ELS2014 –The Earth Living Skin: Soil, Life and Climate Changes
EGU – SSS Conference
Bari | Italy | 22 – 25 September 2014
ELS2014-107-2

Arsenic treatment by AOCF: a remarkable approach to target arsenic-free drinking water

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This study has been undertaken with an aim to develop an efficient arsenic (As) removal technique for one of the Brabant Water's drinking water treatment plants (DWTP) that would realize production of drinking water with less than 1 μg L^{-1} As. The most innovative aspect of the study was the choice of 1 μg L^{-1} as the target effluent As concentration which was adopted from the recommendations of the US Environmental Protection Agency and the US Natural Resources Defence Council to attain an acceptable lifetime cancer risk. In this study, a three step technique, Advanced Oxidation-Coagulation-Filtration (AOCF) has been evaluated and optimized through a series of bench scale and pilot scale experiments using the source water from the given DWTP. AOCF includes an advanced oxidation step to convert As(III) to As(V) with the help of potassium permanganate ($KMnO_4$), followed by the sorption of As(V) onto/into the precipitating coagulations ($Fe(OH)_3$ flocs) formed after $FeCl_3$ is added to the aqueous system and finally, the removal of the floc-As matrix through double layer filtration.

In the first phase of study, batch experiments were conducted in controlled laboratory conditions to determine the suitable type of coagulant, its optimal combination dose with $KMnO_4$, the optimum process pH, kinetics and equilibrium of oxidation and sorption reactions and suitable dosing points of the chemicals in the treatment train of DWTP. In the second phase, the partially optimized technology was implemented at a pilot scale physical model of the DWTP which was especially designed to obtain conditions similar to that of the full scale DWTP. In order to investigate the influence of sand media age on the efficiency of AOCF treatment, virgin sand media (VS media) was filled in one of the two columns of the pilot setup. The other column was filled with metal oxide coated sand (MOCS media) extracted from the filters of the DWTP. In the third phase of study, filter run time was optimized.

Among several coagulants used during bench scale studies, $FeCl_3$ showed the highest As removal efficiency. However, residual As levels lower than 1 μg L^{-1} could not be achieved only with the coagulant. When the pre-oxidation step through the use of $KMnO_4$ was combined with $FeCl_3$ treatment, a significant increase in As removal was noticed and residual As levels lower than 1 μg L^{-1} were achieved with numerous $KMnO_4$-$FeCl_3$ dosing combinations. The batch investigations also revealed that the oxidation and sorption reactions reach an equilibrium state rapidly, ruling out any need of an extra contact basin for DWTP. As soon as the AOCF was implemented at the pilot model, concentration of As in the effluents of both the filters significantly decreased. In the effluent of VS media, residual As concentration of lower than 1 μg L^{-1} was recorded consistently for several weeks; however, the effluent from MOCS contained a slightly higher concentration of As. The treatment process based on AOCF did not affect the already existing removal processes of Fe, Mn, CH_4 and NH^{4+} in both the filters. The Mn, which was added through the use of $KMnO_4$, was effectively removed as well. Implementation of AOCF negatively influenced the filter run times. Dual media/double layer filtration with anthracite (particle size, 0.6-1.6 mm) on top and VS media (particle size, 0.5-0.8 mm) at bottom increased the average filter run time to the desired interval. The total costs associated with the application of AOCF technology at the DWTP (10 Mm^3/year) have been estimated at approx. 0.02 € m^3 - half of which was related to the cost of chemicals.