REHABILITATION OF WELLS USING THE

"ELECTROCHEMICALLY ACTIVATED WATER" (EAW) TECHNOLOGY

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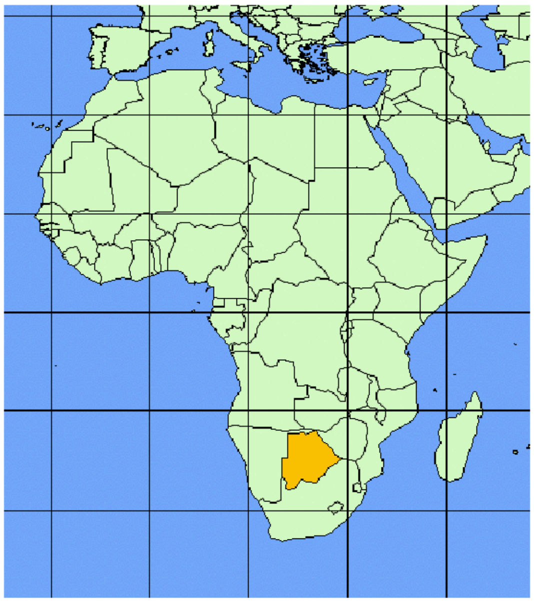
1 The Task

Botswana is a dry country with an annual average rainfall of 400 mm. Lack of surface water in most parts of the country means that wells are required to cover domestic and industrial water needs. Currently there are more than 10 000 water wells in operation, covering the needs of rural communities and agriculture. There are 29 major wellfields with 600 wells providing water to urban and semi-urban settlements.



Many wells show a marked and continuous decline in yield from inception. Historically this was attributed to corrosion and scaling, due to unfavorable chemical characteristics of the groundwater. Corrosion is so severe in some wells that pumping equipment and rising mains have to be regularly replaced, often at intervals of less then 12 months.

The Government of Botswana through the Department of Water Affairs (DWA) has started in 2001 to investigate the causes of well deterioration and to identify and test appropriate technologies to improve the maintenance of the borehole infrastructure.

It is nowadays established that Aquifers are not sterile and often contain a rich and diverse microbial flora *(CULLIMORE, 2000)*. Waterborne bacteria rapidly attach themselves to surfaces and red slime found on pumps and discharge lines is an indication of iron reducing bacteria, whilst black slime, mainly observed in deeper boreholes with stagnant water below the deepest inflow zone, indicates sulfate-reducing bacteria.

The bacteria in a biofilm show high levels of physiological activity and enhanced resistance to chemical antimicrobials. Many methods for treatment of wells affected by bacteriological growth have been documented, such as treatment with hydrochloric acid or other strong chemicals. These methods necessitate using chemicals, which are hazardous to the semi-skilled staff involved in this work at DWA.

In order to minimize these problems the DWA with Active Solutions (Pty) Ltd. has initiated a water well rehabilitation program using Anolyte. Anolyte is a super oxidant solution, at least as effective as hypochlorite, yet completely safe and non-polluting.

2 Principles of "Electrochemically Activated Water (EAW)" Technology

The Electrochemically Activated Water (EAW) technology generates oxidant and anti-oxidant solutions by forcing slightly saline water (0.2%) through an electrolytic cell. The water can be sourced from the well to be rehabilitated. The inventors describe the 'activation process" as a change of molecular state of water from a stable to a metastable state. (Marais et al, 1998). The anti-oxidant solution, Catholyte, contains negatively charged free radicals whilst the super oxidant solution, Anolyte, has positively charged free radicals and is a powerful bactericide *(Bilgeri et al, 1997)*. Anolyte has an oxidation-reduction potential

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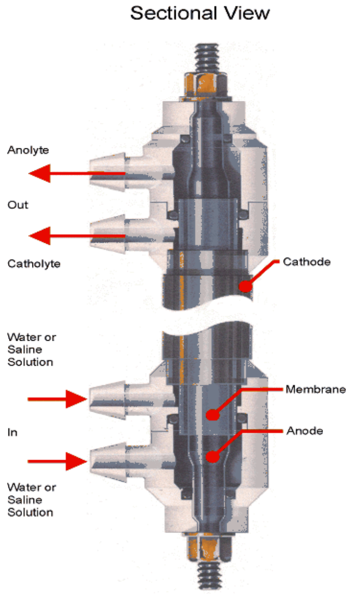


(ORP) of +1000 mV and Catholyte of ~-800mV. Biocidal agents in the solutions are free radicals with oxidizing effects, like ClO, HCLO, H_2O_2, O_3 ,OH

Both solutions are non toxic and fully biodegradable. EAW is highly microbicidal and attacks living cell components developed within and outside the well environment.

The electrolytic cell itself is around 20 cm long and consists of a central rod anode (positive electrode) around which is a concentric ceramic tube membrane which acts as the cathode (negative electrode).

Effectively the ceramic membrane divides the reactor into two compartments, the anode compartment and the cathode compartment. Water enters the reactor and exits from these compartments separated by a high electric field as two streams, the Anolyte and the Catholyte solutions respectively, whose pH, oxidation reduction potentials (ORP) and other physico-chemical properties lie outside of the range which can be achieved by conventional chemical or electro-chemical means.

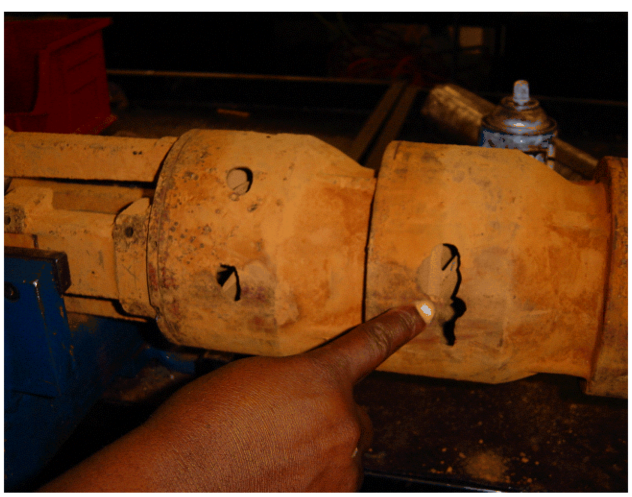
Electrochemically activated water technology is not new, however this system, with its ability to separate the Anolyte and Catholyte solutions, is unique. The solutions can be applied separately to maximum effect; this was not possible with previous systems.

Recent advances have further minimized the size of the electrolytic cell and associated equipment and increased the efficiency of Anolyte and Catholyte separation

Anolyte	**Catholyte**
Positively Charged Solution	Negatively Charged Solution
Powerful Mixed Oxidant Solution	Powerful Ant-Oxidant Solution
Microcidal-extremely effective disinfectant	Negatively charged surfactant properties
Anionic/agglomeration/flocculation properties	Cationic/agglomeration/flocculation properties
Generated at pH between 2 and 8.5	Generated at pH range of 8-13

3 Cause of well performance related problems in Botswana

The significance of microbial fouling on well and pump equipment deterioration has been described in various studies (CULLIMORE 2000). Investigations by the DWA have revealed the presence of iron and sulfate related bacteria in nearly all affected wells. Groundwater in Botswana occurs mainly in sedimentary aquifers in confined to semi-confined conditions and in some basement aquifers. Wellfields most affected by yield and corrosion problems are within sedimentary environments. Explosive bacteriologic growth is likely caused by widespread organic layers, such as coal, containing organic carbon as the prime source of energy, and allowing microorganisms to flourish within the porous structures of the aquifer. With time the flow conditions within the system deteriorate. It is not yet understood why sudden burst of bio-slime growth affects the well and pumping gear. It is believed that short pumping intervals, typical for most wells in Botswana, play an important role.



In non-sedimentary basement aquifers nutrient flow within fractures is probably influenced by weathered layers, containing important by-products such as iron or manganese. Semi- to unconfined flow conditions within the fracture system permit continuous oxygen inflow and build up of biofilm.

In Botswana, bio-slime, caused by microorganisms is now acknowledged as the main cause of well performance problems. As it develops within the screen section, Bioslime grabs silt, clay and mineral particles, which originate from shale layers typical of many sedimentary aquifers in Botswana and which move with the groundwater flow into the well. Some by-products associated with bacterial growth, such as oxidized iron and manganese also accumulate and finally the well and often also pump components are blocked by a thick bio-slime and mineral mass obstructs the groundwater flow from the aquifer into the well.

When well or pump problems are left unattended for a long period, the material is very difficult to remove since it hardens and solidifies. Re-drilling and / or the installation of new equipment are often unavoidable as a result.

In Botswana the problems are exacerbated by three unique circumstances:

- *Many boreholes have a considerable amount of stagnant water below the lowest inflow zone. These boreholes were constructed as open holes where even insignificant inflows were considered useful. The unproductive lower zones have rarely been refilled and wells with > 50 m depth of stagnant water are not uncommon.*

- *Many boreholes have unfavorable pumping cycles of 10 hours pumping and 14 hours non-pumping per day. The main reason for the short pumping cycle in Botswana is the remoteness of wells and wellfields from users and the need to supervise the equipment during daylight hours. Therefore wells are pumped at a higher then normal rate. This production cycle results in a daily large decline of water levels and large expansion of the drawdown cones and inflow of oxygen to the temporarily denuded aquifer zones. During the non – pumping hours bacterial cells have ample time to settle and anchor to surfaces in the aquifer around the well intake, the well itself and inside the pumping equipment and to strengthen and harden their cell coatings. This hardening makes standard treatment chemicals ineffective.*
- *Traditional use of mild steel for casings and screens, this favors the settlement of bacteria and development of biofilms.*

The full complexity of the interactions of the hydrogeological environment, borehole design and pumping schedules on bacterial activity in wells is not yet fully understood and needs further investigation.

4 EAW technology for well rehabilitation

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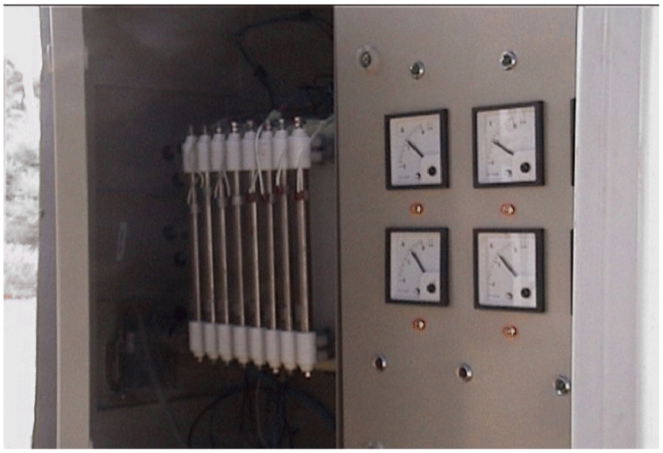
Like other treatment processes for well rehabilitation EAW treatment involves three phases to remove plugging biofilms. A first phase kills the bacterial cells in the biofilm, the second disrupts (breaks up) the biofilm and hardened slime, and the third removes the biofilm and other plugging material.



Many boreholes in Botswana are remote and difficult to access with equipment and material. *DWA* and *Active Solutions* designed a mobile device, which allows production of Anolyte at the site itself. This eliminates the need to transport large volumes of fluids and the mobile device uses the in-situ well water to produce the Anolyte. The mobile device is capable of producing 5000 l of Anolyte in a 20-hour cycle.

The mobile device ensures that Anolyte is available in large quantities. Production costs are minimal and generously introduced Anolyte guarantees more effective cleaning and deeper penetration of the aquifer.

The test treatments with Anolyte were carried out only on boreholes that had experienced considerable decline in yields. Bio-fouling was identified using a borehole camera and microscopic tests, followed by visual inspection of pumps and discharge lines to confirm the presence of iron or sulfate biofilms on pump and pump intakes. Wells most affected were selected for rehabilitation with the EAW technology. One specific borehole was virtually filled with white slimy iron related bacteria and its capacity had been reduced to 20%. A thick reddish-brown layer of bio-film obscured the slots of the screen.

The method which has proved to be most effective for heavily clogged boreholes in Botswana is as follows: First undiluted Anolyte is introduced in large volumes to displace the water in the bore and the gravel pack. The Anolyte kills the bacteria which are suspended in the water, or attached to the borehole walls and screens and softens the encrustations and hardened bacterial plugs in the gravelpack and a aquifer.

Photo 0: Thick red slime after treatment is a good indicator for heavy iron bacteria attack

Then after an exposure time of approx 60 minutes the wells are mechanically bailed using a surge block attached to the cable of the cable tool rig, starting at the top of the screen and progressively working down. The motion of the tool forces Anolyte through the gravelpack into the aquifer. This process normally lasts 3-4 hours. The efficacy of the Anolyte solution is tested at regularly intervals and additional Anolyte added as required. Afterwards sediment and loosened bio-film is cleaned out with a mechanical bailer. Finally, the pump is re-connected and water pumped from the well until clear and the well is reconnected to the system

A quantity of 1000 to 2000 l Anolyte was sufficient to efficiently clean most boreholes, which were between 100 and 250 m deep and had an 8-10" internal diameter. Larger volumes might be necessary for deeper boreholes and if the aquifer is very heavily biofouled. In one case 4000 l had to be introduced.

5 Results

In all wells treated so far the removed bioload was extremely high, an excellent indicator for the efficiency of the method. Due to a biokill efficiency which is far superior to that of most chemicals used for well rehabilitation the EAW treatment was extremely effective in removing bio-film and softening hardened plugging layers. We experienced a considerable improvement in well performance in all boreholes tested. Yield increases of between 30% and 300% were achieved and post-treatment specific capacities were significantly greater than the pre-treatment specific capacities. Increases were in a range from 40% to 300%.

To summarize the results so far:

- ***Inspection with borehole camera confirms effective removal of Bioslime and plugging material in all wells***
- ***No bacteria detected after treatment in all boreholes***
- ***Considerable Yield improvement in all boreholes, between 30-300%***
- ***Specific capacity improvement between 40 and 300%***

Although testing the EAW treatment process in well rehabilitation is still in it's initial investigation stages it is proving to be an exciting and effective treatment method for Botswana, superior to other treatment methods because of the following advantages:

- ***Safety and Simplicity***
- ***Ease of use***
- ***Cost effective***
- ***Efficiency***
- ***Environmental acceptability as in effect EAW solutions return to a stable inactive state within 48 hours, pure water in fact.***

With further refinements to the treatment process, EAW treatment should prove to be effective in rehabilitating not only water wells but also of biofouled Aquifers. This method is therefore of potential interest for all drilling contractors with interest in the restoration of boreholes.

A last remark: The technology was originally developed for medical applications. Human safety trials have recently been completed in Botswana, which have proven Anolyte completely non-toxic and totally safe for use with humans. This level of safety cannot be achieved with existing chemicals and other electro-chemical technologies used in water well rehabilitation. The rehabilitation crew required no protective clothing or masks for handling and storage of Anolyte.

6 Sources

BILGERI, Y.R ., HINZE, G., KIRKPATRICK, R and CREWE-BROWN (1997): Electro-chemically activated Water as an Anti-Microbial Agent. Microbiological Analysis

CULLIMORE,R. (2000): Microbiology of Well fouling Lewis Publishers, Chelsea

MARAIS, J.T, BRÖZEL, V.S.(1998): Electro-chemically activated water in dental unit water lines. British Dental Journal 187, P. 154-158.

SMITH, S. (1995): Monitoring and Remediation Wells. Lewis Publishers, Boca Raton, Florida.

Dr. T. Riekel is a Hydrogeologist and was acting head of the Drilling Section of the Dep. of Water Affairs in Gaborone/ Botswana from 1999 to 2001. He is now Advisor to the Section. He has 30 years experience in the Water Well Business and worked all over Africa mainly for German Government funded water supply projects.

Dr G Hinze is a veterinary surgeon and Director of Active Solutions which is the company developing this technology in Botswana in the fields of food hygiene, human medicine, agriculture and recently also water well technology.