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Extended Abstracts

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Decision support tools for sustainable groundwater management

title: **Field tests for subsurface iron removal at a dairy farm in Saxony, Germany**

author(s): **Jakob Ebermann**
HTW Dresden, Germany, ebermann@htw-dresden.de

Dieter Eichhorn
University of Applied Sciences Dresden, Germany, DH.Eichhorn@web.de

Wolfgang Macheleidt
HTW Dresden, Germany, mach@htw-dresden.de

Thomas Grischek
HTW Dresden, Germany, grischek@htw-dresden.de

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INTRODUCTION

Iron and manganese are commonly present in anoxic groundwater worldwide. High iron concentrations are not harmful to human and animal health, but can result in technical problems such as clogging of production wells, precipitation and incrustation in the water supply distribution systems, orange/brown colour and bad taste of drinking water.

Iron removal from groundwater can be accomplished in two different ways. The quality of raw water, the available financial resources and the philosophy of the water company are the main criteria in deciding on either of the groundwater treatment processes. The most common process is the treatment of groundwater on the surface (after abstraction). Another treatment process is the in-situ subsurface removal of iron from groundwater, using the Vyredox method (Hallberg, Martinell, 1976), Subterra (Rott, Friedle, 2000; Rott et al., 2002; Herlitzius et al., 2008) or Uneis methods (Eichhorn, 1985).

Subsurface iron removal is an ecologically sound in-situ oxidation treatment without chemicals. The operating mode is based on abstraction and infiltration between two or more vertical or horizontal wells (Fig. 1).

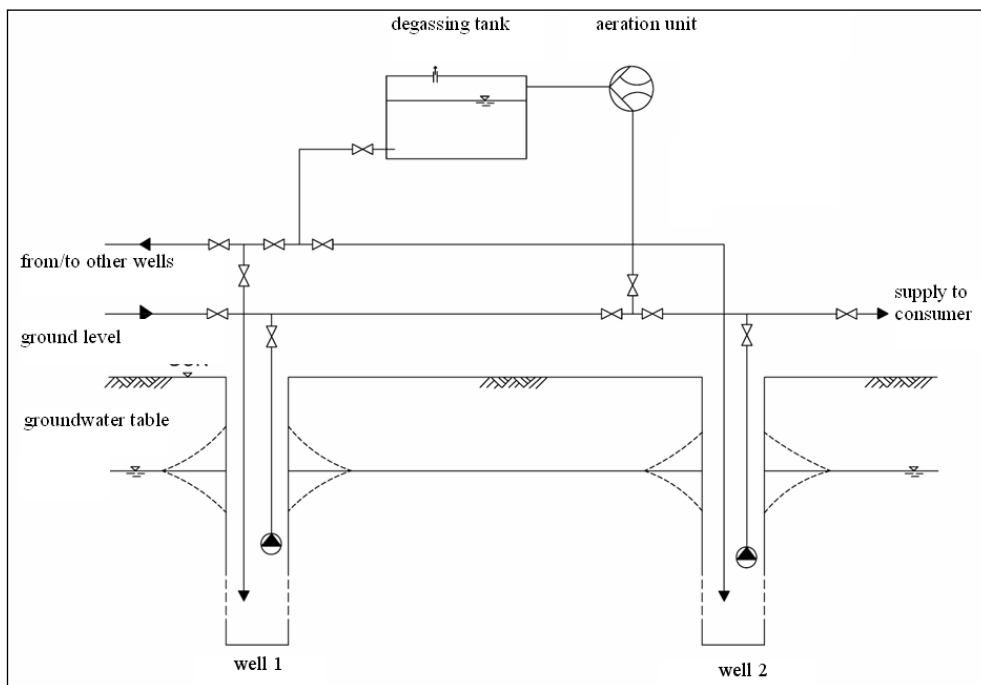


Figure 1. Illustration of subsurface iron removal with two vertical wells.

The applied technique includes the following steps:

1. Abstraction of groundwater from the first well, aeration of a portion of the pumped water and re-infiltration of the aerated groundwater containing dissolved oxygen into the second well (Fig. 1).

2. In the aquifer: Oxidation of the dissolved and adsorbed Fe(II), transformation of the soluble Fe(II) to its less soluble form Fe(III), formation and precipitation of iron(hydr)oxides providing further adsorption sites for Fe(II).
3. Abstraction of anoxic groundwater and removal of Fe(II) by adsorption onto iron(hydr)oxide in the reaction zone around the pumped well. The second well is used for abstraction and the first well is used for infiltration of aerated/oxygenated water.

The efficiency of this groundwater treatment process is calculated as the ratio of the volume of water infiltrated to the volume of water abstracted, which can range from one part infiltrated water to three to ten parts of abstracted water.

Through adsorption in the reaction zone, it is also possible to remove arsenic, manganese and dissolved organic carbon. Limitations of subsurface iron removal are low pH, low hardness, and high Fe(II), Mn(II) and ammonia concentrations.

In 2008, a mobile unit on a vehicle trailer was developed for pilot tests to determine the applicability of subsurface iron removal. The mobile unit contains an aeration unit for controlling the dosage of technical oxygen, a static mixing unit, a degassing unit, valves for discharge control and devices for continuous measurements of discharge, pH, temperature and electrical conductivity. The objective of this paper is to present a field test approach for subsurface iron removal, based on field investigations at a dairy farm in the state of Saxony, Germany. At the farm, the drinking water for the livestock is supplied by two groundwater abstraction wells.

STUDY SITE AND METHODOLOGY

The research site at the farm in Dobra is located in northern Saxony 40 kilometres from the city of Dresden. The Pleistocene sediments are underlain by greywacke with a thickness of 10-20 m. The sediments are fine to medium sands with a hydraulic conductivity of about 1×10^{-3} m/s. At the time of the experiment the water table was 1.5 m beneath the ground surface, and the groundwater had a mean concentration of 10 mg/L Fe(II), 0.5 mg/L Mn, 0.1 mg/L ammonia and a mean pH of 6.5.

To conduct the field test for subsurface iron removal in Dobra, an existing old shaft well (PW 2) with a diameter of 2 m and depth of 5 m, and a new vertical well (PW 1) having a diameter of 125 mm and a depth of 14 m were used. Additionally, for measuring the dissolved oxygen concentration (O_2), electrical conductivity (EC) and pH in the reaction zone, two monitoring wells (MW 1 & MW 2) having a depth of 12 m were also installed at a distance of 5 m and 10 m from the new vertical well PW 1 (Fig. 2). The mobile unit used in this study was developed at the Division of Water Sciences of the University of Applied Sciences Dresden.

The field tests were conducted from September to December 2009, with a total abstraction rate of $4.5 \text{ m}^3/\text{hour}$ of which $1.2 \text{ m}^3/\text{hour}$ was infiltrated. One test period consisted of a cycle of an abstraction from one well and infiltration into the other well. During the first testing period it was necessary to create a reaction zone with a water volume of around 300 m^3 and an O_2 concentration of 15-25 mg/L. In the first period the water was abstracted from PW 2 and infiltrated in PW 1. Using data loggers in the production and monitoring wells it was possible to measure the O_2 , pH and EC automatically at regular intervals. Samples of the abstracted water were taken during all 7 test periods.

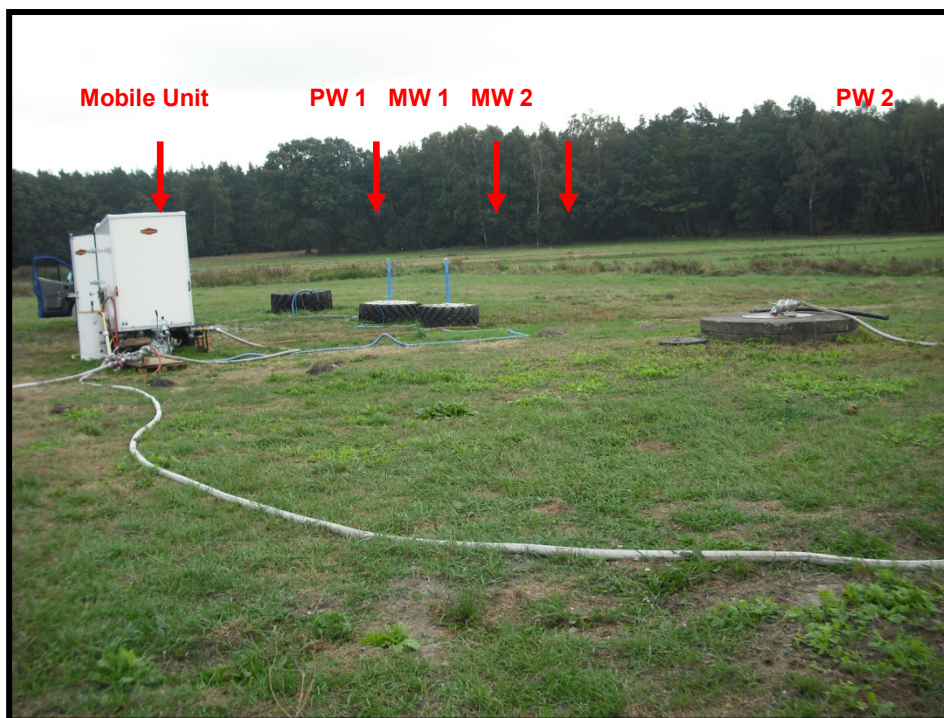


Figure 2. Mobile car unit for subsurface iron removal tests with production wells (PW) and monitoring wells (MW).

RESULTS

A tracer test to determine the size of the reaction zone around one well was conducted by measuring the EC and O₂ concentration. The infiltrated water containing 15-25 mg/L O₂ and a chloride tracer were injected in PW 1. O₂ and EC were measured in PW 1 and in MW 1 separated by a distance of 5 m. The results (Fig. 3) show a breakthrough of the injected tracer in MW 1 after 3.5 days, peaking at 1.3 mS/cm after about 4 days. A breakthrough of oxygen (from the oxygen-rich infiltrated water) was observed in MW 1 after about 7 days with a peak of 22 mg/L at 8.5 days.

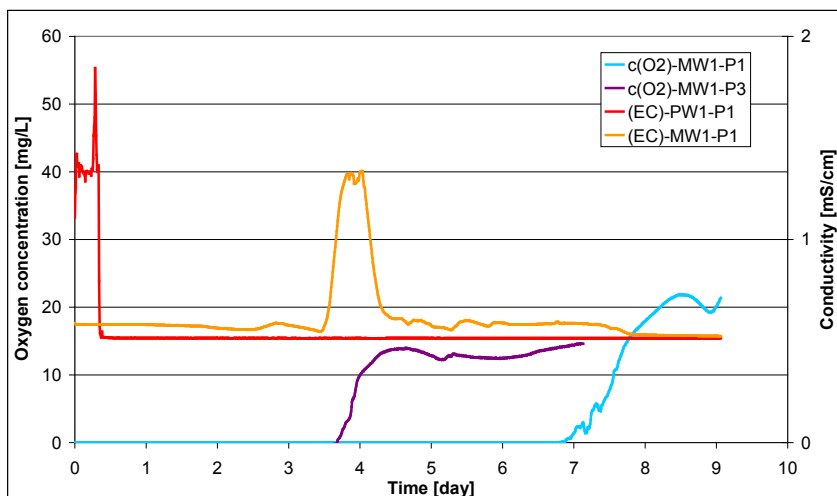


Figure 3. Oxygen concentration and electrical conductivity during the tracer test in the production well 1 (PW 1) and monitoring well 1 (MW 1) during period 1 and 3 (P 1, P 3).

The infiltrated volume before every abstraction was around 300 m^3 in both of the wells. The iron concentration of 10 mg/L at a depth of 14 m in PW 1 was less than 0.5 mg/L in three periods after an abstraction volume of 700 m^3 (Fig. 4). Figure 4 shows also that the iron removal in PW 1 is improving after subsequent periods of infiltration and abstraction.

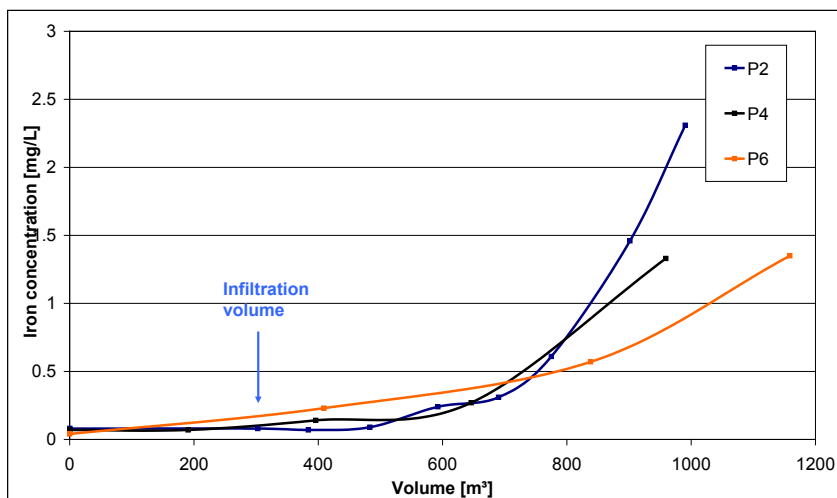


Figure 4. Iron concentration during abstraction in period 2, 4 and 6 at production well 1 (PW 1).

In PW 2 it was possible to lower the iron concentration from around 5 mg/L to less than 0.5 mg/L for an abstraction volume of up to 1200 m^3 (Fig. 5).

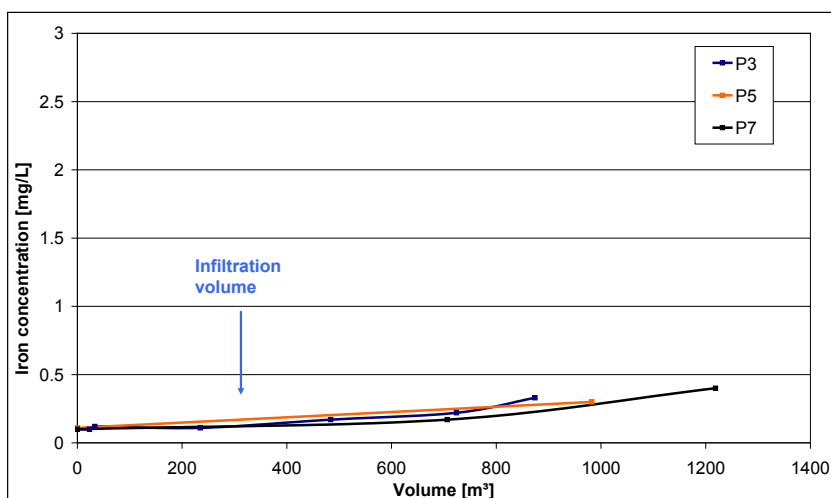


Figure 5. Iron concentration during abstraction in period 3, 5 and 7 at production well 2 (PW 2).

CONCLUSION

After application of the subsurface iron removal technique, an iron concentration of less than 0.2 mg/L (a 98% change from background) was achieved in the abstracted groundwater within one week. Results from a tracer test were used to determine the size of the reaction zone. The ongoing experiment provides data for different oxygen concentration in the infiltrate, the efficiency of iron removal and the oxygen consumption by other processes. Results will be used to choose an optimal subsurface iron removal treatment technique, especially in deciding on long-term subsurface treatment using aeration or technical oxygen. The mobile unit can be used to characterise site-specific aquifer conditions within one week and to determine whether subsurface iron removal can be successfully applied at a site.

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