Managing the Clogging of Groundwater Wells

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Groundwater wells are common to many civil engineering schemes and are used for a wide range of purposes such as construction dewatering, open loop geothermal systems or alternative water supplies for buildings and facilities. Whatever the application, well performance must be optimised and high levels of operational efficiency and service availability achieved. However, the benefits of proactive planned maintenance of groundwater wells on civil engineering projects are not widely recognised.

Typically, wells have a near surface section of well liner, from which groundwater is excluded. The deeper part of the well is the permeable well screen, through which water enters the well. Water enters the well exclusively through the well screen, and it is here that clogging processes occur.

Pumping lowers the water level in the well by an amount known as the 'drawdown'. This comprises the drawdown in the aquifer and the 'well loss', a head difference between the inside and outside of the well that represents the resistance to flow of water into the well. An inefficient (clogged) well will have a greater well loss than an unclogged well, and therefore a greater drawdown for a given pumped flow rate. Clogging can become so severe that the yield of the well is reduced, so that less water is available to users, or so that dewatering is less effective.

CLOGGING AND ENCRUSTATION PROCESSES

A groundwater well is a complex hydrodynamic environment. As water passes through the well and the downstream pumping system, it undergoes pressure changes, temperatures changes, is exposed to the atmosphere and comes into contact with artificial surfaces in well screens and pumps. This can create ideal conditions for clogging to occur.

Three main clogging processes occur in and around wells: physical clogging, where particulate matter is re-arranged; bacterial clogging, where bacterial colonies grow in the well, feeding from dissolved material in the well; and chemical clogging, where mineral compounds derived from dissolved material in the water are deposited. The focus of this paper is on chemical and bacterial problems.

Iron-related deposits on well pumping equipment

Bacterial clogging: Iron bacteria are one of the most common clogging processes in wells. Their life cycle oxidises the soluble ferrous iron (Fe2+) in the groundwater to an insoluble ferric form (Fe3+). The potentially turbulent, oxygenated environment in a well and pumping system creates an ideal environment for this to occur. The bacteria produce a biofilm, typically a slimy or gelatinous red-brown deposit (commonly known as biofouling) that can be difficult to remove.

Chemical clogging: Occurs by chemical precipitation induced by the natural pressure release on the water as it moves from the formation into the well bore and to the pump, combined with the oxygen available in the well. The most commonly reported chemical encrustations are iron oxyhydroxides, sulphides and calcium carbonates. Carbonate clogging occurs when the natural carbon dioxide dissolved in solution is released, resulting in an increase in water pH. As the pH increases in waters with high levels of calcium carbonates, rapid precipitation of white or pale grey calcareous deposits occur in the well and pump.

STRATEGIES TO MANAGE CLOGGING AND ENCRUSTATION

Chemical treatments are widely used to rehabilitate wells; many products and commercial treatments, are available (see table below, which is based on US Army Corps of Engineers 2000). Research has shown that chemical rehabilitation can provide 40 to 60% of the total gain during a combined chemical and hydro- or mechanical rehabilitation (Houben 2001). The challenge for the well owner or operator is that each site will have unique aspects, requiring care in the choice of rehabilitation methods and chemical agents if well performance is to be returned to close to its original levels.

Chemical	Advantages	Disadvantages
Hydrochloric Acid (also known as Muriatic Acid) (HCl)	Effective against a range of mineral deposits and highly effective at removing scale. Widely used in groundwater well rehabilitation.	Corrosive to most metals, particularly stainless steel because of chloride content. Not effective against iron biofouling. Produces toxic fumes, requires careful handling, purity levels needed be defined before handling, lowers pH levels.
Sulfamic Acid (H_2NSO_3H)	Strong acid which reacts very quickly against carbonate scales. Powder form should be dissolved in water before adding. Safer to handle than muriatic acid.	Not effective against iron or manganese deposits. More effective as a combination chemical treatment against biofouling or metal oxides.
Phosphoric Acid (H_3PO_4)	Less corrosive than hydrochloric acid but slower acting. Effective against iron and manganese deposits.	Requires careful handling. Leaves phosphates behind which can provide nutrients for microbial growth.
Sodium hypochlorite (NaOCl)	Liquid product. Good disinfectant capabilities. Effective at oxidising and killing bacteria.	Not effective against mineral deposits. Short shelf life. Can increase the redox potential of the aquifer.
Acetic Acid (CH_3 COOOH)	Effective biocide and biofilm dispersing acid. Relatively safe to handle.	Glacial acetic is very corrosive to the skin and produces a pungent vapor that can cause mild to severe lung damage.
Oxalic Acid $(COOH)_2$	Strong, reducing acid and is excellent against iron and manganese oxide. Biodegradable. As a combination chemical works with even greater power.	Salts of the acid are poisonous but during a treatment converts to inert elements, with any residues easily removed from water body.

However, rehabilitation alone is not the optimal solution. The most effective programmes to manage well performance typically incorporate a monitoring and measurement plan alongside a regular chemical treatment. The elements of a well rehabiltation can be illustrated by reference to the *BoreSaver* well management programme intended to return performance to as close to the original drilled capacity as possible and to help maintain a continual, problem-free water supply. The elements of such a programme are:

Pre-rehabilitation survey: Collation of operational data (pumping rates, water levels and water quality), visual inspection of pumps following removal, and a downhole camera survey.

Assessment of borehole condition and required rehabilitation: Review and analysis of key well performance parameters and benchmarking against historical data for each well and wellfield.

Rehabilitation treatment: A combination of mechanical and chemical methods is usually the most effective approach. Mechanical treatments can include: scrubbing; surging; water or air jetting; vibration. The chemical treatment component requires suitable treatment products and specialist rehabilitation equipment to deliver the products to the relevant section of the well screen.

Post-treatment survey: Downhole camera survey and monitoring of initial post-treatment pumping.

Continuing monitoring and maintenance: To provide the data to allow future rehabilitation treatments to be planned and scheduled.

Well rehabilitation rig used in BoreSaver maintenance programmes

Selection of the appropriate chemical treatments is important to ensure that they are effective against the type of clogging identified, have the necessary regulatory approvals and the post-treatment residues are harmless and can be safely disposed of.

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