.5 ng/l is in good agreement with the expected concentration of 3 ng/l (Fig. 2A). It should be noted that sample B showed exceptionally high concentrations of estradiol and estron.

Expected and Measured Hormonal Activities in WWTP Effluent

Based on chemically determined concentrations of hormonally active compounds, the overall estimated estrogenic activity of a water sample (expressed in estradiol equivalents) may be calculated using the relative hormone activities of the individual compounds, as determined with the yeast estrogen screen (Fig. 2B). Assigning estradiol a reference activity of 1, the degradation products estron and estriol show relative hormonal activities of 0.474 and 0.003, respectively, while the synthetic steroid hormone ethinylestradiol shows the same activity as estradiol. Estrogenic activities of industrial chemicals, on the other hand, are typically lower by several orders of magnitude. Since they can be present in far higher concentrations than natural and synthetic estrogens, however, they cannot be neglected. Nonylphenol, for example, has a hormonal activity roughly 40,000 times lower than estradiol, but is present in the effluent of the WWTP Rontal at concentrations that are 1000 times higher than estradiol, resulting in an estrogenic activity of 0.04 ng/l.

Estrogenic activities measured by the yeast estrogen screen generally agree well with the calculated activities. Solely in sample B, the calculated estrogenic activity is lower, accounting only for 60 % of the measured activity (Fig. 2B). This is strong indication that there are other, possibly unknown, chemicals present that exhibit hormonal activity. They need to be identified using chemical analytical methods.

Additional research in this area is essential in order to gain a more complete picture of the complex problem of endocrine disruption. Beyond identifying hormonally active compounds and determining their concentrations, it will be important to investigate the effect of environmental hormones and mixtures thereof on populations, aquatic communities and entire ecosystems.

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Pathogens in (Drinking) Water?

Drinking water quality is generally good in most industrialized countries. Despite this, there have been recurrent “accidents” worldwide over the last few years, which have often lead to illness patterns of epidemic proportions. Drinking water quality is routinely monitored for microbial contamination based on cell counts of so-called “indicator” organisms. Such organisms include, for example, harmless *Enterobacteriaceae,* which are part of the normal flora of the intestinal tracts of humans and other mammals. But for some emerging pathogens that have shown up more frequently in recent years, the concept of testing only for conventional indicator organisms is inadequate. Molecular techniques, based on biochemical, genetic or immunological principles, are gaining importance. These methods allow selective detection of certain pathogens and are usually more rapid and more sensitive than traditional methods.

Microorganisms are present in any water, but the situation becomes of critical concern when viruses, bacteria or protozoa with human pathogenic potential are present in large numbers [1]. This not only applies to drinking water; the spread of microbial diseases may also occur by taking a bath or a shower with contaminated water as well as through the consumption of raw fruit or vegetables that have been watered or washed with contaminated water. It is also important that water used in industrial aquaculture of fish, shrimps or mussels, be free of any pathogens.

The Century of Drinking Water Plagues

A typical characteristic of diseases caused by pathogens in drinking water is the occurrence of acute symptoms due to replication of the pathogen in the host. In contrast, consumption of chemically contaminated drinking water typically leads to chronic disease. In the 1800s, the “century of drinking water plagues”, catastrophic epidemics caused by contaminated drinking water were almost a part of daily life in central Europe. The larger cities in particular, regularly fell victim to cholera, typhoid fever, and dysentery. As many as 50% of the people contracting waterborne diseases actually died. Even today, these “classic” drinking water diseases occur sporadically in industrialized countries, although normally in very localized incidents. A few of the more recent cases are listed in Table 1.

Generally speaking, drinking water quality in Switzerland is excellent, and there is no need for concern. Even with 60% of our drinking water being distributed to households without any kind of treatment, the legal requirements for drinking water quality are fully met. There could, however, be a considerable number of unreported cases of disease caused by drinking water contaminated with pathogenic organisms. Improved epidemiological data collection, i.e., the introduction of a requirement to report all cases as is being practiced in the USA, the UK, Australia or Sweden, would also be highly desirable in Switzerland.

Legionnaire’s Disease on the Rise

Industrialized countries are experiencing increasing numbers of cases caused by so-called “emerging” pathogens (Tab. 2). In most instances, the causative agents are well known, but have been observed only very rarely as pathogenic microorganisms. Legionnaire’s Disease is such an example. It is caused by the bacterium *Legionella pneumophila* and has been diagnosed in increasing numbers over the past several years. This bacterium and closely related species are present in small numbers in all natural waters, can survive in amoeba and

Year	Place	Cause	Number of persons ill (dead)
2001	Pamplona, SP	*Legionella*-infection in hospital	18 (3)
2001	Paris, F	*Legionella*-infection in hospitall	12 (6)
2001	Murcia, SP	*Legionella*-infection in village	315 (2)
2000	Walkerton, CAN	Heavy downpour washes pathogenic enterohemoragic *E. coli* (EHEC) from liquid cow manure into drinking water supply	2 000
1998	La Neuveville, CH	Defective pump causes back-up of waste water and overflow into ground water; pathogens: *Shigella sonnei, Campylobacter jejuni*	1 600
1998	All of Switzerland	*Legionella*-infection	78 (8)
1993	Milwaukee, USA	Defective filters in drinking water processing plant cause spread of highly chlorine-resistant oocytes of *Cryptosporidium parvum*	403 000
1979/80	Ismaning, DE	Contamination of a drinking water source by defective sewer line causes spread of bacterial dysentery (*Shigella* and others)	2 450
1963	Zermatt, CH	Discharge of untreated waste water into Zmuttbach, a stream used as drinking water source, and simultaneous malfunction of chlorinating plant in Zermatt led to the spread of *Salmonella typhii*	437

Tab. 1: Examples of major incidents involving drinking water in industrialized countries.

Pathogen		Disease symptoms
Bacteria	Pathogenic *Escherichia coli* (EHEC)	Dyspepsis, severe diarrhea
	Pseudomonas aeruginosa	Skin and ear infections
	Legionella pneumophila	Pneumonia, "Pontiac fever"
	Aeromonas hydrophila and others	Diarrhea, wound infections
	Campylobacter jeuni and others	Intestinal infections, diarrhea
	Yersinia enterocolitica	Enteritis, inflammation of the intestines, possibly arthritis
	Chlamydia	Eye infections
Viruses	*Calici* viruses	Flu-like infections, summer influenza, sore throat
	Rota viruses	Severe diarrhea, especially in children
	Hepatitis A	Infectious jaundice
	Norwalk virus (small round virus)	Intestinal infections, particularly in children during winter
Protozoa and Parasites	*Cryptosporidium parvum*	Diarrhea, dangerous for children, the elderly and AIDS patients
	Pfisteria	Mostly fish diseases
	Giardia intestinalis	Diarrhea

Tab. 2: "New" pathogenic microorganisms and associated symptoms. For a number of these organisms, current information is limited about their occurrence, distribution pathways, effects and infectious dose.

biofilms, and are harmless to the human body if ingested in drinking water. If the bacterium reaches the lungs by inhalation of aerosols, however, it may cause severe pneumonias (Tab. 2). Aerosols may form in showers or in air conditioning systems. A risk only exists if the warm water systems are operated at too low temperature, i.e., below 55 °C, where *Legionella* can reproduce rapidly. Outbreaks of Legionnaire's Disease have caused numerous mortalities, especially in hospitals. According to the statistics of the Swiss Federal Institute of Public Health, Switzerland registers an average of 40–80 cases per year, with 10% of the infections resulting in death [1, 2]. For a number of gastrointestinal infections caused by (drinking) water, we have to assume that "new pathogens" in the form of viruses are responsible.

The Indicator Concept: Strengths and Weaknesses

Routine tests that determine the microbial quality of drinking water (as well as mineral water, swimming pool water, or process water) are not specifically looking for pathogens. Such analyses would be far too involved. Instead, the assumption is made that pathogens are excreted in human or animal feces together with harmless intestinal microorganisms and that they are subsequently distributed in water. If "indicator species" are identified, their presence suggests contamination of the water with human or animal feces. According to the World Health Organization (WHO), indicator organisms should satisfy the following conditions:

- be excreted by the host and always be present when pathogenic organisms are present,
- be present in larger numbers than the pathogens,
- be specific to feces,
- be more resistant to environmental stress and disinfection than the pathogens,
- not be pathogens themselves,
- be easily and quickly detected and enumerated by simple methods.

This rather demanding list illustrates why the "ideal" indicator organism may not exist. Worldwide, however, a number of different organisms have become the standard indicators (Tab. 3). The intestinal tract bacteria, *Escherichia coli* and enterococci, and the total number of heterotrophic bacteria (not as an indicator of pathogens but as a general measure of eutrophication) have become such generally accepted standard indicators. Additionally, other bacteria or viruses may be used as indicators in certain regions or in specific cases. The standard set for the maximum acceptable number of *E. coli* and enterococci in water in Switzerland is less than 1 cell per 100 ml for untreated, natural drinking water. That *E. coli* does not always adequately fulfill the role of an indicator organism was shown in a case in Milwaukee (Tab. 1): despite the fact that the drinking water was adequately chlorinated and fulfilled the regulatory requirements with respect to *E. coli* numbers, an outbreak of cryptosporidiosis occurred. This was due to the presence of oocytes (a permanent stage of the organism), which are extremely resistant to chlorination.

Traditional and Molecular Detection Methods

One especially difficult problem in the analysis of drinking water is that small numbers of organisms have to be detected in large volumes of water. Enrichment is, therefore, the first step in practically all methods designed to detect pathogens in drinking water. In classic culture techniques, which are easy and inexpensive to perform, individual *E. coli* and enterococci cells are transferred to agar plates of selective media where they multiply to form visible colonies. The drawback of this method is that it is rather time-consuming: it can take three working days before a result is obtained. Another disadvantage is the relatively poor selectivity of the approach.

The situation is even more challenging if one attempts to detect individual pathogens instead of indicator organisms. For many

Indicator organism	% in feces of mammals	Numbers per g feces	Advantages	Disadvantages
Escherichia coli	100	10^7–10^9	Easy to enumerate	Less resistant than some pathogens
Enterococci	100	10^5–10^6	Ubiquitous in waste water	Reservoirs in the environment
Clostridium perfringens	13–35	10^6–10^7	Resistant in the environment and towards disinfection	Difficult to culture because of anaerobic techniques
Coliphagen (F-specific)	6	10^1–10^2	Possibly models for enteroviruses	Not resistant in the environment

Tab. 3: Indicator organisms currently used to detect contamination of (drinking) water with feces and possibly by microbial pathogens.


P. Nadler, Kuesnacht

Safe drinking water – to be taken for granted?

pathogenic organisms, there are either no practical culturing techniques or the existing techniques are extremely time consuming, elaborate and expensive. For this reason, there is growing interest in using molecular techniques in microbial analyses of drinking water [3]. Many of these methods have been used successfully in medicine for the diagnosis of diseases caused by microorganisms. Unfortunately, they must be modified before they can be used to analyze drinking water.

For example, molecular techniques can detect fragments of nucleic acids that contain a specific sequence indicative of a certain pathogen. Even if only one cell (and so only one single fragment) with the desired nucleic acid sequence is present, the so-called PCR-method (polymerase chain reaction) can, in theory, selectively multiply this fragment until a detectable number of fragments has been produced. Other methods use antibodies; that is, they are based on the immunological detection of cell components specific for the pathogen of interest (overview in OECD report, in preparation). The coupling of antibodies or nucleic acid fragments to dyes can further simplify their detection. In terms of selectivity and time required for analysis, molecular methods clearly have an advantage over classical culturing methods. For some molecular methods, it is even conceivable that the sample processing could be fully automated. Molecular methods are likely to play a major role in basic research of the behavior of pathogenic bacteria and viruses during epidemic outbreaks; however, applications in routine analyses are still relatively uncommon. There is substantial hope that molecular methods can create enormous advantages for the detection of viruses as well. Expectations range from being able to detect pathogens by a "dip stick" method to on-line measurements employing glass fibers coated with antibodies that send light signals upon contact with pathogens, where the light signal is again picked up by optical fibers.

A Holistic Approach to Clean and Safe Drinking Water

The development and validation of molecular methods for drinking water analysis and the comparison to results obtained by classical methods is a research focus that is being pursued all over the world. A working group formed jointly by the OECD and the WHO, in which EAWAG representatives play a leading role, is currently working on a document that will present general guidelines. The document, due to be published this year, will summarize state-of-the-art concepts and methodologies for microbial drinking water analysis and present some thoughts on future developments. Experts agree that it is not necessary to create entirely new concepts; they would rather recommend a holistic approach, i.e., to work within the existing system of barriers (wastewater treatment plants, protective zones, disinfection in drinking water processing, etc.) and to incorporate and link information on water resources, climate and hydrology, monitoring of drinking water preparation, collection of epidemiological data regarding waterborne disease, risk assessments, to name a few.

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FORUM

Challenges in Ecological Risk Assessment

More than 100 000 chemicals have to be evaluated for their risks to human health and the environment. To achieve this goal, test methods as well as modeling and screening techniques have to be developed or improved. In addition, there is also an urgent need for more research concerning the effects of chemicals at the ecosystem level.

The world-wide chemicals industry produced 400 million tons of chemicals in 1995. Europe is the largest chemicals-producing region in the world, accounting for about 40 % of the total. There is an increasing social awareness of potential chemical hazards, which is also documented in the white paper "Strategy for a future Chemicals Policy"* published in 2001 by the EU. Since 1981, new substances placed on the market must be evaluated in regard to their risk to human health and the environment. However, more than 100 000 "existing substances" marketed before 1981 have never been tested systematically. Therefore, the EU white paper recommends closing the knowledge gap for existing substances while recognizing that achieving this aim requires an enormous research effort. Tasks include:

- improvement and simplification of risk assessment procedures,
- improvement and development of new toxicological and eco-toxicological methods,
- development and validation of *in vivo* and *in vitro* test methods as well as modelling and screening methods.

Testing Different Species

At present the usual risk assessment schemes take into account a limited set of toxicity data for a few representative species and extrapolate these data to a larger number of organisms. However, different organisms show varying sensitivities towards the same substance. Main determinants for variations in species sensitivity are the abundance of chemicals at the target site and the mechanism of action, which in turn are directly linked to physicochemical and structural properties of the substance. The QSAR-method (Quantitative Structure-Activity Relationship) takes advantage of the relation between structural and effect parameters. It enables us to predict fate and effect parameters of chemicals and is therefore of great interest for regulatory agencies. The QSAR-method is based on three essential prerequisites:

- descriptors for structural and physiochemical properties,
- measures of the chemical activity and,
- statistical techniques to quantify the relationship.

Testing Chemical Cocktails

The more field-oriented risk assessment of polluted sites is not dealing with individual compounds only but has to evaluate the potential effects of complex mixtures present in the environment. Much experimental work has been focused on evaluating the combined effects of mixtures of pollutants with the objective of deriving general principles that can then be applied in risk assessment. In addition, group or sum parameters are often applied to measure "total concentrations" of particular classes of chemicals. However, the toxicological relevance of such parameters is highly questionable and information on the mode of action is crucial for the development of sound mixture toxicity parameters or other (bio- and *in vitro*-) assays for the evaluation of complex mixtures in the field.

Effects on Ecosystems

Besides the need for more mechanistic studies in ecotoxicology, there is also an urgent need for more research into effects occurring at the ecosystem level. Therefore, the "Netherlands Organization for Scientific Research" (NWO) started the stimulation program "System-oriented Ecotoxicological Research" in 1999. The overall aims of the program are:

- the determination of ecosystem responses to acute or chronic chemical pollution including mixtures of substances and
- the development of fundamental knowledge in order to assist policy makers in formulating and implementing legal regulations.

Further information on the NWO stimulation program is available as a newsletter in English at www.nwo.nl/sseo (see "nieuws").

Joop Hermens is working at the Institute for Risk Assessment Sciences at Utrecht University, The Netherlands. His research interests include the development of methods and technologies to predict and measure the fate and effects of chemicals and complex mixtures in the environment. During his stay at EAWAG, he and Beate Escher from the department "Environmental Microbiology and Molecular Ecotoxicology" wrote a review on "Mechanisms in Ecotoxicology", which will be available by mid-2002.

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* http://www.europa.eu.int/comm/environment/chemicals/whitepaper.htm)

Publications and Books

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Hannes Wasmer and his activity at EAWAG

Hannes Wasmer died on October 13, 2001 at the age of 62. He was at EAWAG for over 30 years and contributed significantly to EAWAG's success, its recognition in the environmental sciences, and to the development of environmental protection in Switzerland.

Hannes Wasmer joined EAWAG in 1969 as a collaborator in the Department of Waste Research, hired by the then director Otto Jaag. That same year, he became head of the "International Reference Centre for Waste Management", an institution of the WHO that had its home at EAWAG and which led to the current process area SANDEC "Sanitation in Developing Countries". In 1970, the new director Werner Stumm promoted him to the position of vice director. Hannes Wasmer was chosen primarily because of his education as a mechanical engineer at ETH-Zurich and as a sanitary engineer at the University of Berkeley, but also because of his professional experience in Switzerland, the USA, and his managerial abilities, which became apparent early on.

Hannes Wasmer was active at EAWAG until the Spring of 2001 and contributed significantly to shaping EAWAG. Since 1969, EAWAG has roughly quadrupled both its budget and personnel and has continuously increased its national and international recognition through research, education and scientific services. Despite the overall upward trend, there were a number of difficult phases during which Hannes Wasmer's leadership qualities were needed.

Over the years, Hannes Wasmer became involved in a variety of areas, always maintaining his trademark of future-oriented thinking. As Chief of Logistics, he was responsible for providing EAWAG with money, personnel, instrumentation and infrastructure. Early on, he successfully advocated liberalization of budget management and flexible, client-oriented administration. He recruited competent personnel and together with them, built an efficient organization that oversaw all areas of logistics, from human resources to building management. In his last few years at EAWAG, he initiated and headed a common facilities center for the four institutions of the ETH domain.

As the head of consulting services, Hannes Wasmer advocated that scientific consulting should not be a one-way street from research to application, but rather an active cooperation between equal partners. Furthermore, he personally ensured that EAWAG's services were of the highest quality. He was legendary for his stringent quality control, and he was also highly respected for it. Hannes Wasmer also led demanding consulting projects himself; for example, during the aftermath of the catastrophic fire at Schweizerhalle in 1986. He immediately created a task force that offered scientific support on-site.

Over the years, Hannes Wasmer developed a high level of expertise in legal issues and had considerable influence on the development of policies within the ETH domain. He also contributed to the development of modern environmental law, particularly with respect to waste management and to accident prevention and risk management. He continuously expanded his knowledge and maintained an enormous range of expertise, from waste management, recycling and raw materials management to risk management, where he drew on his analytical capabilities and made major contributions to the development of new concepts. His activities affected EAWAG itself, but his influence was felt well beyond EAWAG. He passed on his knowledge in many lectures and courses. He was highly respected by EAWAG partners at ETH and other universities, and by the federal government, the cantons, and industry.

We have all benefited a great deal from Hannes Wasmer's activities. We experienced his visions with forward looking, unconventional ideas, as the thinker who could breakdown complex relationships with analytical clarity, as a patron who had a deep sense for justice, as one always engaged in looking after EAWAG personnel, and last but not least, as a colleague who always put the cause above his own fame. Moreover, he was all this while a distinct, original personality. With his humanity and his efforts for EAWAG and its employees, he earned many friends. He was always trusting towards other people and, in turn, was deemed to be trustworthy by others. We will always remember Hannes Wasmer as a personality that shaped his environment and as a reliable friend.

Ueli Bundi

IN BRIEF

Ecoelectricity for Expo 2002

Expo.02 is the first large Swiss consumer to tap exclusively into sustainable electricity sources. According to a mandate by the federal government, Expo.02 had to develop a comprehensive energy plan which included the exclusive use of "naturemade star" ecoelectricity from hydroelectric power plants. The "naturmade star" label is based on the certification procedure "greenhydro" which was developed at EAWAG and signifies that the electricity was produced in hydroelectric power plants that are operated in an environmentally sound manner. The electricity supplier has created "expo.star", a "naturemade star" certified electricity product especially for this event and will be offering this product only during Expo.02. A number of exhibitors and Expo.02 partners have decided to sign up for "expo.star" ecoelectricity.

No Danger in Goma

In early 2002, approximately 1 million m^3 of lava flowed into Lake Kivu near Goma (Ruanda). There was a great concern that CO$_2$ and methane, which are dissolved in large amounts in deep layers of the lake, may outgas and that the developing gas cloud might suffocate nearby residents. A team of researchers measured depth profiles for various parameters and concluded that there was no threat to the population.


A. Lorke, EAWAG

New Workshop Building in Dübendorf Replaces Tüffenwies

In the construction of the new workshop building in Dübendorf that replaces EAWAG's Tüffenwies facility, ecological criteria were top priority. All of the construction materials were disclosed and evaluated before the beginning of the project. The eventual demolition of the workshop building and the materials produced in the process were also considered. In spite all of these considerations, the workshop building was completed within budget and without compromising in functionality. The new building, designed by the architectural firm of Bob Gysin and Partners AG, is a utility building with an expected lifetime of approximately 20 years. Bob Gysin sees his creation as a "light, floating box". Transparent polycarbonate panels form the façade, enclosing the wooden construction and creating a bright, friendly atmosphere on the interior. All laboratories and offices are housed in movable red construction containers, allowing maximum flexibility for their arrangement. The heart of the new building is an experimental wastewater treatment plant where new water treatment processes can be tested. It replaces the out-of-date facility EAWAG had been operating at Tüffenwies in Zurich.


BaFA, Dübendorf

Ruth Dreifuss Visits EAWAG

In October of last year, Federal Council Ruth Dreifuss visited EAWAG, along with representatives of the ETH Council. From among the broad palette of EAWAG research, the projects "Fish Net" and "Solar Water Disinfection" were selected for special presentations. The reception following the talks led to a number of interesting conversations between the visitors and EAWAG personnel. The day ended with a "water tasting" in which Ruth Dreifuss sampled a young surface water and a 30,000 year old ground water taken from a depth of 200 m.


S. Wey, Zürich

PEAK Program 2002/2003

Under the name PEAK (practice-oriented EAWAG courses), EAWAG offers ongoing education in the environmental sciences for professionals working in the field. The courses are based on current research and the newest findings.

More information can be found under:
http://www.peak.eawag.ch

24–26 September	System identification and modeling with AQUASIM
7–11 October	Modeling of water flow and solute transport in variably saturated media
28–30 October	Fische in Schweizer Gewässern
29 October	Infotag zum Thema "Alpine Gewässer"
5 and 6 November	Water treatment at household level
3–5 December	Chemische Problemstoffe
20–22 January 2003	Neue Methoden der Restwasserbemessung

The language of the course title indicates the language in which the course will be offered.