The first full-scale advanced ozonation plant in the Dübendorf WWTP running; the new Swiss water protection act approved

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NEUGUT WWTP IN DÜBENDORF

The Neugut plant in Dübendorf is the first wastewater treatment plant (WWTP) in Switzerland where a full-scale advanced treatment of wastewater with ozone has been installed [1]. The plant has a capacity of 150 000 population-equivalents and is currently operating with 105 000. It is cleaning daily 20–50 million litres of wastewater using a primary clarifier, followed by biological treatment with nitrification, denitrification, biological P-removal and subsequent sand filtration. As early as 2009, the first discussions started about adding an ozonation treatment, and on October 2, 2012 the foundation stone ceremony took place. The project was supported by the supervisory board and the local communities served by the plant, the Swiss Federal Office for the Environment (FOEN), the canton of Zurich, and scientifically by Eawag, the Swiss Federal Institute of Aquatic Science and Technology [2]. For the implementation, several favorable conditions were present at Neugut, including a reserve capacity sufficient until 2050, an installed sand filtration unit and the reserve area for the installation of the reactor. After about a year of construction, the ozonation plant came into operation on March 24, 2014 (Figure 1). The WWTP was supported by the companies Holinger AG and Ingenieurbüro Gujer AG for the construction and operation of the ozonation stage. The operation has been running smoothly from day one. In May 2014, the first results were presented, showing that the overall removal of 80% of the five indicator substances could comfortably be achieved using an ozone concentration of 3.5 mg/L (corresponding to 0.7 g ozone /g DOC), regulated by the water flow. The investment costs added up to CHF 3.27m, and with additional energy consumption of 0.03 kWh/m^3 the operating costs of the ozonation plant account to CHF 0.023/m^3.The Swiss water protection act has now been approved and more WWTPs will be upgraded. The planning and construction of other WWTPs are drawing on the experience gained at Neugut.

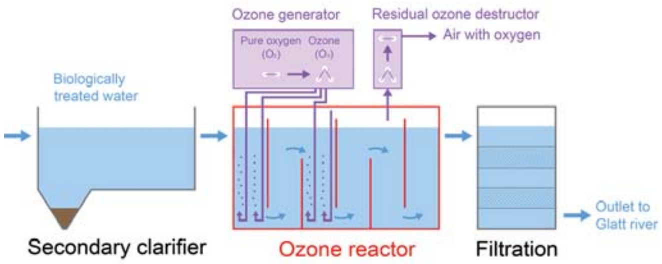

Figure1: Schema of the ozone reactor as implemented at the Neugut WWTP.

THE STORY OF THE NEW SWISS WATER PROTECTION ACT

Switzerland is located at the source of fresh water resources with two large rivers, the Rhine and Rhone, originating in the Swiss Alps. The observed concentrations of micropollutants are therefore lower than in other European countries such as Germany. Nevertheless, concentrations of selected compounds still exceed environmental quality standards at which adverse effects to aquatic organisms cannot be excluded [3]. From this viewpoint, and also from the perspective of a responsibility for the downstream inhabitants in neighbouring countries, FOEN decided to launch the project "strategy MicroPoll" in 2006 to investigate the pollution situation of Swiss surface waters and assess potential measures to reduce the load of micropollutants from urban areas [4,5]. The focus was on measures at municipal wastewater treatment plants, since they are a major source of many organic pollutants.

Current WWTPs are only capable of reducing the overall load of micropolluants by about half. Since hydrophilic compounds in particular – including many pharmaceuticals, personal care products and cleaning agents – still remain in the treated wastewater [6], it is technical measures at the WWTPs that can achieve the most substantial and effective reduction of micropollutants. The FOEN initiative was taken in line with other actions taking place in Europe: the International Commission for the Protection of the Rhine (ICPR) planned to develop a joint and comprehensive strategy for reducing and avoiding micropollutant inputs from urban wastewater and other sources; North Rhine-Westphalia and Baden-Württemberg (Germany) also investigated advanced wastewater treatment; and similar activities related to micropollutants took place in countries such as The Netherlands, UK and Sweden.

The Swiss project "Strategy MicroPoll" eventually resulted in a proposition of the Swiss government in the year 2009 to adapt the water protection ordinance (GSchV). The overall goal was to enhance water quality by the elimination of 80% of micropollutants in wastewater treatment using technical measures. The focus was on three groups of WWTPs: (i) large WWTP to reduce the sources of high loads; (ii) WWTPs at surface waters which have an impact on drinking water resources, for their protection; and (iii) WWTP at rivers with a high fraction of wastewater, to protect the ecosystem. On these criteria, about 100 out of the 700 Swiss WWTP would need to be upgraded and overall about half of the current load of micropollutants could be removed. Five indicator substances were defined for use in evaluating the effectiveness of the measures taken.

After the public consultation, it was found that 80% of the comments supported the targeted measures, but were in favour of a financing plan based on the 'polluter pays' principle and a solution for the whole of Switzerland. In 2010, ideas were floated on the way to finance the proposed measures. The final outcome was the establishment of a Swiss fund to finance the initiative, paid for by all Swiss inhabitants connected to a WWTP. With this money, 75% of the investment costs at the WWTPs were to be financed. The investment cost for the 100 WWTP under consideration was estimated to be in the order of CHF 1200m. The increase in costs for wastewater treatment was estimated at CHF 130m per year, which equates to about 10–15 % of the current costs of wastewater treatment. CHF 9 per year per Swiss inhabitant with a connection to a WWTP would be sufficient to finance 75% of the investment costs (for comparison: current average costs are CHF 112). In April 2012, the adaption of this new water protection act (GSchG) was proposed and accepted first by the federal council, then the council of states and finally the national council on March 3 2014. The implementation of the new water protection act and the start of the financing is planned for January 2016. Within 20 years, the following groups of WWTPs will need to be upgraded: (i) WWTP with more than 80 000 connected inhabitants; (ii) large WWTP (> 24 000 inhabitants) in the catchment of lakes; and (iii) WWTP (>8 000 inhabitants) on rivers with a fraction of wastewater greater than 10%. The energy consumption is expected to increase by 5–25% in a WWTP, and nationally by 0.1%. This additional energy demand should be compensated by energy optimisation and recovery at the WWTP.

EVALUATING AND CONTROLLING THE ADVANCED WASTEWATER TREATMENT

The technologies proposed for the advanced wastewater treatment are ozonation or treatment with powdered activated carbon (PAC). These technologies are well known from drinking water treatment and were tested within FOEN's federal project "Strategy MicroPoll" at two sites at pilot-scale in Switzerland: at the Regensdorf WWTP close to Zurich by Eawag [7], and the Lausanne WWTP on Lake Geneva by EPFL [8]. In these plants, and other plants installed in Germany, a broad range of micropollutants

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can be reduced by over 80%, reducing the overall toxicity of the effluent at the same time [9,10,11]. Other technologies could reach the same goals (e.g. adsorption to granular activated carbon, tight membrane filtration, advanced oxidation processes such as UV/H_2O_2 or O_3/H_2O_2), but current considerations of technical feas bility and cost favour the treatment with ozone or PAC. Recently, Envilab AG and Eawag have develop with FOEN a new selection of twelve substances to be used for the evaluation of the effectiveness of the measures. These compounds represent a wide variety of compounds typically present in municipal wastewater, are insufficiently eliminated in conventional wastewater treatment, and can be easily analysed in a single run with LC/MS/MS [12]. Out of this group, at least six compounds have to be selected: four from the group of "very well eliminated compounds" (amisulpride, carbamazepine, citalopram, clarithromycin, diclofenac, hydrochlorothiazide, metoprolol, venlafaxine), and two from the group of "well eliminated compounds" (benzotriazole, candesartan, irbesartan, mecoprop).

To ensure a good performance of the advanced treatment, appropriate control and operation strategies need to be developed. The effectiveness of the treatment technology needs to be assessed not only for chemical, but also for ecotoxicological quality control. In the treatment with ozone, transformation products are produced, which are so far not assessed in much detail. Moreover, the effects on complex ecosystems of removing micropollutants from wastewater should be studied to gain insight into how the pollutants affect their structure and function [13].

FURTHER INVESTIGATIONS AT NEUGUT WWTP

Further assessments are currently taking place at the Neugut WWTP. Eawag is involved with two projects funded by FOEN and the EU project DEMEAU with investigations at the WWTP. Demeau (Demonstration of promising technologies to address emerging pollutants in water and wastewater [14]) is a three-year EU project, funded within FP7 until August 2015, with the overall objective of promoting the uptake of knowledge, prototypes and practices from previous EU research, enabling the water and wastewater sector to face emerging pollutants. Eawag focuses on demonstrating the potential of ozonation for wastewater treatment at the Neugut WWTP in a collaboration by the Departments of Environmental Chemistry, Process Engineering, Water Resources and Drinking Water as well as the Swiss Centre for Applied Ecotoxicology (Ecotox Centre)[15]. Removal processes and the influence of the source water composition on the efficiency of eliminating micropollutants with ozone are being studied, together with ecotoxicological investigations. In addition, the transformation products produced by ozonation are being investigated with chemical analysis as well as kinetic studies in more detail. Appropriate online control of the technology to assure constant high water quality with minimal energy consumption is an important task to improve the long-term stability and robustness of the processes. The control of the ozonation process by monitoring the difference in UV absorbance between the reactor inlet and the outlet is being investigated, partly funded by FOEN [16,17]. Furthermore, aspects of environmental impact and cost assessment in the life cycle (LCA/LCC) of the technology are being addressed by researchers at the University of Applied Sciences and Arts, Northwestern Switzerland (FHNW) within DEMEAU to support decision-making and in overcoming market barriers for novel technologies. Ecotoxicological investigations have shown a temporary increase of toxicity after ozonation in certain tests, which can be reduced again by a biological filter such as sand filtration [9,10,11]. Based on these investigations, a biological treatment after ozonation is recommended. Within the project ReTREAT, funded by FOEN in a project framework for the promotion of technologies, different biological post-treatments (fixed-bed and moving-bed bioreactors, a biological activated carbon filtration) are being tested for their suitability and efficiency to reduce ozonation transformation products and ecotoxicological effects. The Ecotox Centre is therefore investigating different levels and mechanisms of effects with *in vitro* as well as *in vivo* bioassays in the laboratory and in flow-through systems directly on the WWTP.

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