> Micropollutants in the aquatic environment

Assessment and reduction of the pollutant load due to municipal waste water

Summary

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> Introduction

Rivers and lakes in Switzerland have a variety of natural functions: They shape landscapes, are important leisure areas, carry water and sediments, are important eco systems with great natural diversity and replenish groundwater reserves. To maintain these watercourses for future use for power generation, drinking water provision and irrigation, and to protect people, animals, the environment and infrastructure effectively from the force of the water, watercourses have to be sustainably managed. The Guiding Principles for Swiss Watercourses focus on three development goals:

- Ensuring the watercourses are given adequate space, left in as natural a state as possible
- Guaranteeing near-natural water flows and bed load balances
- Guaranteeing adequate water quality

This report is devoted to the topic of water quality, with particular focus on water pollution by micropollutants from urban wastewater. It contains an analysis of the state of pollution of Swiss surface waters which is based on land wide modelling and the results of various measurement campaigns. This situation analysis was carried out within the FOEN project «Micropollutants in Watercourses – MicroPoll Strategy» initiated in 2006. The report also includes an overview over the impact of micropollutants on watercourses and identifies measures that can be taken regarding urban wastewater to significantly reduce water pollution.

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> Summary

Starting point

A situation analysis of micropollutants in Swiss water bodies has been carried out on the initiative of the Federal Office for the Environment (FOEN). This report summarises the results of the different studies.

Water quality in Swiss water bodies has considerably improved over recent decades. The nutrient loads have been significantly reduced by expanding and upgrading municipal waste water infrastructure (sewers, stormwater tanks and wastewater treatment plants). However, the input of organic trace contaminants through municipal drainage continues to present a water quality challenge. The numerous substances present in water in very low concentrations (nanograms or micrograms per litre) are denoted as micropollutants. Some organic micropollutants have even been found in fish and drinking water.

Where do the micropollutants come from?

Over 30,000 substances are in daily use in Switzerland as ingredients of plant protection products, biocides, pharmaceuticals and consumer products (body care products, cleaning agents etc.) in numerous industrial, commercial and domestic applications. A systematic overview is missing on the quantities, the uses, the emissions, the behaviour in the environment and the toxicity of these substances.

How do micropollutants reach the aquatic environment?

Input into the aquatic environment occurs through the urban drainage system and from diffuse sources, such as agriculture. This report focuses on urban drainage. Persistent substances may pass the wastewater treatment plant (WWTP) unchanged. In addition, input of easy degradable substances occurs through WWTPs that are not state of the art and periodically through storm water or combined sewer overflows. If several WWTPs drain into the same water body, micropollutants can accumulate along the stretch or in lakes. Even groundwater used as drinking water may be contaminated by micropollutants from urban drainage via infiltration of polluted surface water. As the water tower of Europe, Switzerland also has an upstream responsibility towards its neighbours. Micropollutants are continuously exported out of the country with the treated wastewater in rivers.

What is the effect of micropollutants in the water?

Micropollutants may have adverse effects on aquatic life even at very low concentrations. Usage, physical-chemical and ecotoxicological properties determine whether a substance causes problems in the aquatic environment. The concentration of a compound in the WWTP effluent is determined by the load into the wastewater treatment plant and the physico-chemical properties of the compound. Generally, substances that are water soluble and persistent are not removed in WTTPs and can therefore be detected in natural waters. High concentrations occur principally in small streams with a high fraction of treated wastewater. The comparison of the exposure with ecotoxicologically based thresholds allows to asses the risk to affect the aquatic life. Specific effects for example by hormonally active substances, can occur at levels as low as the nanogram per litre range. Such effects have been identified in Swiss surface waters. So

far, only for a few of these substances exist sufficient data allowing to evaluate their influence on the aquatic environment. Particularly, data are available for substances that have a specific effect on organisms and that are therefore subject to a regulatory procedure (e.g. plant protection products).

Many different micropollutants are simultaneously present in water bodies. Therefore, the overall toxicity of the mixture of micropollutants determines the impact on aquatic life. Furthermore, in order to understand the overall effect, both the parent substances as well as their transformation products have to be considered.

Important findings from the research projects

Pollution of water bodies and its effects

Six studies established an overview on micropollutants in Swiss surface waters. The results of these projects are summarised below.

Concentration ins Swiss Surcae waters

It is difficult and very cost intense to measure the extent of micropollutant contamination in all the relevant water bodies in Switzerland. Therefore, a National Material Flow Model was developed and verified with measured data. The model allows to evaluate the contribution of urban drainage to total water pollution for many substances. The analyses showed that damage of aquatic organism cannot be excluded from exposure to micropollutants in small streams with a high fraction of treated wastewater. The model was used to identify heavily polluted stretches of water and to assess technical measures at WWTPs.

What micropollutants are relevant?

Various methods were applied in two projects to identify classes of compounds, substances and transformation products with aquatic relevance.

As no data were available on the biocide quantities used or discharged into the aquatic environment, surveys were carried out among manufacturers and users. Based on these data, a simple prioritisation method was developed and used to identify 21 substances with a high relevance for aquatic systems. This procedure can be applied to other groups of chemicals.

Since appreciable quantities of both parent compounds and their transformation products may occur in water bodies, a model was developed to evaluate the formation and distribution of transformation products in the environment. It was shown for both plant protection products and pharmaceuticals that transformation products can have a significant impact on water pollution, although they are generally less toxic than the parent compounds. Therefore, substance evaluation as part of the regulatory process should include routine analysis of transformation products or at least initial rough modelling of their behaviour in the environment.

Biological test methods for analysis of micropollutants in water courses

Ecotoxicological tests with fish, water fleas, algae etc. are often carried out to evaluate the water quality of water and wastewater samples, in addition to chemical analyses. Most standard tests are intended to determine acute substance toxicity (high concentra-

tions and short exposure times), which makes them unsuitable for analysis of chronic effects caused by micropollutants. Two projects investigated alternative test systems including analysis of the development of zebra fish embryos and the measurements of the oxidative stress using fish cells. The main finding was that ‚both methods were insufficiently sensitive to the micropollutants tested (pharmaceuticals, biocides, plant protection products) at concentrations occurring in waste water or polluted surface waters.

Measures to reduce water pollution

The current urban drainage infrastructure in Switzerland has a replacement value of about CHF 100 billion. It costs about CHF 1.7 billion annually to maintain the system and keep the technology up to date. The predicted increasing need for renewal is pointing to the question of additional organisational and technical measures reducing water contamination by micropollutants. Such measures were studied in four research projects that are summarised in the following sections.

Organisational measures in municipal drainage

One of the projects studied the potential of organisational measures. It concluded that the efficiency of the urban drainage system currently in use in Switzerland can be increased. This can be achieved by connecting small communities to a central wastewater treatment plant of larger catchments and by more efficient infrastructure management. Larger catchments simplify municipal drainage professionalization measures such as joint use of highly qualified operating personnel who can work to improve the performance of wastewater treatment plants and simultaneously reduce costs.

Technical measures in municipal drainage

Technical measures can be divided into decentralised measures (wastewater pretreatment at source) and centralised measures (optimisation of existing central treatment plants). The following three projects focused on decentralised measures as an alternative to the existing centralised system. The relevance of measures at critical sources (e.g. hospitals) was evaluated and the potential of toilets separating urine was investigated. Finally, a fully decentralised system was evaluated of municipal drainage in which every building has its own “WWTP” with a separate collection and treatment of urine, faeces and grey water

The example of the Cantonal hospital in the city of Winterthur indicated that decentralised measures are not appropriate, since emissions from the hospital are quite low expressed as percentage of the total emissions. Obviously, decentralised measures only make sense where one or more point sources (e.g. hospital, nursing home) represent a high proportion of the total pharmaceuticals load in a catchment. Decentralised measures are already implemented at many industrial plants which have their own wastewater (pre)treatment plants.

The second project investigated the impact of NoMix toilets on the input of pharmaceuticals into the aquatic environment. This system collects and disposes of the urine separately so that micropollutants (particularly pharmaceuticals) contained in it do not enter the wastewater. The project revealed that only 60–70 % of the pharmaceuticals ingested by humans are excreted through the urine, therefore the NoMix toilet cannot

totally prevent domestic input into wastewater. In addition, all the other problematic consumer products used in the home such as cleaning agents go directly into the wastewater and then into the public sewers.

The third project compared current municipal drainage by a sewer system and central wastewater treatment with a hypothetical decentralised system which operates without a sewer system and integrates wastewater treatment within each individual building. The micropollutants contained in domestic/household wastewater are suitably treated or collected and disposed of externally (urine, faeces). The results showed that a change from the current system is not worthwhile. Apart from the much higher costs and the long transition periods required for conversion, operational problems could also be expected. A decentralised system would however be suitable for small, remote communities with a lack of wastewater infrastructure.

Conclusions

Conclusions and Recoomendations

The input of micropollutants from urban drainage affects aquatic organisms and the quality of drinking water resources in lakes and in groundwater adjacent to rivers. There is evidence for harmful effects to aquatic organisms in Swiss surface waters caused by micropolluntant exposure. Hormonally active substances cause feminization of male fish. The fact that little is known about hundreds or thousands of micropollutants emphasises the clear need for action. Currently, measured levels of micropollutions in Swiss drinking water do not indicate unacceptable risk to the population. However, because relatively little is known, measures have to be taken for reasons of precautionary consumer protection.

The occurrence of micropollutants in Swiss water bodies demonstrates that regulatory measures such as chemical legislation and the Water Protection Ordinance do not go far enough in their present form and are only suitable for controlling the use of individual substances and material groups. Educational measures such as deposit systems, consumer awareness programs and modification of disposal channels can help to reduce emissions. Initiatives should be taken to create widespread awareness of micropollutants in industry and among consumers and therefore to increase acceptance of more stringent measures. The number of substances used in products and their consumption is likely to rise in future due to increases in population and longer life expectancy (pharmaceuticals and body care products).

The research projects summarised in this report demonstrate that specific decentralised and organisational measures can contribute to solve the problem of micropollutants in the aquatic environment. However, measures should mainly focus on improving existing WWTPs. It is only possible to remove the majority of micropollutants through increased wastewater purification efficiency.

At the time, the initiation of more far-reaching measures in the urban wastewater sector is beneficial because infrastructure replacement is due. The planning for these projects should include measures necessary to reduce micropollutant loads. Consideration

should be given now to the technical measures capable of improving the current system. The methods applied should have the following characteristics:

- Broad range effect against as many micropollutants as possible
- Flexibility of implementation in the existing process engineering
- Easily achievable upgrading of existing infrastructure
- Acceptable cost/benefit ratio

It is known from public literature that measures at the WWTP (e.g. ozone or activated carbon treatment) can eliminate a broad range of micropollutants. In order to apply these techniques most efficiently as part of a Swiss waste water treatment strategy one should focus on load reduction and water quality improvement. The measures should apply to

- Large WWTPs, to reduce high loads (upstream responsibility, reducing loads discharged into the sea),
- WWTPs on stretches of water with inadequate dilution of the treated wastewater discharged, and
- WWTPs on water bodies with significance for drinking water use (lakes used as important drinking water reservoirs, rivers with bank infiltration into groundwater around drinking water wells)

A preliminary cost/benefit analysis indicates that approximately 100 WWTPs larger than 10,000 population equivalents would have to be upgraded in order to achieve the objectives outlined above These upgrades involve investment costs estimated at CHF 1.2 billion. The anticipated additional costs (operation and investment including filtration stage) for the existing wastewater treatment are 5–10 % for larger and 15–25 % for smaller WWTPs.

Technical measures in testing

Within the project “Micropollutants in the aquatic environment”, the FOEN collaborates with cantonal water pollution control agencies, research institutions, professional associations and industry to define principles for the assessment of centralised technical measures. Further treatment steps (ozone and activated carbon treatment) are being evaluated in large-scale trials. The assessment includes determination of the elimination capacity for many micropollutants, monitoring of ecotoxicity in the treated wastewater and collecting key operational and economic parameters. Criteria for checking the efficiency of technical measures and an assessment of the effect of the above measures on water quality are also being prepared.

Other main activities of the FOEN in the area of micropollutants are:

- Reduction of micropollutant emissions from diffuse sources
- Preparation of a systematic overview on micropollutants (including a large number of micropollutants in the water quality monitoring)
- Preparation of methods for ecotoxicological evaluation of water pollution