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EXPLORATORY STUDY FOR WASTEWATER TREATMENT TECHNIQUES AND THE EUROPEAN WATER FRAMEWORK DIRECTIVE

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FRONTCOVER

WWTP of Deventer near the river IJssel, picture is property of the Water Board Groot Salland

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SUMMARY

THE EUROPEAN WATER FRAMEWORK DIRECTIVE (WFD)

The European Water Framework Directive recently became effective in December 2000. The WFD aims to achieve and maintain European water bodies in a “good status”. The European Commission identified priority substances for which community legislation is likely to be implemented. These priority substances are considered to be dangerous enough that their levels need to be systematically reduced in all European countries, in order to achieve a “good chemical status”. For some of these priority substances zero-discharge will be aimed for by the year 2021. In addition to the priority substances, new discharge limits will also be established for “relevant river basin” substances. Meanwhile, the environmental standards for surface water specified in the 4th Article on Water Quality Management still apply, as well as the European Bathing Water- and Dangerous Substances Directives.

After an initial national screening of the effluent produced by wastewater treatment plants (WWTPs) in The Netherlands, it appeared that a certain number of priority substances are regularly measured in WWTP-effluent, forming a significant emission source of priority substances into regional surface water. The Exploratory Study of Wastewater Treatment Techniques and the European Water Framework Directive provides basic information about the WFD-relevant substances in WWTP-effluent and treatment techniques that can be applied now or in the near future to reduce the load of these substances emitted from WWTPs.

SUBSTANCES

A list of substances is set up in this report which includes important and relevant substances for surface water in The Netherlands, in the light of the WFD. These are substances which are present in WWTP-effluent and which have been shown in area-specific reports to be present in higher concentrations than is specified in the surface water legislation. It is assumed that point-source reduction of these substances will be insufficient to reduce levels. To achieve the not yet fully established discharge limits for these substances before 2015, extra treatment steps will be required. The following substances need to be considered:

- the nutrients nitrogen and phosphorous;
- certain polyaromatic hydrocarbons;
- the pesticides hexachlorocyclohexane, atrazine and diuron;
- the metal ions cadmium, copper, zinc, lead and nickel;
- a plasticising agent DEHP (diethylhexylpthalate).

There has been no testing of brominated diphenyl ethers or octyl-/nonylphenol compounds, since at this moment no limits are available yet. However based on the general occurrence of these substances in WWTP-effluent and the low concentrations at which they cause adverse effects on aquatic organisms, these substances are also considered as being relevant to WWTPs.

TECHNIQUES

The WFD dictates that plans for the required measures shall be in place by 2009, such that the desired water quality can be obtained by 2015. This time schedule requires a choice of techniques that can be operational at WWTPs within a period of three to five years. Further selection criteria used for an inventory of treatment techniques are:

- the tec hniques will be capable of removing the selected substances from wwtp-effluent to the standards of surface water;
- the techniques will be capable of handling large flow rates;
- the techniques will preferably be capable of removing a broad spectrum of substances;
- the techniques preferably consume minimal energy, additional chemicals and building space.

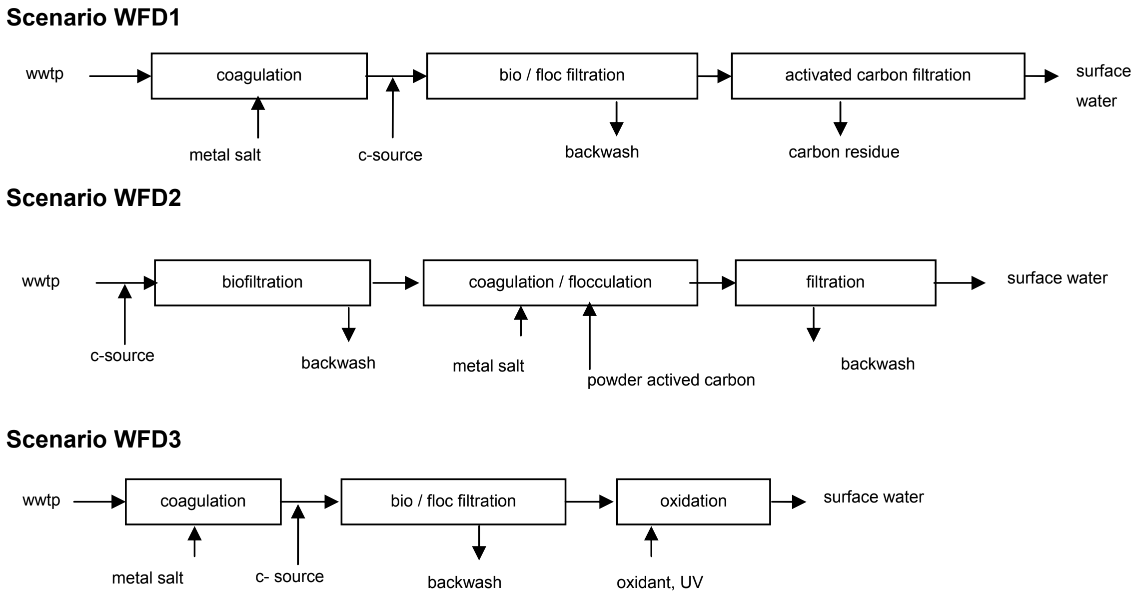
Current techniques for treatment of domestic wastewater are not designed to remove the selected substances from wastewater. Applicable treatment techniques have been selected based on their treatment principle and their estimated effectiveness for treating WWTP-effluent. This estimation is partly based on results from pilot-scale tests and/or full-scale applications for the advanced treatment of WWTP-effluent. Where inadequate information is available over certain techniques the potential effectiveness of the technique was estimated from other applications such as drinking water production or industrial water treatment. In addition to end-of-pipe techniques for post-treatment of WWTP-effluent, attention is also paid to integrated techniques, amongst which the Membrane Bioreactor. For quality-improvement within the WFD the Membrane Bioreactor is considered as an activated sludge system followed by an ultra- or microfiltration membrane.

TREATMENT SCENARIOS

Many of the WFD-substances are more or less present in suspended or colloidal particles. Removal of suspended solids from the effluent as a first step therefore leads to improvement of the quality of the effluent. The extra advantage is that disturbing effects on the end-of-pipe techniques are avoided.

The treatment scenarios for removal of WFD-substances are largely based on systems in which advanced removal of suspended solids, nutrients, dissolved organic macromolecules and metals can be achieved, in combination with adsorptive or oxidative techniques for the removal of organic micro-contaminants and pesticides. With the techniques applicable for organic micro-contaminants, also the hormone disrupting substances and medicinal substances are removed. The applicable treatment scenarios for complete removal of all WWTP-relevant WFD-substances are shown in the figure.

FIGURE APPLICABLE TREATMENT SCENARIOS FOR THE REMOVAL OF ALL WWTP-RELEVANT WFD-SUBSTANCES



It is necessary to mention that the removal of heavy metals in these scenarios has not yet been confirmed. It is expected however that the advanced removal of suspended solids and the (partial) removal of dissolved complex organic metal complexes will lead to an effective overall removal of heavy metals. Due to the presence of high concentrations of interfering macro-ions (Ca, Mg) in WWTP-effluent it seems likely that the application of ion exchange techniques will be difficult. This would require the development of specific resins that are capable of achieving the required removal efficiency of priority substances that are present at the ppb level, in the presence of other interfering and competing substances in higher concentrations. In addition to this, treatment of the brine solution produced during ion exchange is required.

COSTS

For each technique or combination of techniques a cost estimate has been set up, comprising the investment costs and the total yearly costs. The cost estimates have been calculated for two plant sizes, namely 20,000 P.E. and 100,000 P.E. The average dry weather flow (DWF) rate is calculated based on an average daily flow of 200 l/P.E. during 16 hours per day. The treatment units have been designed for a hydraulic flow of 1.5 x DWF. Using this hydraulic flow, the capacity of the combination of techniques is lower than the maximal flow during wet weather flow. At the chosen capacity about 75% - 85% of the annual hydraulic flow of the wwtp will be treated.

The specific treatment costs vary from 18 - 43 EUR-ct/m³ (13 -31 EUR/P.E./year) at a plant size of 20,000 P.E. and from 6 - 24 EUR-ct/m³ (5 - 18 EUR/P.E./year) at a plant size of 100,000 P.E. A scale-up from 20,000 to 100,000 P.E. results in a decrease in the specific treatment costs by a factor of 2 to 3. This effect is mainly caused by the costs for adjustment of the existing infrastructure, application of an effluent pumping station and pre-treatment (removal of large particles) and extra facilities such as chemical storage and dosing systems (for coagulant, carbon source). These items are approximately the same price over the considered scale-range from 20,000 to 100,000 P.E.

Nutrient removal in a single-stage filter configuration combining coagulation and filtration with denitrification in one process unit, results in the lowest treatment costs. The highest costs are incurred when coagulation and filtration are used in combination with advanced oxidation (UV/H2O2). Biofiltration with powdered activated carbon dosage combined with coagulation and filtration or biofiltration with activated carbon filtration, leads to the lowest costs for the "WFD-scenario".

GAPS IN KNOWLEDGE

The implementation of the WFD policy will lead The Netherlands and Europe into a new phase of domestic wastewater treatment. This will lead to a new focus in wastewater treatment in which the number of relevant substances to be removed will be largely expanded, leading to the application of new techniques and the introduction of new cost factors. Each of these aspects still contain several gaps in the knowledge and further research is necessary before 2009 in order to implement adequate measures to cope with the new legislation.

For some WFD-substances, especially organic micro-contaminants, pesticides, hormone disrupters and medicinal substances, there is little or no data available for WWTP-effluent. More information regarding the distribution of these components between the water phase and the suspended material phase is required to enable an appropriate choice of treatment.

The different treatment scenarios have been compiled based on the expectation that the required treatment standards for the relevant WFD-substances will be achieved with these techniques. This expectation is partially based on results from pilot scale research results and/or full-scale applications. In cases where insufficient information was available the potential removal efficiencies have been derived from other applications such as drinking water production or industrial wastewater treatment. This means that further research is needed in order to establish the exact removal efficiencies of these treatment techniques for a number of substances, including pesticides, organic micro contaminants, heavy metals, hormone disrupters and medicinal substances.

The estimated costs for a number of techniques (especially microfiltration / ultrafiltration, activated carbon treatment and oxidation) have been extrapolated from applications in the drinking water sector in cases where no information is available on WWTP-effluent. A risk in this approach is that the actual costs may be higher or lower depending on the development of the construction costs (e.g. if a more economical construction is developed), or on the development of the operational costs (e.g. if the required chemical dosage is higher than thought). The applicability of these techniques to WWTPs in practice will depend on the costs. It is therefore important to test these cost estimates again as soon as further insight is available in effluent treatment (laboratory → pilot → demonstration scale), and adjust them where necessary.