Transformation of Ag nanoparticles in managed waste facilities

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Silver nanoparticles (Ag-NP) used in numerous consumer products will most likely be discharged into the sewer system. During the transport, Ag-NPs will be sulfidized to various degrees due to the reaction with bisulfide or metal sulfides [1] [2]. The sulfidation continues during the wastewater treatment and the resulting Ag_2S is accumulated in the sewage sludge [3]. In Switzerland and in large parts of Germany, the digested sludge is incinerated in mono-combustion facilities (fluidized bed reactors). To investigate the fate of Ag-NP discharged to the wastewater stream, we spiked Ag-NP into a pilot wastewater treatment plant (WWTP, primary clarifier, nitrification, denitrification, secondary clarifier) followed by an anaerobic digestion. Samples from the digested sludge were dewatered and incinerated in a bench-scale fluidized bed reactor. The reactor was operated at 800 °C in an atmosphere of 4 % O_2, 12 % CO_2, 84% N_2 with 300 ppm SO_2 and humidified to 30% H_2O.

The Ag content in the dried sludge was ~1000 mg/kg and increased to ~4000 mg/kg in the fly ash. The same enrichment was observed for other (conservative) elements such as Ti, confirming that Ag was not volatilized during the incineration process. Results from transmission electron microscopy (TEM) and X-ray absorption spectroscopy (XAS) confirmed that the Ag-NP spiked to the WWTP completely transformed into Ag_2S particles during the wastewater treatment. Fly ash collected from the fluidized bed reactor after only 1 minute reaction time revealed that Ag was dominantly present as metallic, spherical particles < 50 nm. The fly ash is currently deposited in landfills but to a limited extent, it is used in agriculture. The study revealed that sulfidized Ag-NP will be transformed back into metallic NP during the incineration process. It remains to be investigated whether the metallic NP are incorporated into the fly ash matrix during the combustion process or whether they are only loosely attached to the fly ash and may be released upon contact with water during storage in a landfill.

[1] Thalmann B. et al., *ES&T*. 2014;48:4885–4892. [2] Kaegi R. et al., *Water res*. 2013;47:3866–3877. [3] Kaegi R. et al., *ES&T*. 2011;45:3902–3908.