Applicability of Zero-Valent Iron With Lignite Additives as Geochemical In Situ Barrier for Acid Mine Water

Christoph Klinger[1], Ulf Jenk[2] and Jochen Schreyer[3]

Abstract: Acid mine waters can contain high concentrations of metals like iron, aluminum, zinc, uranium and heavy metals. Research has been conducted for several years to establish the extent to which under the conditions of the former uranium mine of Königstein (Saxony, Germany) reduction of pollutant concentrations can be positively influenced and accelerated by storage of reactive materials in open mine cavities. Experimental investigations ranging in scale from laboratory and underground column tests up to a flooded heading were conducted by WISMUT GmbH and DMT GmbH. Reactions induced by zero-valent iron form a basis for a further improvement of pollutant immobilization by additives. A mixture consisting of iron and lignite proved to be the most effective combination of materials. The structure of iron turnings and coarse brown coal remains stable in spite of partial dissolution and precipitation of reaction products. For periods of more than one year a sufficient reaction capacity without re-release could be verified. The conveyance of reactive materials can be regarded as practical for reducing pollutant loads in mine water in open mine cavities as a supporting measure to be taken during the controlled flooding and as a safety component after conclusion of the flooding.

Within the framework of the flooding concept for the former uranium mine of Königstein (Saxony, Germany), various supportive measures were considered with the aim of attaining the clean-up objective (long-term stable conservation of the mine) more quickly (Schreyer 1996). To minimise the duration and hence the cost of flooding the mine it is generally possible to reduce the mobile pollutant potential by introducing reactive materials. Due to chemical underground leaching using a circulating sulphuric acid solution as main mining method used since 1984, mine water contains high concentrations of uranium, radium, acid, sulphate, iron, aluminium, nitroaromatics and various heavy metals.

The storage of reactive materials in working cavities must take account of the site conditions. This relates both to the hydraulic conditions and to the pollutant profile with the hydrochemical setting. In the majority of cases backfill of the working cavities in the mine is limited for reasons of accessibility, which is why reactive materials can only have a supporting effect when flooding. It is only possible to guarantee effective through-flow for materials which have excellent long-term water-permeability.

For the acid flood water in the Königstein mine materials which are effective in hydrochemical terms are those which lead to an sustainable change in milieu in the

[1] Project Manager, Deutsche Montan Technologie GmbH, GUC Division, Am Technologiepark 1, 45307 Essen, Germany, Ph 0049.201.172.1812, Fx 0049.201.172.1891, Klinger@dmt.de

[2] Technical Expert (Geochemistry), Wismut GmbH, Jagdschänkenstraße 29, 09117 Chemnitz, Germany, Ph 0049.371.8120.141, Fx 0049.371.8120.107, u.jenk@wismut.de

[3] Manager Mine Rehabilitation, Wismut GmbH, Jagdschänkenstraße 29, 09117 Chemnitz, Germany, Ph 0049.371.8120.157, Fx 0049.371.8120.107, j.schreyer@wismut.de

water towards rising pH values and falling EH values and which have good sorption properties. In connection with an experimental flooding several test series were conducted by WISMUT GmbH and Deutsche Montan Technologie GmbH with iron and other materials and material mixtures respectively.

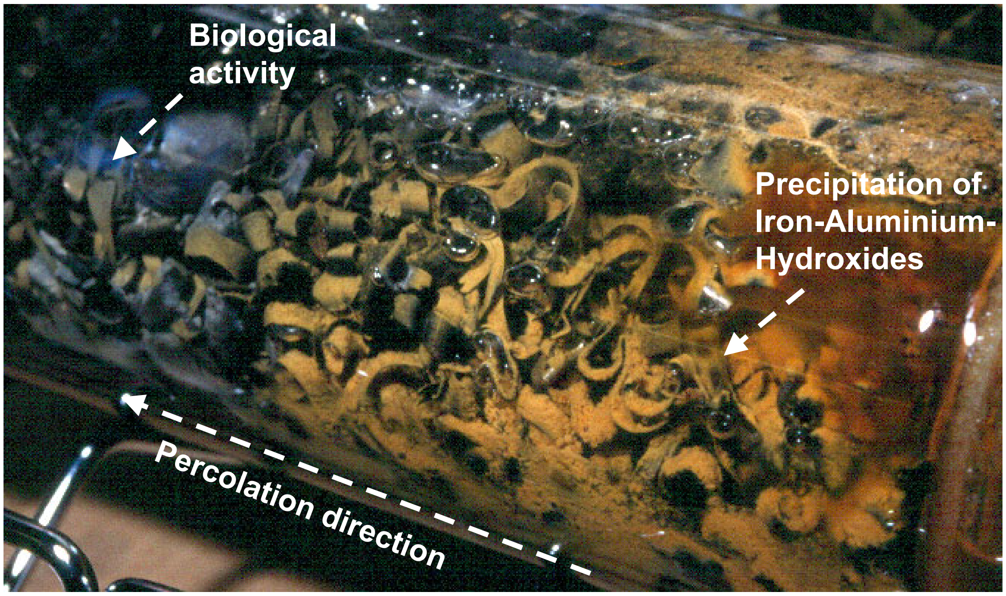

Figure 1 - View on a laboratory column filled with iron turnings and lignite during percolation.

Reactions induced by zero-valent iron form a basis for further immobilisation processes (Fiedor et al 1998). The milieu conditions thus arising facilitate or support the precipitation and greater sorption of heavy metals. Therefore the effectiveness of the metallic iron is enhanced once more with the use of additives. A mixture consisting of iron and lignite immobilises practically all potential pollutants almost quantitatively. Even the relatively mobile elements of U, Co, Zn, Ni and the nitroaromatics are immobilised substantially better with this mixture than with the other additives examined (e.g. hard coal, lime, fermentation residues). This is caused by acid buffering, sorption and the degradation of organic substance in combination with sulphate reduction. Changes in permeability did not occur. The fabric of the iron lathe turnings from metalworking industry and the coarse lignite (Figure 1) remains structurally stable in spite of partial dissolution and precipitation of reaction products. The mixture can be stowed in the mine as a lumpy and hence water-permeable material and it is easy to obtain.

The scale of these experimental investigations ranged from laboratory (2 kg) and underground column tests (20 kg and 200 kg) up to a flooded heading (270 t iron only). Percolation direction was varied from vertical to horizontal and water solid ratios up to 120 L/kg were obtained for conditions as close as possible to reality. There were no significant changes in barrier function depending on test set-up or scale.
For periods of more than one year a sufficient reaction capacity without re-release could be verified. Electron microscope investigations show the precipitation of uranium rich phases on the surface of the iron turnings (Figure 2). Other samples prove

coprecipitation of uranium and aluminium phases. Zinc immobilisation seems to be combined with sulfide production.

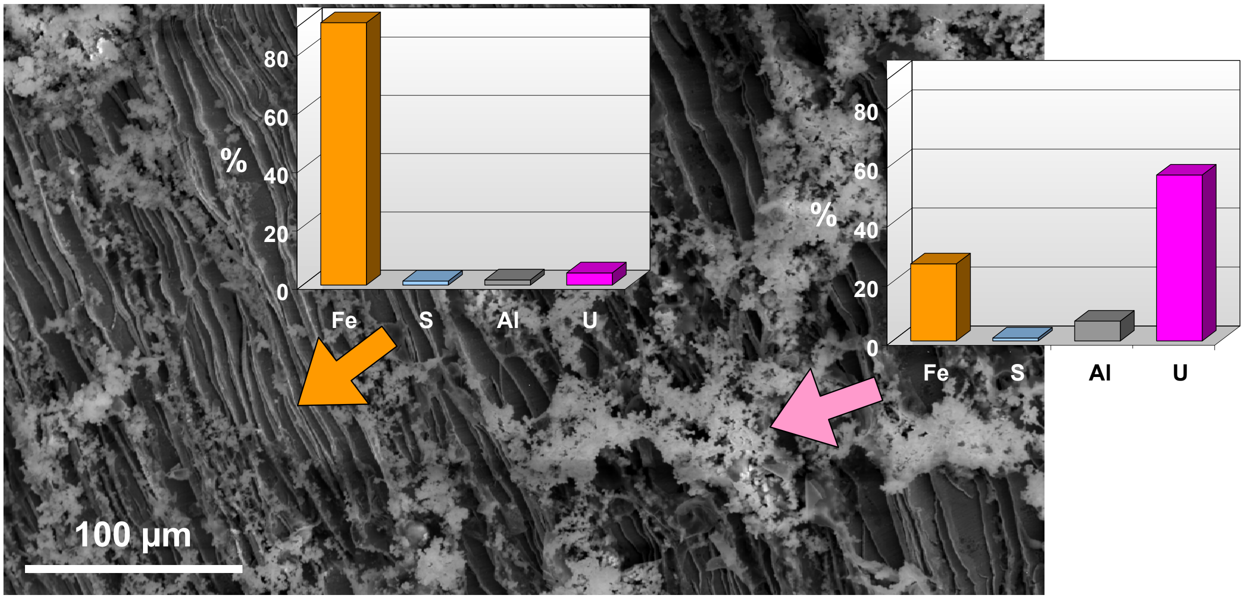

Figure 2 - Electron microscopy of the surface of a iron turning with EDX analysis of the zero-valent iron and precipitation products.

The H_2 gas production could be minimised at pH values of pH 3.2 corresponding with the expected future mine water quality (Jenk and Luckner 1998). Thus it seems realistic to prevent the development of hydrogen during mine flooding. The use of "geochemical barriers" as part of the underground clean-up of the mine assumes the exercise of a controlled influence on the discharge stream particularly, but reactive materials can also be used in the centre of the pollution (i.e. in the mine workings). The conveyance of a mixture of metallic iron and lignite in open mine cavities provides a supporting measure for reducing pollutant loads during flooding and as a safety component after conclusion of the flooding. Long-term effects and accompanying reactions will be investigated further to refine the method for a technological application in the Königstein mine.

References

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