Impact of Human Activity on Groundwater Dynamics (Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, The Netherlands, July 2001). IAHS Publ. no. 269, 2001.

Well ageing and its implications for well and piezometer performance

GEORG HOUBEN

IML/Geochemistry & Environmental Sciences Laboratory, RWTH Aachen, Suesterfeldstr. 22, D-52056 Aachen, Germany

e-mail: georg.houben@rwth-aachen.de

Abstract Wells and piezometers are the main tools used to gain information on the hydraulic properties and water quality of aquifers. They often experience a decrease in performance over time due to the formation of scale. This leads to elevated entrance resistivity and subsequently to incorrect readings of hydraulic head, and values calculated therefrom. Iron and manganese oxihydroxides and sometimes calcite are the main constituents of well incrustations. Laboratory experiments showed that strong acids and strong reducing agents are the most efficient well rehabilitation chemicals. Field applications of combined hydro-mechanical and chemical rehabilitations support this evidence. Well performance tests are useful to quantify the extent of well rehabilitation.

Key words incrustation; iron oxihydroxide; piezometer; scale; well; well ageing

INTRODUCTION

Scale formation

Scale formation is a result of oversaturated waters precipitating minerals that clog the well screen and filter pack. This is often caused by mixing of waters with differing hydrochemical conditions inside a well. Another important cause is the loss of CO_2-gas from groundwater due to turbulent flow. This subsequently leads to disruption of the carbonate equilibrium and carbonate precipitation. Incrustations are subdivided into several types based on mineralogy, geochemistry and reactive behaviour (Houben, 2000). Many scales consist predominantly of iron- or manganese-oxihydroxides ("ochre"). Carbonate, sulphate, sulphide and aluminium hydroxide incrustations are less common.

Wells and piezometers are the main means of obtaining water levels, hydraulic aquifer characteristics and water samples. Incrustations may negatively influence their performance, e.g. by enlarging entrance resistance. This can lead to incorrect readings of hydraulic heads subsequently leading to erroneous assessments of groundwater flow and hydraulic conductivity. In many cases pumping tests have to be performed with water levels measured only in the well itself. Consider a virtual well being pumped at 50 $m^3 h^{-1}$ resulting in a drawdown of one metre per log cycle. The resulting transmissivity calculated after Cooper/Jacob is 2.54×10^{-3} $m^2 s^{-1}$. Increasing drawdown due to well ageing leads to significantly decreasing values of transmissivity and conductivity (Fig. 1).

Scale often affects the uppermost sections of the well screen so that oxic near-surface groundwater may not enter the well. Figure 2 gives an example of how nitrate-containing shallow groundwater alters the total hydrochemistry after removal of scale.

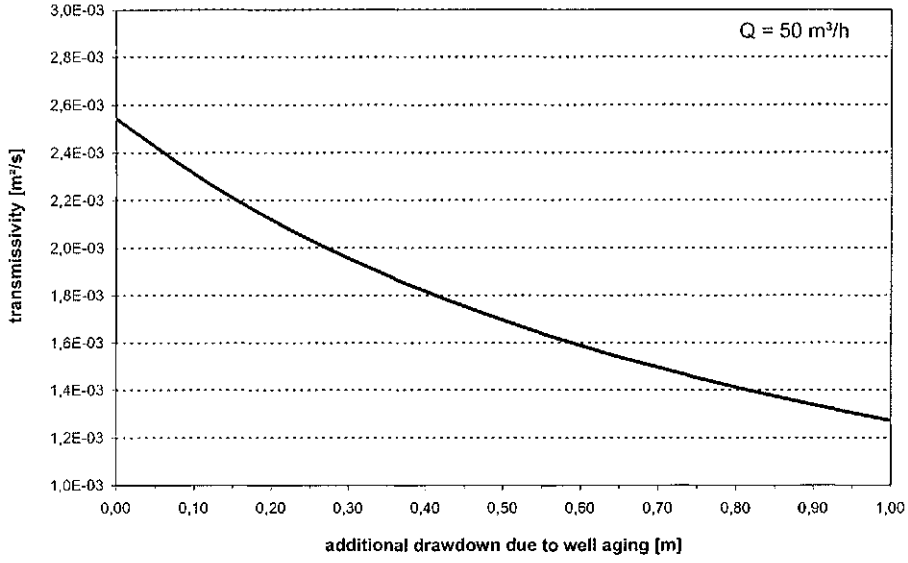

Fig. 1 Effect of additional drawdown caused by well ageing on transmissivity determinations through pumping tests.

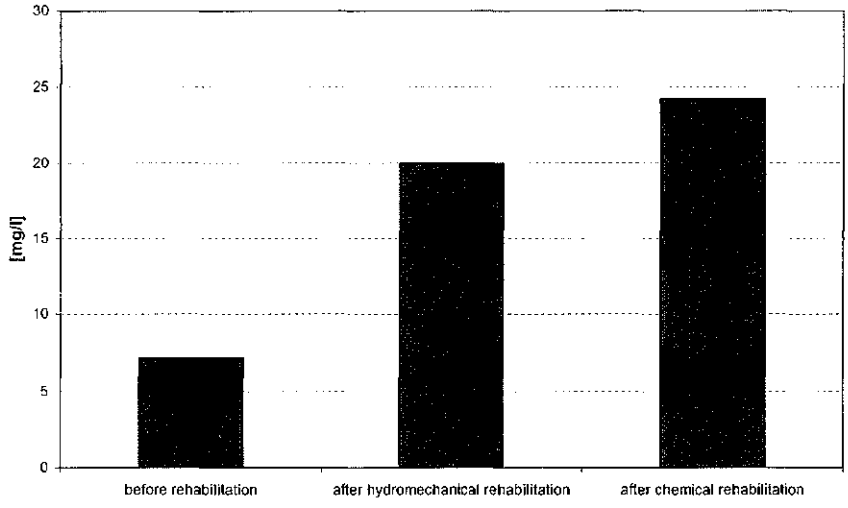

Fig. 2 Nitrate content in a drinking water well before and after well rehabilitation.

REHABILITATION TECHNIQUES

Common mechanical rehabilitation utensils are surge blocks and scrubbing-brushes with plastic or steel bristles. Hydro-mechanical methods mostly utilise pressurised water or air. Pressure impulses created by the explosion of gas mixtures ($H_2 + O_2$) or the ignition of explosives are also used to stimulate the break-up of incrustations.

Techniques such as shock-freezing (liquid carbonic acid), pulsed ultrasonic and rapid drawdown of static water level with compressed air (air-lift-technique) are also available.

Carbonate, aluminium and sulphide incrustations are easily dissolved using inorganic acids. Three types of chemical processes propagate the dissolution of iron and manganese oxides: (a) proton-assisted, (b) ligand-assisted and (c) reductive dissolution (Banwart *et al.*, 1989). Protons can be added through inorganic acids. Due to their relatively low cost hydrochloric, sulphamic and sulphuric acids are the most commonly used. Organic acids, such as ascorbic or citric acid, have an effect through low pH as well as their reducing capacity. The dissolution capacity of ligands alone is usually low. They are usually used to enhance the effects of acids or reducing agents.

Laboratory experiments were performed to test the efficiency of different chemicals at dissolving iron and manganese oxihydroxide scales (Fig. 3). Strong inorganic acids showed fast and efficient reaction rates at pH << 1 although safety and corrosion issues may limit the application at such low pH. Citric acid has only a very low potential. A combination of ascorbic and oxalic acid proved to be efficient but was hampered by re-precipitation of iron oxalate in our experiments (Fig. 3). In addition, citric and ascorbic acid are known to propagate secondary microbial pollution. A combination of a strong inorganic reducing agent and a ligand operating under neutral pH was found to be a good alternative. It was successfully applied at several well sites after hydro-mechanical pre-treatment. Well performance tests showed that chemical rehabilitation can be responsible for up to 50% of the total performance gain (Fig. 4).

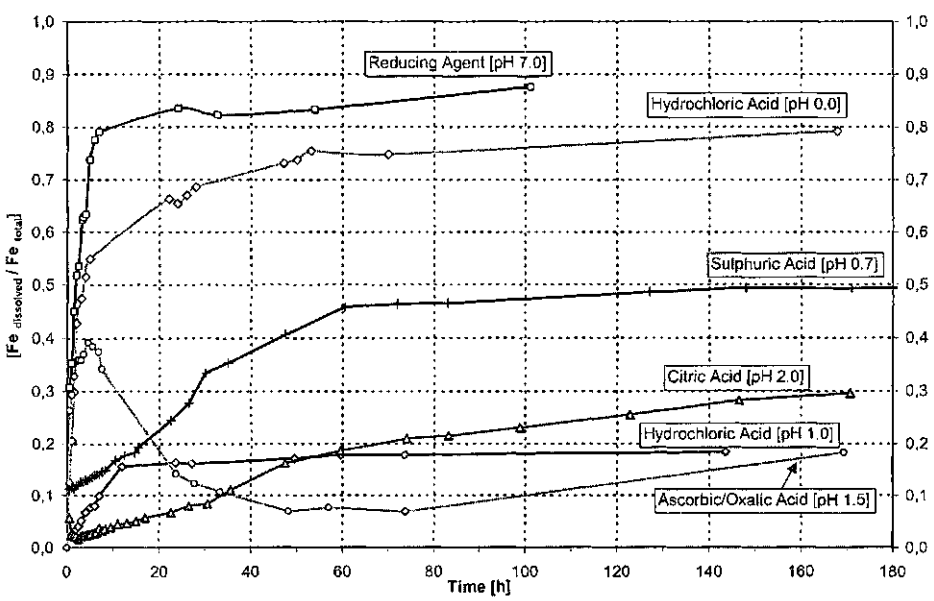

Fig. 3 Dissolution of an iron oxihydroxide scale using different chemicals.

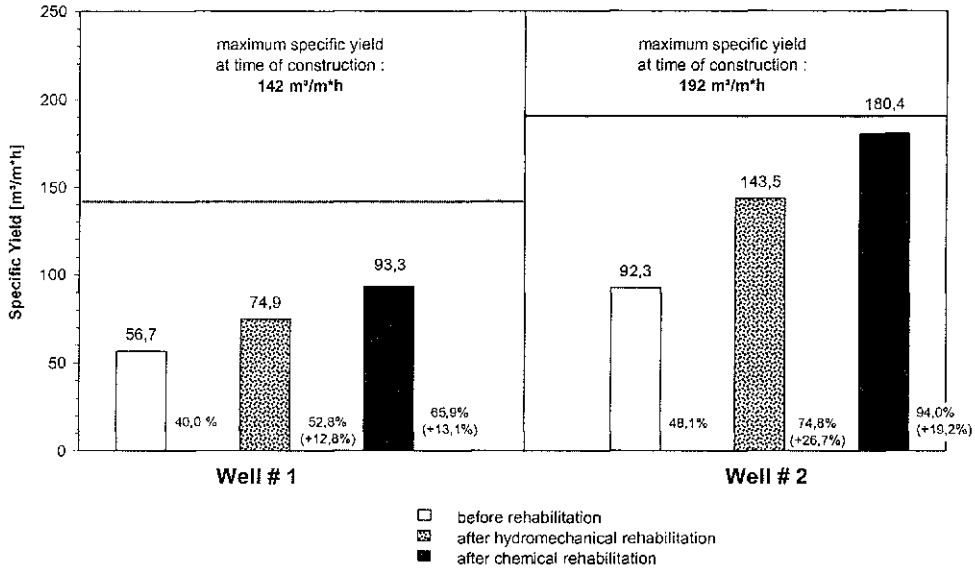

Fig. 4 Results of hydro-mechanical and chemical well rehabilitations at two drinking water wells in Krefeld, western Germany.

CONCLUSIONS

- Scale formation often inhibits the performance of piezometers and wells.
- Limited performance may result in erroneous hydraulic or hydrochemical data.
- Scale type identification is necessary to select appropriate rehabilitation chemicals.
- Only highly reactive chemicals such as strong acids or reducing agents are suitable.
- Chemicals must not cause corrosion or secondary microbial pollution.
- Chemical rehabilitation can be responsible for ≥ 50% of total efficiency gain.
- Hydro-mechanical pre-treatment is essential for all chemical rehabilitations.

REFERENCES

Banwart, S., Davies, S. & Stumm, W. (1989) The role of oxalate in accelerating the reductive dissolution of hematite (α-Fe_2O_3) by ascorbate. *Colloid Surfaces* **39**, 303–309.

Houben, G. (2000) Genesis, aging and chemical removal of well incrustations. In: *Applied Mineralogy in Research, Economy, Technology, Ecology and Culture*, vol. II (ed. by D. Rammlmair *et al.*) (Proc. Sixth Int. Congr. Appl. Mineral., ICAM2000 Goettingen), 803–806. Balkema, Rotterdam, The Netherlands.