# SIX®: A New Resin Treatment Technology for Drinking Water

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**Summary**

**The history of ion exchange is marked by many important milestones, notably the development of novel polymeric materials and considerable advances in our understanding of the underlying fundamental principles. Separately, there have been major advances in the design and development of the apparatus and equipment required to perform industrial ion exchange and also for large scale applications in the production of drinking water, like the MIEX® process from Orica. This paper reviews the progress that has been made during the last three years within the research facilities of PWN which have resulted in a new ion exchange process for the direct treatment of water containing high amounts of suspended matter such as surface waters. This new process has been called SIX® and will most likely be operational at a flow of 4000 $m^3/h$ by 2012.**

**Keywords**

Ion exchange, DOC-removal, surface water treatment.

## Introduction

In 1920, when NV PWN Water Supply Company North Holland (PWN) was founded, the demand for drinking water was satisfied by ground water extraction. However, with the growing drinking water demand PWN was compelled to utilize surface water as an additional source. Therefore in 1968 Water Treatment Plant Andijk (WTP Andijk) was constructed for the direct production of drinking water from IJssel Lake (River Rhine). Originally the plant consisted of microstraining, breakpoint chlorination, coagulation, sedimentation, rapid filtration and post disinfection. In 1978 the plant was upgraded with pseudo moving bed GAC filtration. After about 40 years of operation, WTP Andijk still complied with all Dutch drinking water standards. Nevertheless a second upgrade was desired to install an universal barrier against pathogenic micro-organisms such as protozoa and organic micropollutants such as pesticides [Kruithof, 2000]. This retrofit included the worlds first large scale application of advanced oxidation with UV/$H_2O_2$ which became operational in 2004 [Kruithof, 2005] This advanced oxidation is placed between the existing pre-treatment and GAC filtration. The GAC treatment providesremoval of residual $H_2O_2$ and easily assimilable organic carbon (AOC). Since the advanced oxidation with UV/$H_2O_2$ delivers more radiation than necessary for primary disinfection, the breakpoint chlorination was abandoned. In a third phase the existing pre-treatment which still dates from 1968 will be renewed. The wish to renew the pre-treatment is based on a few challenges:

- increase the UV-transmission (UVT) to increase the efficiency of the advanced oxidation process (AOP);
- increase the removal of dissolved organic carbon (DOC) to increase the efficiency of the AOP and to lower the formation of AOC;
- remove nitrate to increase the efficiency of the AOP and to lower the formation of nitrite;
- total removal of suspended and colloidal matter independed of the feed water quality;
- increase overall capacity from 3000 to 4000 $m^3/h$.

The wish to remove all suspended matter led quickly to the idea of using micro- or ultrafiltration (MF/UF). A former PWN study [Galjaard, 2005] indicated that the direct treatment of IJssel Lake water with MF/UF was only possible after the removal of the low molecular weight (LMW) DOC fractions with an anion resin ( at that time MIEX®), which resulted in a high gross flux rate with almost no fouling. The use of an anion resin like the MIEX® resin also increased UVT considerable and removed a large amount of nitrate and DOC. The hypothetical pre-treatment of ion exchange followed by MF/UF seemed to fulfil the needs for the post-treatment. However the technical and economical feasibility needed to be improved.

## Background development SIX® technology

MIEX®, an acronym for Magnetic Ion Exchange, is manufactured and commercialised by Orica. A very fine magnetic resin is dosed into the feed water and after sufficient time in contact reactors, the resin is removed by settling. The magnetic properties of the resin particles enhance the settling which makes it possible to use very small resin particles with a relatively high specific surface area resulting in better kinetics and lower resin inventories [Slunski 1999]. This process is especially developed to treat waters containing high levels of suspended and colloidal matter and is until now the only ion exchange process that has been used on a large scale to remove DOC as a first treatment step [Orica Watercare]. The process had a few disadvantages for PWN making it less attractive to use in WTP Andijk. Disadvantages of MIEX®:

- Resin and the technology can only be purchased from one supplier;
- major part of the settled resin (90-95%) is re-circulated without regeneration, resulting in large detention times of the resin which leads to changing adsorption kinetics and possible 'blinding' of the resin by a biofilm, not mentioning the release of adenosinetriphosphate (ATP);

These disadvantages led to the need for an alternative ion exchange process to treat surface water directly in which other commercially available non magnetic resins could be used. The adsorption process should be based on a so called ' single pass' process which means that 100% of the resin that has been dosed is regenerated before re-use to overcome the formation of a biofilm on the resin.

## Procedure development SIX® technology

The procedure that has been followed to develop an alternative process can be described in short as follows:

- development of a kinetic model to describe the adsorption process;
- jar tests to find the parameters for this model for different resins;
- validation of batch model with batch experiments;
- conversion of batch model to a continuous process model;
- optimize process conditions based on model;
- design of a pilot plant based projections;
- building a pilot with a capacity of 50$m^3$/h.
- validation of model with pilot experiments;
- adapt and optimize pilot;
- long term trials to test the economical and technical feasibility.

## Results

After described a basic adsorption model jar tests were carried out to find the different parameters. Results with suspended resin indicated almost immediately that the use of 'fresh' resin (resin that has been re-generated) led to the highest possible removal of DOC (analogous to increase in UVT) at the lowest resin concentration leading to lower resin inventory, higher removal rates and lower contact times compared to recirculated resin. That meant that the basic idea of 'single pass' improved the kinetics enormously besides overcoming blinding of the resin by biofilm formation as shown in Figure 1.

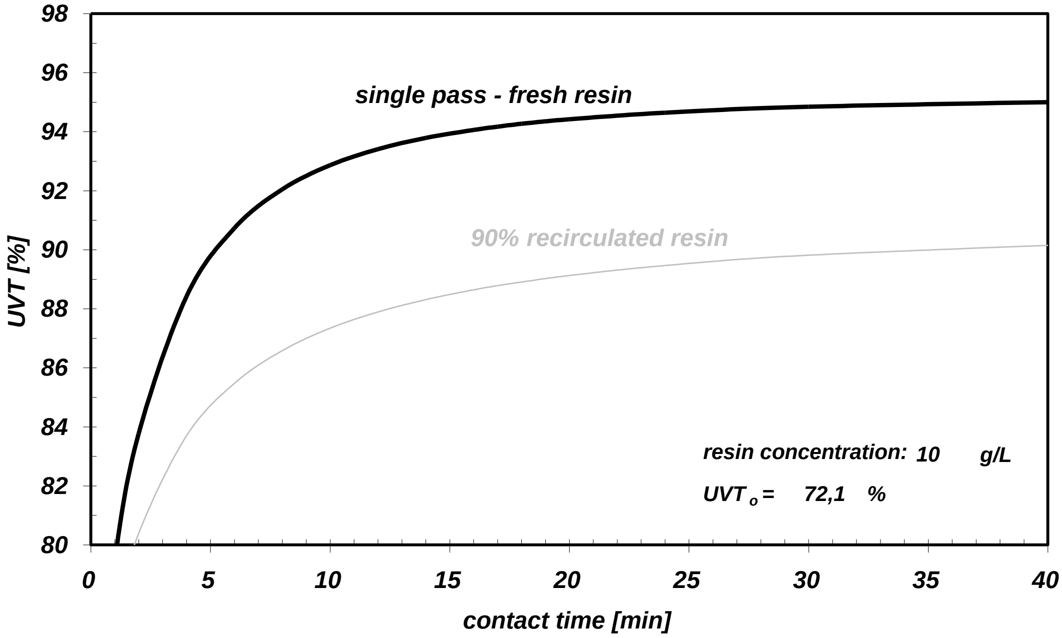


**Figure 1** Fresh resin versus recirculated resin based on kinetic model for batch experiment

Combining the development of a continuous flow model and batch test-data from various resins, a pilot plant was designed with build in flexibility for the application of a wide range of commercial available resins. To be able to use a wide range of non-magnetic resins a very efficient separation was designed. After the pilot was ready it had overall a 50% smaller footprint then a similar capacity with the MIEX® process caused by a smaller contactor and settler volume.

First results with the pilot have been very promising. Having the model and being able to control the resin concentration in the reactor with sensors, that measured UVT and DOC in the feed water and the product, water quality could easily be controlled by changing resin concentrations or flow. This feature makes the process very tolerant to flow variations (enforced by water demand) or changing water quality.

In total 6 different anion resins are being modelled from 3 different suppliers (Orica, Rohm and Haas, and Lanxess). From these 6 resins, 3 have been tested within the pilot leading to a final choice for a long term trial to fine tune all operating parameters including the re-generation and the re-use of the regeneration fluid. Since the resin is not completely loaded before regeneration desorption, can take place at lower salt concentrations (30-60 g/L instead of 120 g/L or more), lower volumes and shorter contact times leading overall to a lower salt usage.

## Conclusions

Compared to any other ion exchange process on waters containing suspended matter the ‘single pass’ ion exchange process named SIX® distinguishes itself by being very compact, having a low resin concentration and inventory, low salt usage, high effluent quality and full control of the adsorption process without ‘blinding’ the resin or producing biomass. The adsorption process of the SIX®concept has been modelled very well making it possible to design reliable installations based on only a few jar tests for any commercially available resin. Since the used resins are at maximum adsorption capacities and rates, the overall performance is unsurpassed..

Additional advantages are:

- no pumps are used to displace the resin giving low attrition rates;
- new sensors are used to control resin concentration and water quality.;
- additional technologies to reduce salt consumption are developed.

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