Biological-adsorptive iron removal: the path towards a superior groundwater treatment plant for drinking water

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INTRODUCTION

The aim of this research is to study the impact of an innovative pilot water treatment plant (WTP) on produced water quality, use of resources (e.g. chemicals) and surface footprint in comparison with the current industrial WTP.

Pidpa is a Belgian water company active in drinking water, process water and sewer management. Pidpa provides drinking water in the province of Antwerp to more than 550.000 customers.

The WTP of Oud-Turnhout has been selected for design and building a new WTP based on:

- Aging infrastructure with a lifetime nearly 50 year of the current WTP.
- The presence of naturally occurring arsenic levels up to 90 µg/l in individual groundwater sources. The WHO's recommended limit of arsenic in drinking water is 10 µg/l, thereby attempting to keep concentrations as low as reasonably possible and well below the guideline value when resources are available.
- Issues with the biostability of the water e.g. growth of Aeromonas in the WTP and distribution network. Since 2016 Pidpa has been the first Flemish water utility ceasing the addition of residual disinfectants to the distributed water, thereby adopting the approach of other water companies in The Netherlands, Switzerland, ...

MATERIALS & METHODS

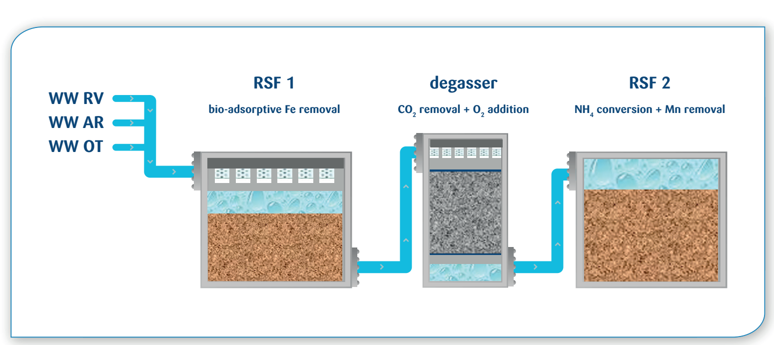
The water treatment plant (WTP) of Oud-Turnhout treats groundwater from 3 different groundwater sources. Table 1 summarizes the average raw water quality treated at the pilot WTP.

Table 1 average raw water quality

Parameter	average	Stdev	min	max
CH_4 (µg/l)	869	230	456	1371
Fe (mg/l)	15	3	10	21
As (µg/l)	56	3	50	65
TNPOC (mg/l)	3,17	0,34	2,37	3,79
NH_4 (mg/l)	0,47	0,05	0,36	0,55
Mn (µg/l)	36	3	28	43

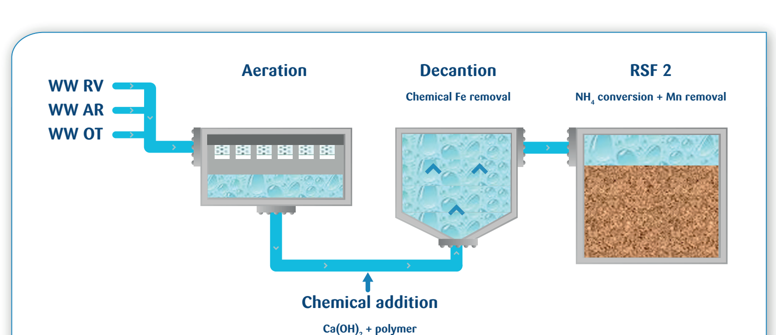
The pilot plant has a capacity of 0.4-1.2 m^3/h and consists of (1) spray aeration, (2) rapid sand filtration (RSF 1) for biological-adsorptive iron removal, (3) degasser (CO2 removal and O2 addition) and (4) RSF 2 for nitrification and manganese removal. Inoculation of RSF 1 was carried out with rinsing water from a Pidpa WTP that contains a large concentration of Gallionella spp.

pilot WTP scheme



The industrial WTP consists of (1) turbine aeration, (2) sedimentation tank for iron removal (with dosage of lime and polymer) and (3) RSF for nitrification and manganese removal.

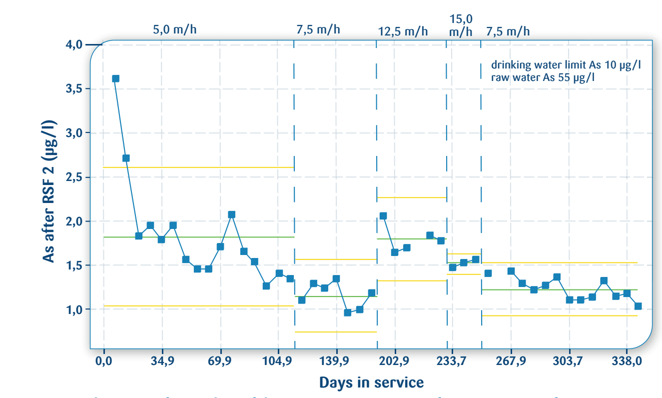
industrial WTP scheme



RESULTS & DISCUSSION

The first step was the establishment of a stable drinking water quality of the pilot WTP. During the first 3 weeks arsenic removal improved (Figure 1) due to inoculation and further growth of a bacterial community able to oxidise As(III) to As(V) (Gude et al., 2018). The value of As(III) after the first RSF diminished from 3.0 µg/l after 1 week until < 0.5 µg/l after 3 weeks. This resulted in a substantial improvement of the total arsenic removal from a final concentration of 3.5 µg/l to 1.8 µg/l (Figure 1) with an Fe/As ratio in the raw water of 200.

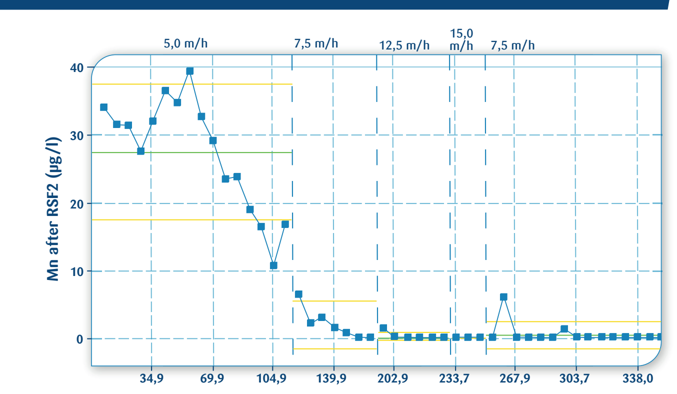
Figure 1 Arsenic concentration after RSF 2



I chart of As by filtration rate in function of time.

Nitrification and manganese removal were complete after respectively 70 and 110 days in service.

Figure 2 Manganese concentration after RSF 2



I chart of Mn by filtration rate in function of time.

From this moment on, the filtration rate of both RSF was increased to 15 m/h. This maximum filtration rate resulted in a total removal of Fe (< 0.02 mg/l), NH4 (< 0.05 mg/l), Mn (< 0.5 µg/l) and an arsenic removal of 97 % (from 54 to 1.5 µg/l with Fe/As ratio in the raw water of 290).

The current industrial WTP removes iron by a sedimentation tank at 1 m/h and subsequent RSF at 5 m/h. The average arsenic concentration of the current drinking water is 3.5 µg/l. Obviously the new pilot WTP results in a significantly lower arsenic concentration in the drinking water and much lower surface footprint in comparison with the industrial WTP.

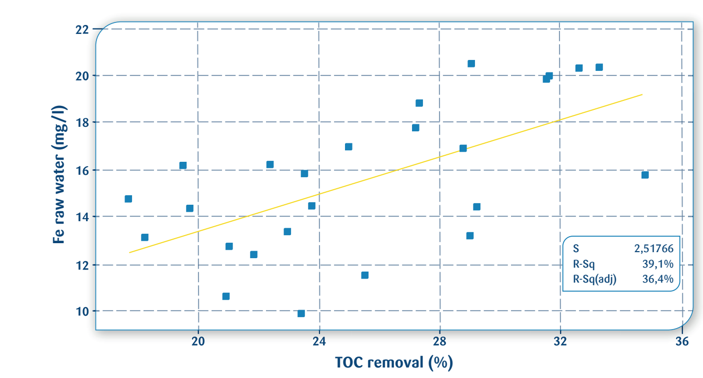
During a full year of operation the pilot WTP showed no spontaneous growth of Aeromonas (0 cfu/100ml on weekly basis). After 1 year of operation both RSF of the pilot WTP were inoculated with backwash water (10 L with an Aeromonas concentration of 105 cfu/100ml) and filter material (12 kg with an Aeromonas concentration of 200 cfu/g filter material) from the industrial WTP. 3 days after inoculation analyses of concentrated backwash water (at the end of the combined air-water cycle) showed the presence of Aeromonas only in the RSF 2 (not in RSF 1). However, the concentration was low in comparison with the amounts of Aeromonas bacteria that had been dosed and it decreased over time. Absence in the backwash water was established 38 days after inoculation (Table 2).

Table 2 aeromonas in backwash water of RSF

Days after inoculation	Sample	Aeromonas (cfu/100ml)
3	Backwash RSF 1	0
3	Backwash RSF 2	1870
17	Backwash RSF 1	0
17	Backwash RSF 2	140
38	Backwash RSF 1	0
38	Backwash RSF 2	0

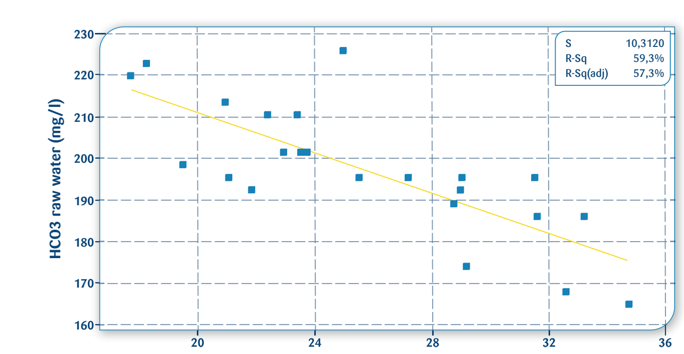
TOC removal of the pilot WTP averaged 25%, whereas the industrial WTP only removed a limited amount of 5%. In the total data set there is a variation in raw water parameters because of different mixtures of the three groundwater sources. Multiple linear regression analysis shows a significant correlation of the percentage of TOC removal with Fe (Figure 3) and HCO3 (Figure 4) raw water concentrations. This shows that TOC removal is enhanced by higher iron and lower bicarbonate concentrations in the raw water. In the industrial WTP the HCO3 concentration in the raw water is increased by lime dosing, which explains the negative impact on TOC removal capacity. Because limitation of organic carbon is the most used way to control microbial regrowth (Hammes et al., 2010), the pilot WTP performs better than the current WTP.

Figure 3 Correlation TOC removal and Fe in raw water



fitted line plot Fe (mg/l) = 5,45 + 0,40 TOC (%)

Figure 4 Correlation TOC removal and HCO3 in raw water



fitted line plot HCO3 (mg/l) = 259,4 - 2,42 TOC (%)

The current industrial WTP uses lime dosing and polymers for iron removal by sedimentation. Biological-adsorptive iron removal can eliminate both chemicals which results in lower operational costs and lower Ca concentrations in the drinking water. The total hardness reduces from an average of 15.6 to 13.8 °F.

CONCLUSIONS

This research clearly demonstrates the benefits of biological-adsorptive iron removal in combination with a degasser and subsequent RSF for treatment of groundwater with high concentrations of iron, arsenic and methane. The pilot WTP is superior to the conventional WTP. The water quality improves with lower arsenic, TOC and hardness in the drinking water as a consequence. There is no need for lime and polymer dosing. The surface footprint of the new WTP is lower due to high filtration rates (15 m/h) of both RSF.

REFERENCES

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