

Modification of iron nanoparticles for ground water remediation



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Introduction

Since some years, iron nanoparticles (so called nanoscale zero-valent iron, nZVI) have been used to treat ground water and rock environment for the decomposition of chlorinated hydrocarbons, heavy metals, radionuclides and other contaminants.

The method is based on injection of Fe(0) nanoparticles to ground water through drill holes. Due to nanodimensional character and suitable surface stabilization, the injected nanoparticles can migrate through the rock environment, where they induce reduction reactions with pollutants dissolved in the ground water.

It was experimentally confirmed that by this way, it is possible to eliminate or significantly reduce the activity or the content of many toxic substances.

Aims and Concept

This work is a part of the NAPASAN project, which is dedicated to the further development of ferrous and nonferrous nanoparticle production processes while considering the treatment of contaminants and role of economic aspects. The particles are modified in such a way that transport in the ground zone can take place and contact with contaminants can be achieved to ensure degradation (to get more information see NAPASAN-homepage : www.napasan.de).

The tendency of iron nanoparticles to aggregate after getting in contact with the soil and ground water is the outstanding problem to be solved.

Our primal aims within this project are the search for appropriate coatings, the optimization of the coating process and the characterization of the coated particles.

Results

A method for the formation of iron nanoparticles covered by some special molecules (e.g. some surfactants) was developed (see scheme in Fig. 1). Some PEG-derivatives and also some carboxylic- or phosphonic acids (see Fig. 2) were found to significantly increase the stability of aqueous dispersions from iron nanoparticles.

This particles can be coated during or direct after their formation process. The function of this coating is to diminish aggregation / precipitation of the dispersed nanoparticles and also to increase their stability.

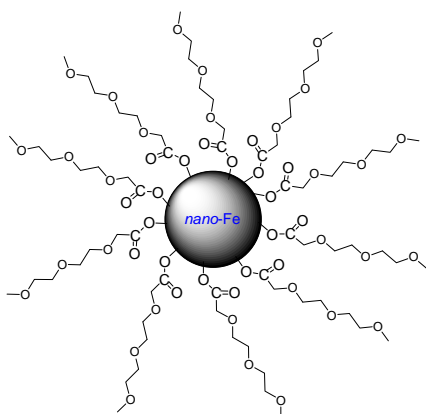


Fig. 1 : Scheme of a nanoscale iron particle covered by MEEA (see Fig. 2)

Molecules for surface modification

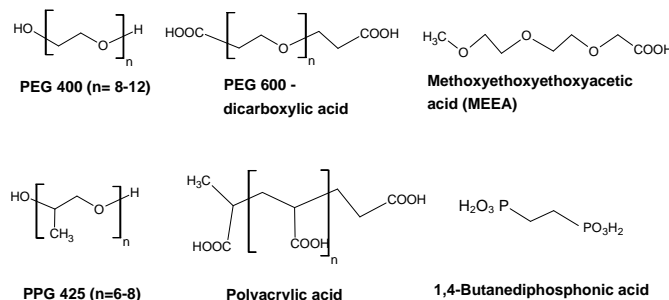


Fig. 2 : Molecules which were successfully tested to improve the stability of aqueous nZVI dispersions (strong inhibition of the agglomeration of the iron nanoparticles)

The effect of phosphonic acids (e.g. 1,4-Butane-diphosphonic acid / BDPS, see Fig. 2) to diminish the aggregation of iron particles was shown by photometric measurements (see Fig. 3). The increase of adsorption is due to an increase of dispersion of nano iron as a result of BDPS addition. Besides the use of commercial available nZVI dispersions, iron nanoparticles were synthesized by reduction of FeCl₂ with NaBH₄ in ethanol-water solution with and without the presence of stabilising molecules (in most cases PEG derivatives, see Fig. 2).

Particle size measurements by light scattering and TEM (transmission electron microscopy) showed typically particles with a size between 20nm and 400 nm. The average particle size (relating to the mass dispersion) was usually in the range between 100 nm and 400 nm and is depending on the reaction parameters and on the type and concentration of the used stabilising (coating) molecules. In several cases aqueous nZVI dispersions could be obtained by this method, which were stable during one or two weeks in the absence of oxygen or diluted salts.

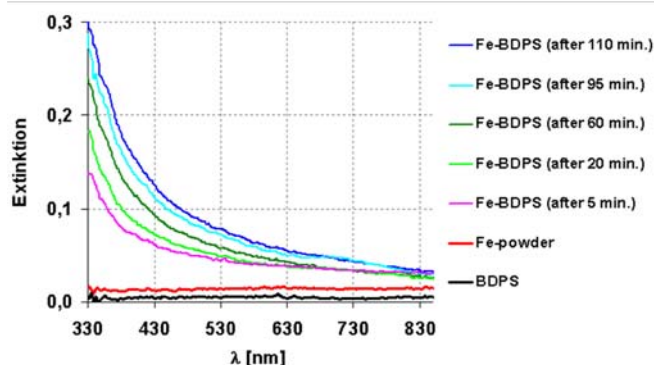


Fig. 3 : Photometric measurements of Fe-powder in water without BDPS (red line) and after addition of BDPS. The black line represents the spectra of BDPS in water without particles.

Summary and Outlook

Current results show that the aggregation of iron nanoparticles can be strongly reduced by adding some stabilising molecules (see fig. 2) during the formation process. However, the lifetime of the coated iron nano-particles is still limited, especially in the presence of air / oxygen or salts (e.g. calcium or magnesium salts in the ground water). Further developments with a technical production of stabilised nZVI dispersions (e.g. by milling iron powders in the presence of adequate solvents and stabilisers) will be necessary to see, if this concept of stabilisation (for nZVI dispersions) will meet the technical requirements for the requested applications.