> Micropollutants in municipal wastewater

Processes for advanced removal in wastewater treatment plants

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> Foreword

Good surface water quality is important in order to protect aquatic ecosystems and drinking water resources. Water quality has seen dramatic improvements over recent decades as a result of the construction of wastewater treatment plants. However, increasing development density, the rise in water temperatures and pollution from housing developments, transport infrastructure, agriculture and other land uses is continuously increasing the pressure on watercourses.

Various research projects in recent years (NFP50 “Endocrine Disruptors: Relevance to Humans, Animals and Ecosystems”, Network Declining Fish Yields Switzerland “Fischnetz”) have investigated the micropollutants problem and have indicated the need to improve wastewater treatment. The FOEN launched the “Micropoll Strategy” project in 2006 with the aim of developing a strategy to tackle micropollutants in municipal wastewater. This report now concludes that project. The report evaluates technical processes which enable the wastewater treatment infrastructure to be upgraded so that adequate protection of ecosystems and drinking water resources against micropollutants can be guaranteed.

The report is addressed to the authorities, owners and operators of wastewater treatment plants, consulting engineers, members of policy committees with water protection remits and those who have an interest in the issue of micropollutants. It is divided into two parts: the first part has general information on the problem of “Micropollutants in municipal wastewater”, and the second part contains detailed information on the different methods and processes and is addressed at specialists.

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> Summary

Micropollutants cause unwanted effects in the aquatic environment. The most important pathways for continuous input of these problematic substances are municipal wastewater treatment plants (WWTP). This report demonstrates that the installation of an additional treatment process at WWTP can significantly reduce the discharge of micropollutants into the watercourses. It is then possible to minimize the impact of micropollutants from municipal wastewater on ecosystems and pollution of drinking water resources.

What are micropollutants?

The term “Micropollutants” refers to organic substances occurring in the water in concentrations of a few nanograms or micrograms per litre which can affect fundamental biochemical processes in nature, even at such low concentrations. They include many synthetic substances such as active pharmaceutical ingredients, compounds with biocidal properties (e.g. for material protection or gardening), food additives, cosmetics ingredients or detergents etc. on the one hand, and naturally occurring substances such as hormones on the other.

Micropollutants are inadequately removed in existing WWTP

Today’s municipal WWTP are designed to remove solids, degradable organic substances and nutrients. They contribute significantly to water protection and the generally good quality of Swiss surface waters. Some micropollutants are also effectively removed in a modern, state of the art WWTP. However, many of these potentially harmful substances are not biodegradable and do not adsorb easily, which makes it difficult or impossible to eliminate them. And because they are discharged continuously into the drainage system from domestic or industrial sources, they enter watercourses with the treated wastewater.

Permanent water pollution

As a result of the continuous input of treated municipal wastewater, aquatic organisms are permanently exposed to this pollution. Even at very low concentrations, micropollutants can be harmful to sensitive aquatic organisms: for example, they affect the growth and reproduction of fish and amphibians, damage the nervous systems of aquatic organisms or inhibit algal photosynthesis. Whether a substance causes problems in the water depends on its physicochemical and ecotoxicological properties and its concentration in the water. Higher concentrations of a wide range of substances are mainly found in watercourses with a high percentage of wastewater. This is often the case in small to medium sized watercourses in the Swiss Plateau.

Measures

Measures are necessary at various levels to achieve a significant reduction in the discharge of micropollutants from municipal wastewater. Measures at source can prevent these substances entering the wastewater. Measures on licensing, production, use and disposal are appropriate for problematic substances. Selective restrictions on the use of these substances make sense in ecological and economic terms but are impossible in some cases such as pharmaceuticals. In order to achieve a significant reduction of a broad spectrum of substances from municipal wastewater into the aquatic envi-

ronment, an optimization of the existing wastewater treatment is required. Two processes have been shown in various national and international studies to be suitable for implementation on an industrial scale: Powdered activated carbon (PAC) treatment and ozonation. These two processes were therefore selected for pilot trials. The suitability of PAC was trialled at the WWTP in Lausanne and Kloten/Opfikon and at Eawag. Industrial scale ozonation was tested at the WWTP in Regensdorf and Lausanne. The objectives of the pilot trials were to establish design bases, gain operating experience and evaluate the effects on the quality of the treated wastewater.

Powdered activated carbon adsorption: Efficient removal of micropollutants and decolourizing of the wastewater

PAC is very finely ground activated carbon. It is mixed with the wastewater so that the effluent ingredients can be deposited on the surface of the carbon particles. Since both natural organic matter (DOC) and micropollutants adsorb onto the activated carbon, the PAC stage is best located after extensive biological treatment in order to minimize the PAC consumption. When loaded with micropollutants, the PAC has to be separated from the purified wastewater and needs to be disposed of. Various separation processes were tested, all of which retained the solids efficiently: sedimentation followed by cloth filtration, sand filtration, ultrafiltration (membrane). If the activated carbon is recycled back to the biological treatment, better utilisation of the PAC can be achieved due to the higher micropollutant concentrations, and its consumption can be further reduced. The PAC is disposed of along with the sludge (by incineration). The use of PAC does not significantly increase the energy requirement of a WWTP (< 5 % excluding filters). Micropollutants can be largely eliminated (> 80 %) with 12–15 g PAC/m³ of wastewater. Ecotoxicological effects (e.g. endocrinal effects, algal toxicity) are significantly reduced and significant decolorization of the wastewater can also be achieved. It is generally possible to install a PAC stage at an existing WWTP depending on the separation process, though sufficient space must be available.

Ozonation: Extensive elimination of micropollutants and hygienization of the wastewater

In the ozonation process, gaseous ozone is added to treated wastewater. The dissolved ozone then reacts with the micropollutants and transforms them (oxidation). Because the efficiency of the ozonation process is also dependent on the organic matter content, it is as well used after extensive biological treatment. It is generally easy to integrate and operate an ozonation stage at an existing WWTP. Gross energy consumption of the WWTP is increased by 10–30 %. An ozone dosage of 3–5 g O_3/m³ of wastewater is required for elimination of the majority of micropollutants (>80 %) and this also significantly reduces ecotoxicological effects (e.g. endocrine effects, algal toxicity etc.). Most pathogens are also destroyed and the wastewater is decolourized. Due to the process-related formation of reactive transformation products, it is recommended to install a stage with biological activity (e.g. sand filter) after ozonation of the wastewater so that these products can fully biodegrade in the WWTP.

Other processes

In addition to adsorption to PAC and ozonation, other processes are also suitable in principle for removal of micropollutants. Among others they include adsorption to granulated activated carbon, retention by selective membranes (nanofiltration, reverse osmosis), substance oxidation with OH radicals (Advanced Oxidation Processes – AOP) and the use of ferrate. These processes are not yet suitable for large scale use in municipal WWTP for various reasons such as lack of industrial scale experience, technical problems or poor economics.

Improved water quality

Treatment of the wastewater by either PAC or ozonation significantly improves the quality of the treated wastewater in relation to micropollutants and their undesired effects. Studies showed that the concentrations of most of the micropollutants in watercourses having a high percentage of waste water from WWTPs having an additional treatment process were reduced to such an extent that the negative effects on aquatic organisms were almost completely eliminated (e.g. inhibition of reproduction and growth).

FOEN package of measures: Targeted WWTP upgrading

The studies and pilot trials carried out have shown that the additional treatment processes at municipal WWTP are an effective method for improving water quality in the aquatic environment. Since the relevance of the micropollutant problem largely depends on the watercourse affected, a targeted approach to upgrade municipal WWTP is required. Large WWTP (load reduction), selected WWTP on watercourses with a high wastewater percentage (protection of the ecosystems) and WWTP on watercourses which are important for supplies of drinking water (protection of drinking water resources) need to be upgraded. By upgrading around 100 of the total of more than 700 WWTP in Switzerland, around 50 % of Swiss wastewater could be treated and the targets could be met. Selection of the relevant WWTP is the responsibility of the cantons, but should be carried out in close cooperation with all the stakeholders, with consideration of the catchment area.

Justifiable additional energy consumption

Installation of an additional treatment stage impacts on the energy budget of a WWTP, with energy consumption normally rising by 5–30 % (excluding filters) though this increase can be higher in worst case scenarios, depending on plant size, wastewater quality and the process selected. At the individual WWTP level, ozonation results in a greater increase in energy consumption. When production of all the resources is taken into account (grey energy), the energy requirement for activated carbon treatment is somewhat higher, since it takes 3–5 kg of carbon to produce 1 kg of activated carbon. The use of activated carbon or ozone would have a minor effect on the energy budget of Switzerland (< 0.15 % of Swiss power consumption), which is considered justifiable in view of the improved water quality achievable.

Minor additional costs can be expected: CHF 17 per head of population p.a.

The average costs of wastewater treatment in Switzerland are currently around CHF 0.70 /m³ or about CHF 130 per head p.a. (WWTP costs only). Upgrading to include an additional process (excluding filtration) increases the treatment costs by CHF 0.05–0.30 /m³ depending on upgrade size, though the costs may be higher in unfavourable conditions (wastewater composition, infrastructure etc.). The additional costs for the use of PAC and ozonation are similar and depend mainly on plant size, existing infrastructure and wastewater composition. The package of measures envisaged generates additional annual wastewater treatment costs of around CHF 130 million or CHF 17 per head of population.

Outlook

This report describes the current state of the art on additional technical processes for removal of micropollutants from municipal wastewater. Other factors relevant to implementation of a package of measures are not part of the report and are covered in relation to ongoing activities. Preparations are now taking place on a nationwide polluter pays funding solution and on the legal basis necessary for planning and fund-

ing of the measures to reduce micropollutants at municipal WWTP. This work is being carried out in close collaboration between the FOEN, cantonal and local authorities and WWTP owners and operators. It will be followed by a national and international exchange of experience on technical processes. This should provide planners and operators of WWTP and the authorities with the necessary broadly-based expertise.