Experimental study of surface modified nanoparticles based on zero-valent iron

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Introduction

Zero-valent iron nanoparticles (nZVI) are widely used in laboratory and field experiments for remediation of groundwater polluted by chlorinated hydrocarbons [1]. Besides particle reactivity with the selected contaminants, particle mobility is the key factor affecting the success of a field application. Pure nZVI particles are too reactive and tend to fast oxidation and agglomeration [2].
Particle surface modification is an effective method of surface protection and in that manner to prolong particle durability and mobility in aquifer. Polyelectrolytes [3], triblock copolymers [4], plant oils [5] are successful examples of organic chemicals used.

New type of nZVI nanoparticles

A new type of nZVI nanoparticles was prepared using a dry reduction of nanoscale precursor. The particles have an average diameter of 50 nm; narrow distribution 30-70 nm; a surface area of approx. 30 m2/g, and elementary iron content over 80% [6]. To prevent particle coagulation, the particle surface was subsequently stabilized with polyethylene glycol sorbitan monostearate (Tween80).
In laboratory, not-stabilized and stabilized particles were compared to nZVI particles prepared after original Zhang´s recipe. The particle stability in suspension was proven by DLS and sedimentation measurements after particle aging in distilled water and artificial groundwater. Batch experiments with both polluted groundwater samples and spiked distilled water prove high nZVI reactivity with chlorinated hydrocarbons and selected heavy metals (As, Cr). Column experiments indicate sufficient increase of particle mobility in sandy soils due to Tween60 surface treatment. The samples after the experiments were studied by Mossbauer spectroscopy, XRD, TEM to get alteration of particle surface.

Field application

After intensive laboratory tests, nZVI was applied in a pilot and latterly a full-scale remediation at the Horice site (Czech Republic). The site has been contaminated by PCE and its daughter products TCE, DCE with total CHC concentrations of up to 60 mg/l. In total, nZVI was applied into 82 injection wells by a direct push method to a depth of up to 10 meters. About one cubic meter of nanoiron suspension (2.5 g nZVI/l) was injected into 4 screens of each application well at a working pressure of 0.8 MPa.

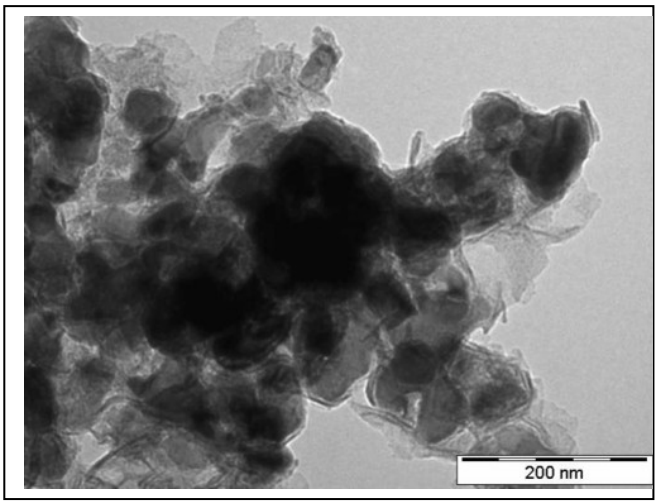

Fig 1 TEM picture of TWEEN80 surface stabilized nZVI

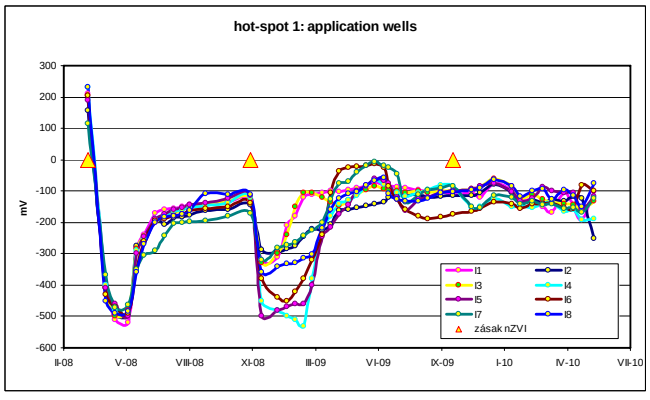

Fig 2 Changes in ORP on the application wells

Till now, the site has been monitored for one and half year since the application. ORP significantly decreased in the application wells and after a month or more in the observation wells (Fig 2). The levels remained low for the whole observation period. A considerable decrease in the concentrations of chlorinated ethenes was observed in a majority of the observation and application wells with a low rebound effect (as an example in Fig.3. for quaternary sediments).

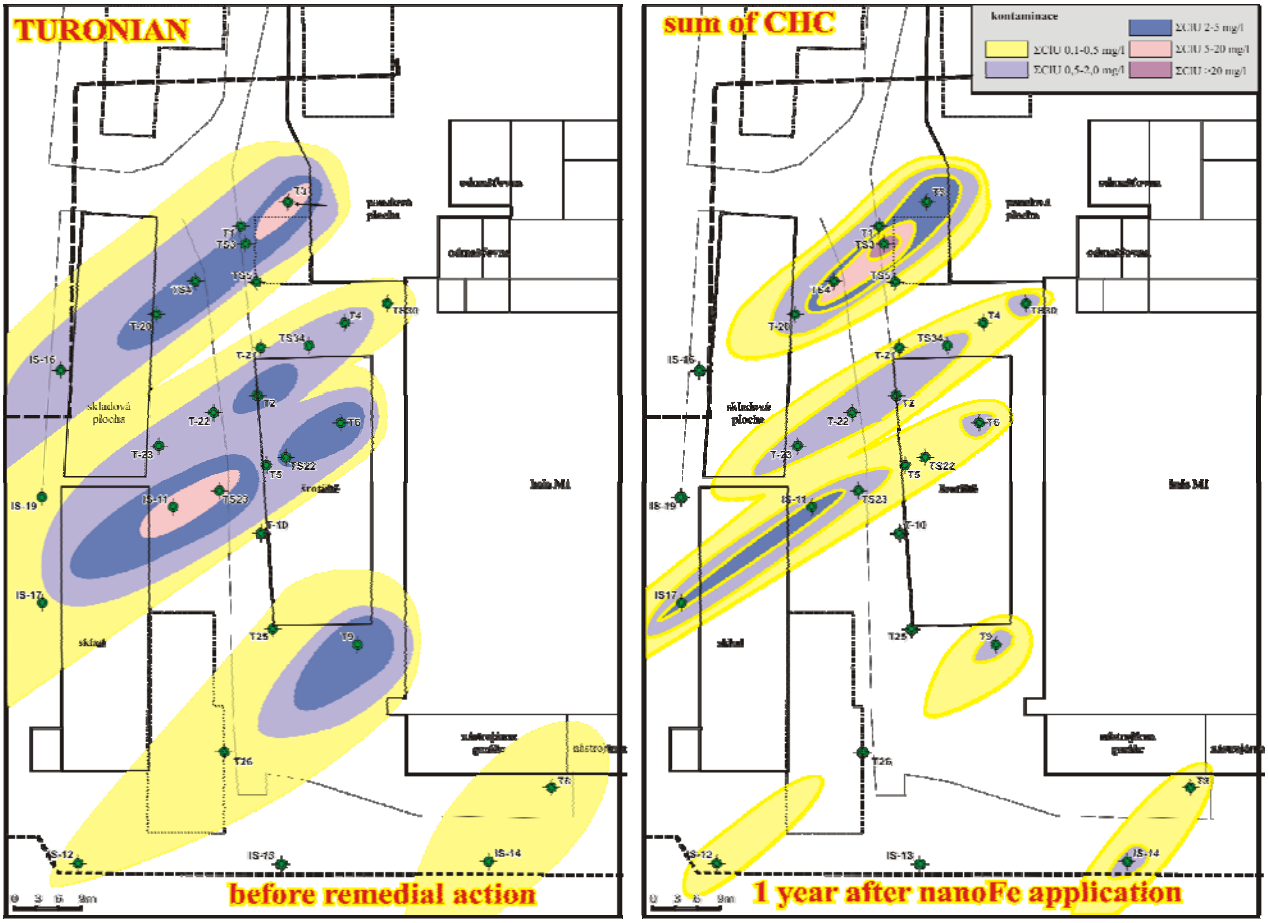

Fig 3 Changes in total CHC concentrations before and after nZVI field application at Horice site

Conclusions

Surface modification of nZVI is the key factor for particle applicability for site remediation. Surface modification by Tween80 was study in laboratory (batch and column experiments, surface characteristics). The results showed sufficient nZVI reactivity and improved mobility in groundwater. The first application of nZVI at the site shows very promising results in contaminant concentration decrease. Based on the results of the first stage of remediation a second set of injections is planned in selected wells.

Acknowledgement

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