Well Rehabilitation with High-Energy Ultrasound

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Content:

Basic Principles

Drinking water supply in Germany is mainly based on groundwater. Abstraction is made by wells. The most popular form of a well construction is a vertical borehole with a filter screen in the middle and a gravel bed around. After a certain time in operation such wells are getting clogged. This is called well-ageing and is due to physical and chemical or biochemical processes between dissolved content of the groundwater and changing conditions with passing from the aquifer into the well construction. These processes cause generally a narrowing of the intake area. This means the slots of the filter screen and pores of the filter gravel become clogged and the hydraulic conductivity decreases. Indices are higher draw-down or decreasing discharge rate, furthermore increasing turbidity of abstracted water or higher power consumption of pumps. Typical reasons for well-ageing are:

- silting up because of sand or silt carried along by the water
- formation of incrustations because of deposition of carbonates, aluminium deposits or iron and manganese deposits
- biofilm-building bacteria
- corrosion of filterpipes and other metallic components

Therefore the coatings consist of iron- and/or manganese oxides or organic matter (biofilms). The earlier the well becomes redeveloped the more is the chance for success and the fewer are the costs. Only a regular monitoring of wells can show necessity of well rehabilitation.

Well rehabilitation

Generally there are mechanical and chemical methods for well rehabilitation. The methods of the first group are based on physical mechanisms to separate the coatings from the filter gravel. Thereto belong:

- Brushing of the filter screen
- over pumping
- using surge blocks
- flushing with hydraulic pressure
- CO2-injection
- pressure wave methods using hydraulic pressure, explosive charges or sound waves

Chemical methods, in comparison, work with anorganic or organic acid-mixtures, which are pumped into the well and left there until the coatings are dissolved. There are different chemical methods. They vary in composition of the solvent and the way it is brought into the filter gravel. Every chemical well rehabilitation requires authorisation because potentially dangerous chemicals are brought into ground water! Choosing the most appropriate rehabilitation method must always consider all given facts of the well and ecological and economical aspects.

Well rehabilitation with high-energy ultrasound

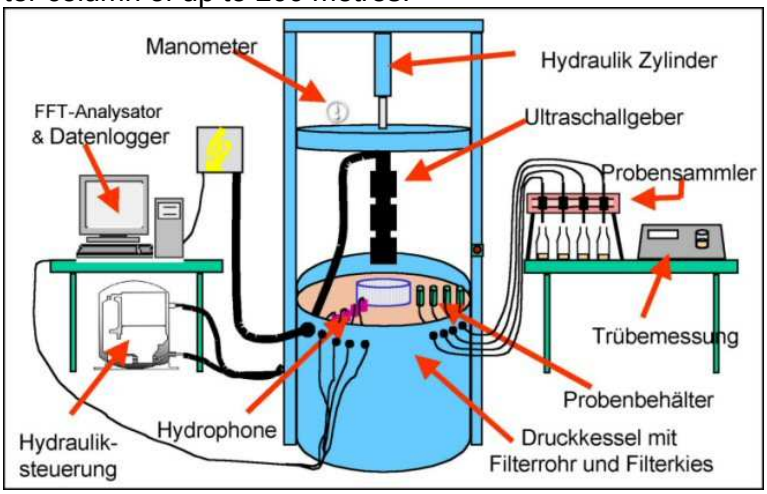
The ultrasound method is among mechanical methods. It is used since the middle of the nineties. With that method the strain on the well construction is very low and there is absolutely no harm for the environment because it works completely without any chemical additives. Furthermore it is a fast progressing and cost effective method.
Ultrasound means sound waves with frequencies between 20 kHz and 1 GHz. For cleaning purposes the low frequency ranges are the most effective. For well rehabilitation ultrasound devices work with 20 to 25 kHz. For they are more robust under the special conditions in a well we chose a magnetostrictive ultrasound device.
Well rehabilitation with ultrasound is a comparatively new, modern and competitive method. During the last ten years more than 500 wells were cleaned successfully. But at some wells there was no considerable increase of efficiency. So the method is still controversially discussed and it is not fully understood how the method works so far. In this context the ESWE Institute for Water research and Water technology, Wiesbaden designed a shared research project together with the BRM GmbH Brunnensanierung Rhein-Main-Bodensee from Biebergemünd. Practical applications of the ultrasound method were accompanied by scientific measurements in laboratory and field tests. Focus lay on how the method works and how it is influenced by specific conditions in different types of wells (i.e. effects of type of filter screen material and filter gravel, hydrostatic pressure from well depth, different types of coatings and others). The project was supported by the Deutsche Bundesstiftung Umwelt (DBU) in Osnabrück for two and a half years (05/ 2001 – 10/ 2003).

The results of this project were basis for a new project with one year duration. From November 2003 till October 2004 further field tests were carried out in in close collaboration with ESWE Versorgungs AG in Wiesbaden. Focus lay on the special conditions in the ESWE Water works Wiesbaden-Schierstein and included all questions related to the constitution and age of the coating materials. It was supported by the ESWE Innovations- und Klimaschutzfonds.

Project “EBRU”

(development of a method for well rehabilitation with an ultrasound device, supported by DBU, 05/ 2001 – 10/ 2003)

This project was divided into two main parts. The first part included primarily laboratory work at a specially designed model well (outline and foto below), named URSEL (Ultrasound – Rehabilitation – System in ESWE-Institute’s – Lab). The heart of this model well is a hydraulic closable pressure vessel, stable up to 20 bar to simulate the hydrostatic pressure of a water column of up to 200 metres.



outline of URSEL with all applications for the first part of the project EBRU

Photo of URSEL in the laboratory of ESWE-Institute

With its construction and implementing there is a worldwide unique experimental equipment available to simulate conditions of a vertical filter well. In laboratory tests all parameters of

wells and the ultrasound device which could effect the rate of success of the rehabilitation were simulated, including:

- period of exposure to sonic waves
- temperature
- hydrostatic pressure up to a simulated water column of 200 m
- sound propagation at different postions in the annular space
- different types of filter screens and filter gravels

All laboratory tests showed sound propagation far behind the filter screen in the annular space. The rate of success was closely connected to hydrostatic pressure. The optimal duration of exposure was found.
The effects of the sound waves to the coatings was simulated using different materials, including e.g.

- original coatings from wells, containing iron-oxides
- original coatings from wells, containing manganese-oxides
- gelatine-like substances to model biofilms

All materials showed clear effects. Ultrasound is able to remove iron- and manganese-oxide-coatings and biofilms from the filter gravel.
Brought forward to well rehabilitation this means that ultrasound has the ability to cause a cleaning of the annular space.
The second part of the project in conclusion should bring evidence of laboratory results in field tests at real drinking water wells. For this three wells were chosen with different characteristics regarding depth, filter screen materials and aquifer qualities. They were rehabilitated closely followed by scientific measurements.
This included videotaping of condition of the filter screen, pumping tests and geophysical applications before rehabilitation, after pre-cleaning and after exposure to ultrasound.
Again the ultrasound method proofed to be successful in rehabilitating aged wells.
All together the project showed how ultrasound is working in wells and how the success is dependent on characteristics of the well.
Results were brought together in a final report (available on request) and on a small conference in December 2003 in Wiesbaden
The examination and evaluation of further results from practical applications ranged from unsuccessful to very successful, but with no clear dependence on the well construction or the pressure conditions. So it is assumed that many, complex-working factors determine the success of using ultrasound for well rehabilitation. Of particular importance seem to be composition and age of the coatings. That question should be in the focus for the new project.

Project “US”

(Ultrasound – an environmentally friendly method to rehabilitate wells, supported by ESWE Innovations- und Klimaschutzfonds, 11/ 2003 – 10/ 2004)
Centre of interest were the drinking water abstraction wells in the waterworks of ESWE Versorgungs AG in Wiesbaden-Schierstein. From extensive data material from former well rehabilitations and well monitoring five suitable wells were chosen with:

- same principle characteristics (such as aquifer, depth, length of filter screen, type of filter screen etc.)
- either iron-oxide or manganese-oxide coatings
- different durations of use since last rehabilitation

On this basis were chosen:

1. a well with aged coatings containing iron and manganese
2. a well with aged coatings with predominantly iron-oxides
3. a well with aged coatings with predominantly manganese-oxides
4. a well with manganese-oxide-coatings, last rehabilitation only 2 years ago
5. a well with iron-oxide-coatings, last rehabilitation 4 years ago

Again, all chosen wells were rehabilitated with the ultrasound method accompanied by extensive scientific measurements. It included videotaping of the condition of filter screen and pumping tests before starting to rehabilitate, a second time after pre-cleaning and the last time after ultrasound application. Furthermore some geophysical methods were used to look behind the filter screen into the annular space, again before and after ultrasound application. With this program results were directly comparable and the effects of the ultrasound method to the annular space were showed.
All five wells showed better discharge rates after rehabilitating them. Success was, as expected, dependent on the age of the coatings. Nature and constitution were also of influence.

Compared to the chemical rehabilitation method, which was used before in the waterworks, the ultrasound method c ould not reach the high amounts of soluble iron and manganese carried out, but far more insoluble fraction was removed from the annular space.
Presently all results are brought together to a final report.

Future prospects

We on ESWE-Institute plan to continue our work and our existing co-operations with developers and users of the ultrasound device and the method. Well-rehabilitation with ultrasound is therefore a method, that is carefully and extensively tested in laboratory and practical scientific work that gave evidence of its efficiency.
If you have any comments or questions please feel free to contact us!

The Model Well

Main component of the device is a steel vessel of 130 cm height 100 cm diameter. It is closed with a hydraulic-controlled steel lid. This system is stable up to pressures of 20 bar and contains may different possibilities to install measurement devices. With installing commercially available filter screens and filter gravel we were able to simulate well conditions for wells up to 200 m depth. Our measurement devices could be put directly to the annular space. The picture below shows view into the model device:

For our laboratory tests we installed for example:

- hydrophones for sound measurement in the annular space in the filter gravel
- temperature sensor to examine possible heating due to ultrasound
- probe containers containing coated filter-materials

- probe containers containing gelatine-like substances (Agar-Agar) to simulate biofilms

Because there is the possibility to easily change the installations, more thinkable assemblies can be realised.

Publications

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