

SO LITTLE ALUMINIUM – SO MUCH OF A PROBLEM FOR THE R.O. PLANT

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Introduction:

Water is a scarce commodity in outback Australia – most of the vast country is desert and recent droughts mean that there is no guaranteed supply of water in non-urban areas of Australia. The town of Kalgoorlie, Western Australia, receives its potable water via a steel pipeline from a suburb of Perth, the state capital. The pipeline extends for over 600 kilometres, almost directly due east, to the gold-mining capital of Western Australia. The water in Perth is provided by run-off into dams from the rain [which has been ever-decreasing in recent years] and is supplemented by bore/well water pumped from underground aquifers. With recent years' rainfalls being well below past years' falls, the present water situation is best described as "restricted". As rainfall drops and demand for water increases, the shortfall is increasingly picked up by underground water. The interesting situation that now exists in Kalgoorlie, is that bore water from Perth is now being pumped 600 kilometres to Kalgoorlie to be used in and around the mining town! The mine that our troublesome R.O. plant resides in, is some 150 kilometres out of Kalgoorlie. The only water around those parts is from underground. The management of the mine decided that they would farm their own water, treat it and save the cost of trucking out water from Kalgoorlie [that had been pumped from Perth]. At the same time they would be lessening the requirement for water in Kalgoorlie, and thus assisting the state's water shortage situation.

In mid-2000, five companies were requested to tender for the supply of a 100 kilolitres per day reverse osmosis plant, to be located in the bushland 150 km from Kalgoorlie, by bush/dirt track. Water analyses were provided to the tenderers, also these companies were offered the right to sample and analyze their own water. The successful bidder was awarded the contract based on a reasonable price and a perception of size and capability.

After 2 months of reasonably straightforward operation the plant started to experience continual problems. The following discusses some of those problems and attempts at rectification.

Initial Water Analyses:

The analyses provided for the water from various bores/wells were reasonably comprehensive. Typically, for the 4 main water sources the waters ranged as below:

pH 5.0-7.8	Turbidity 0-20 NTU
TDS 600-36,000 mg/l	TSS form 20 to below 5 mg/l
Fe below 0.05 mg/l	TCO 4.5 to less than 1 mg/l
Na 200-11,000 mg/l	
Ca 70-180 mg/l	
Mg 50-1500 mg/l	
Cl 250-19,000 mg/l	
HCO ₃ 350-15 mg/l	
SO ₄ 100-4000 mg/l	
SiO ₂ 60 mg/l	

Whereas the water was definitely saline, it was assumed by all bidders that the feedwater would be treatable by R.O., much as a seawater plant might work. The plant was designed to run on this “seawater x 2” quality and it was assumed that the seawater plant would cope with the water adequately. The wide range of water qualities between the sources meant that the plant could be running on water qualities from almost potable to hypersaline on the same day. This was a problem. Whereas the plant was required to run on a RANGE of waters, it struggled once the water mix contained higher solids loadings.

Was the problem the higher TDS or salinity? Definitely not. The problem was a species not analysed in the water.....aluminium!

Aluminium?

Many experts were consulted over the problems that the site experienced with fouled membranes, daily cartridge filter replacements, weekly full chemical cleans, low water production, low recovery rates..... When it was explained that Al was the problem, almost every observer noted that we should reduce or change the Al-based coagulant we were obviously using in the clarification stage. But we were not dosing alum nor poly- aluminium chloride! Nobody could believe the 20-30 mg/l of Al that we were analyzing in the feedwater/borewater from 2 specific bores.

What did it look like? A pasty, white, gooey deposit coated the cartridge filters and the membranes. When analyzed the deposit was found to be over 15% Al and 10% Si. Given that oxides and hydroxides

were likely the species present, the deposit was definitely predominantly Al-Si.

What other analytical work did we do to try to understand, then solve, the problem?

Cleaning solutions were analysed; after a citric acid-based clean in September 2001, Al = 340ppm and Si = 30ppm.

Before and after a citric clean in July 2002 Al went from 4.5 to 835 ppm; Si rose from 5 to 173 ppm; Ca did not move from 30ppm before and after cleaning; Mg similarly remained the same – going from 95 to 99ppm. The obvious conclusion was that the cleaning process was removing the Al-Si compound[s]. From stoichiometric calculations we deduced that we were removing approximately 1kg of deposit from the membranes every clean; further calculations established that every day 5-10 kg of Al-Si compounds made their way through the plant. Precipitate from the feedwater tank floor was characterized as 12% Al; 1.2% Ca; 2.6% Mg; 9.6% Na.

Deposits taken from the small aerator at the top/inlet to the feedwater tank were 25% Al and 14% Si.

Scanning electron microscopy of the cartridge filters after service showed massive peaks for Al and Si with lesser peaks for Ca and Mg.

Laboratory work conducted to precipitate out the offending species, was focused on pH elevation. After extensive laboratory work it was shown that by adding 35kg/day of 48% NaOH the Al-Si could be precipitated out. What was also shown was that the deposit from this reaction was 8-10% Al and 20-25% Mg, with only 1% Si and 3% Ca. In other words a different species was being precipitated out – leaving the Si in solution. What was not evident from the laboratory work was the mess that would be formed in the feedwater tank, when the caustic was dosed into the feedwater flow!

How Do We Resolve the Problems?

As mentioned above, we trialed pH-elevation as a means of pre-precipitating the Al-Si compound[s], that were clogging the cartridge filters and the membranes. In the laboratory, the problem seemed easily fixed; in the plant we discovered the precipitate to be light, fluffy, almost amorphous and determined to stay suspended in the feedwater tank and

not quickly drop to the tank bottom. The addition of flocculants assisted the process but no form of coagulation/flocculation provided the total answer. The proposal to install an intermediate settling tank was to be too expensive for the plant as well as inconvenient logistically.

A trial was conducted using stainless steel wire installed in the aerator to add surface area to the aeration process. This worked in practice but the wire completely blocked up in a couple of days, and had to be replaced daily to be effective. This was not convenient.

A process was introduced where the feedwater tank was drained from the bottom 20% level every day – this removed some of the deposited Al-Si, but not a significant amount.

New cartridge filters were trialed to remove more of the Al-Si; they were twice as expensive and three times as effective. A decision was made to install a 2-stage filtration system, where a less-expensive and coarser filter preceded the more expensive 5 micron filter. This was far more effective in removing the impurities, however, once again was not absolute in its removal ability.

Different cleaning regimes were trialed to clean the surfaces of the membranes in the regular [too regular] chemical cleans that were being undertaken. The budgeted monthly light citric acid/light alkali cleans were replaced by aggressive acid cleaning with a number of strong acids. These later gave way to citric acid cleans, only, which had the best results on the Al-Si deposits over the past 6 months. Various reactions were identified over the 18 months of operation – from matrix dissolution to actual scale dissolution.

Mechanical modifications that were trialed included piping the sand filters in parallel rather than series, changing the media in the filters to catch more of the deposits [it was initially thought that there could be cementing/channeling in the sand filters, but that was found to not be the case], new antiscalant and new pH-adjustment systems were installed, different membranes were trialed from the brackish water membranes that were initially installed. The aerator was disconnected to try to keep the Al-Si in solution rather than starting the precipitation process by the aeration – this did not solve the problem.

Other Problems That Arose Associated with the R.O. Plant

When the company ordered the R.O. plant, they expected trouble-free running and 100kl/day of potable water from the plant. What they received was troublesome operation and an average of 30kl/day of water with a requirement to truck in water from Kalgoorlie [at quite a significant cost]. Apart from the expense of the water importation, the operations staff were becoming more disenchanted with the plant with every passing day. What should have been a 5-minute check-up every shift deteriorated to cartridge filter changes every shift [12 hours] and full chemical cleans every 4 days! All discussions about the R.O. plant were prefaced by expletives and criticisms.

The remoteness of the plant meant that service companies were not clamouring to be of assistance to the mine – when they did service the plant, the cost of airfares, travel and accommodation – as well as their labour charges were quite expensive to the mine.

The reject water was channeled to the raw water dam – over the months this water became more and more saline, with the odd result that brown “icebergs” formed on the water surface. When analysed, these icebergs were found to be almost the same composition as the deposits formed on the membranes and cartridge filters. They now occupy 10% of the surface of the raw water dam. There is a project now under consideration to utilize this water as a dust suppressant on the haul roads – certainly the stickiness and viscosity of the water should assist in binding the dust on the roads. Hopefully the Al-Si compounds will not clog up the water spraying systems in the dust suppression system on the trucks.

The Ultimate Solution?

After nearly two years of operation, the decision was taken to concentrate on the use of the better, less saline bores – not because of the salinity, but because of the associated aluminium in the most saline bores. The cost and logistical difficulties meant that the R.O. plant would be a continual thorn in the side of the operations people, so the plant decided to use however much low salinity [read low Al] water as it could sustainably extract from the ground, and treat this by not only a single pass R.O. system, but also re-running the first pass reject stream back through the plant again. Just how sustainable and successful this is, will only be evident after the passing of a few months' operation. From early modelling, it appears that 95 kl/day of low salinity water, double treated

by R.O. will produce 60-65 kl/day of permeate of exceptional quality. This would satisfy the plant's requirements. While this regime is being run on the plant, small additions of the more saline bore waters will be modeled as additions to the feedwater flow, to determine the level of addition at which the Al-Si fouling recurs.

Conclusions and Recommendations:

We should all be aware of the potential problem[s] that Aluminium, that close brother to the also IIIA, trivalent Boron, can potentially cause. We should all ensure that in our initial questionnaire/survey form, we include Al as a species we want accurately determined – don't allow your computer program to insert a low/negligible figure, because you did not have Al analyzed. And do not assume that if you do have Aluminium deposits, they will be the crystalline, easily removed species that you might have seen before. They too could have the "zeolite-type" character that we experienced in outback Australia. You don't want the problems!