RESPONSE TO WATER QUALITY CRISIS AT NEW WALES

By: James D. Carnes
L. Bruce Wiggins

IMC AGRICO

INTRODUCTION

This paper will provide a brief review of water management at the IMC-Agrico New Wales Plant. The effect of the gypsum stack sinkhole on the quality of well water available for plant use will be examined. The measures taken to compensate for the changing water quality will be reviewed.

BACKGROUND

Water management is an integral part of the present-day phosphate fertilizer production process. Since its start-up in 1974, the New Wales complex has been operated to maximize water reuse and minimize fresh water input into the gypsum cooling pond. The topography of the complex is designed so that any contact water from the Phosphoric Acid, Fertilizer and Animal Feed Ingredient areas is collected and returned through a series of ditches to the gypsum cooling pond. Water from the cooling pond is used to sluice gypsum from the tilting pan filters and the belt filters to the gypsum tanks where it is pumped to the gypsum stack. Water from the cooling pond is also used for direct contact cooling, scrubber water and filter wash water. Water from non contact areas is collected separately and stored in a surge pond.

The original cooling tower (01/02/03) was designed to use once-through cooling water as a portion of its make-up water. Once-through water is well water that has been used for non contact cooling and seal water.

The Third Train Phosphoric Acid plant, built in 1981, used water from the 04/05 cooling tower to supply vacuum pump seal water.

When the New Wales original gypsum stack was nearing the end of its useful life, IMC-Agrico applied for a permit to build a new lined gypsum stack. The new gypsum stack foundation was completed and

Phase 1 was placed in service in July, 1993. At that time, IMC-Agrico began using the old gypsum stack only on an intermittent basis as gypsum compaction allowed.

DEVELOPMENT OF PROBLEM

On June 27, 1994, a hole approximately 100 feet in diameter and 190 feet deep formed in the original gypsum stack. The details of the sinkhole exploration and the program of corrective action are presented in another paper.

The collapse of the gypsum and the drainage of the associated gypsum stack pore water into the underground sinkhole was promptly reported to all involved environmental authorities. IMC-Agrico and the environmental authorities worked closely together to implement an extensive water sampling and analysis program for the on-site and off-site monitoring wells.

IMC-Agrico also hired hydrogeological consultants to predict how the sinkhole would affect the on-site and off-site water supplies. The consultants predicted that the impurity levels in the plant well water would peak within six months and then begin a gradual decline. Of key concern at New Wales were the calcium, phosphate and silica levels. Previous experience with slightly elevated cooling tower water phosphate levels had shown scale formation and loss of heat transfer. Calcium phosphate scale formation and/or silica deposits would have disastrous effects on the reverse osmosis equipment. The consultants' model predicted that phosphorus levels would peak at 130 ppm.

INITIAL ACTIONS

As discussed in a previous Clearwater paper (Harrison and Carnes, 1991), the reverse osmosis (RO) system installed at New Wales has significantly improved the reliability of and lowered the operating cost of the treated water system. The reverse osmosis system was recognized to be the area of highest vulnerability from deep well impurities. A program reducing recoveries by approximately 2% per week was started to reduce the concentration effect in the RO units and compensate for the projected deterioration in water quality. This action was taken to protect the reverse osmosis systems from anticipated water quality problems while long range plans were developed. It was anticipated that recoveries might have to be reduced to as low as 42% before the well water quality began to improve.

For example, feedwater with a phosphate concentration of 50 ppm has a phosphate concentration of 200 ppm in the final concentrate when the RO is operated at 75% recovery. When the recovery is reduced to 65%, the phosphate concentration in the final concentrate is only 143 ppm. The reduction in recovery was also expected to reduce the tendency for silica fouling.

With advice from the hydrogeological consultants, minimum pumping rates were established to maintain a zone of capture and assure that no water containing gypsum stack drainage left IMC-Agrico property.

INVESTIGATION OF ALTERNATIVES

After the immediate crisis had been avoided, IMC-Agrico began investigating longer term alternatives. Active and prospective water treatment vendors were contacted for assistance. Most of the vendors were very cooperative. Several brought experts from their corporate staff to visit the plant and discuss treatment alternatives. Well water samples were collected and sent to their labs for analysis. The initial results were not very encouraging. None of the vendors had experience using water with the anticipated phosphate levels. Once the vendors realized that this really was the water quality that IMC-Agrico would have to deal with, they gave an abundance of support. Suppliers of water pre-treatment systems were contacted to discuss costs and lead times for fabrication and installation.

Alternatives considered included:

- Cold Lime Softening
- Hot Lime Softening
- Zeolite Softening
- Additional Reverse Osmosis Capacity

The lime softening processes would also require clarification equipment such as clarifiers or Lamella settlers. Installation of new treatment facilities would also require real estate in an already congested plant area or pipelines and pumps to transfer well water to and from the new treatment facilities. All of the above alternatives had the disadvantages of high capital cost and/or long time requirements for the design, procurement and installation of additional water treatment facilities. IMC-Agrico faced the very real possibility of spending a prohibitive amount of capital money to install a system that would not be operational in time to help with the peak of the water quality problems. As the results from a Betz model indicate, the operating costs would also be significant. A system to reduce the scaling potential by adding sulfuric acid to the plant well water header was also considered. This was rejected because the risk associated with a control upset far outweighed the potential benefits.

Relying on the consultants' projection that the peak water quality problems would be relatively short (less than 12 months), IMC-Agrico decided to try to live through the water quality problems by making adjustments in our water treatment programs. If required, leased treatment equipment would be brought in only for the period of minimum water quality. Scale formation in equipment using well water would be dealt with on a case-by-case basis. Depending on the particular equipment, this might mean mechanical or chemical cleaning or possibly a small scale inhibitor addition system.

MANAGEMENT OF REVERSE OSMOSIS (RO) SYSTEM

As mentioned earlier, the reverse osmosis system is the most vulnerable part of the IMC-Agrico water treatment system. The three RO trains have a common water supply, common acid feed system and a common antiscalant feed system. Any problems with scaling, fouling or loss in capacity would likely affect all three trains. Plant production capacity has increased since the RO units were initially installed. A decrease in RO performance increases demineralizer operating cost. It may also increase the cost of boiler treatment chemicals. RO membranes typically have a life of five to seven years under normal operating conditions. At the time of the minimum water quality, the membranes had been in service for three years. How much the change in water quality would affect the life of the membranes was a big unknown. In the extreme case, scaling of all the membranes in a short time frame would disable the RO units, limit treated water capacity and restrict plant rates.

The first step in protecting the RO membranes was the program to gradually lower recoveries. Discussions with consultants revealed that lowering the feedwater pH could also have a significant impact on scale formation. The RO trains had been designed to operate at a pH of 6.0 based on New Wales water analyses at the time of installation. With the higher levels of calcium, sulfate and phosphate, the scaling tendency was expected to increase. The Langelier Saturation Index indicated that higher concentrations of impurities could be tolerated before scale formation began if the feedwater pH were lowered. Accordingly, the feedwater pH setpoint was lowered to 5.2. This revealed a capacity problem with the acid metering pumps. Considerable troubleshooting was required before an adequate quantity of acid could be delivered even with the main and spare pumps operating simultaneously.

Several other factors further complicated the management of the RO system during this period. IMC-Agrico had elected to put a portion of the New Wales water treatment out for bid during this period. This included the RO system, the potable water system, 01/02/03 cooling tower and TG2 cooling tower.

Water from the deep wells was originally used to supply the potable water system. As the well water quality deteriorated, a decision was made to switch the potable water system to RO water. The materials and chemicals used in the RO system then became limited to those with NSF-60 certification.

Use of a program to track normalized flow and salt passage data was implemented for all three RO trains. Trains with a loss in performance could be operated at a lower recovery, a lower pH or scheduled for chemical cleaning. As mentioned, the initial protective action for the RO system had been to lower the recovery. The normalized performance data monitors trends in performance so that further adjustments can be made, if required, to avoid a major failure.

The use of normalized performance data in conjunction with a lower feedwater pH enabled New Wales to stabilize RO recoveries at 65%.

When commissioned in 1991, the RO product water had a conductivity of 20 micromhos. In 1995, after operating at lower than design recovery and pH for nearly a year, the conductivity had increased to 200 micromhos and was adversely affecting the downstream demineralizer performance. Part of the increase in conductivity was a result of higher feedwater conductivity. However, trains 1 and 3 had significantly higher conductivities than train 2. Conductivities of product water from individual tubes within trains were measured to identify problem tubes. The tubes were then probed to identify problem membrane/connector assemblies within the tubes. Out of 360 membrane/connector assemblies in three RO trains, six problem assemblies were identified. The six problem assemblies were isolated to one tube in one train. This tube was then bypassed so that it did not produce any water to affect the overall RO product water quality. The product water conductivity of trains 1 and 3 was reduced to 140 micromhos, nearly matching that of train 2.

The reverse osmosis system had been successfully operated on one antiscalant product since start-up. Because this product did not have NSF-60 approval and because we were rebidding this treatment program, another product had to be selected. Considering the quality of water being used, IMC-Agrico had to be very careful in selecting a replacement product. Selecting the wrong product could be disastrous.

Six candidates were selected for a preliminary evaluation. A rental pilot plant RO unit was used for the preliminary evaluations. Analyses of feedwater and concentrate water were used to compare actual cycles of concentration (measured by calcium and silica) to theoretical values (measured by chlorides). The preliminary evaluations were necessarily of short duration and could not be used to predict long-term scaling effects. One candidate that had NSF-60 approval and performed well in the preliminary evaluation was selected for an extended evaluation (60 days) with the pilot plant unit. This evaluation was successful and a decision was made to evaluate this product in the RO system. The RO trains were switched to the new antiscalant product. The normalized flow and salt passage data were monitored very closely during the first sixty (60) days of its use. No problems were encountered with the new product. Monitoring of normalized flow and salt passage continues on a routine basis.

Lowering the feedwater pH lowered the Langelier Saturation Index and the chances of scale formation in the membranes. However, it also shifted the CO_2/bicarbonate equilibrium to produce less bicarbonates (which are removed by the RO process) and more CO_2 which is not removed by RO. If not removed by the decarbonator prior to the demineralizer trains, this would shorten the run times. The CO_2 stripping in the decarbonator was checked and found to be greater than 95% efficient. Checking of the decarbonator is now being done on a quarterly basis by one of IMC-Agrico's water treatment vendors.

OPTIMIZATION OF DEMINERALIZER SYSTEM

As the well water and RO product water quality deteriorated, so did the performance of the demineralizers. Units which had produced 2.0 - 2.5 million gallons of treated water per run were reduced to 200,000 gallons per run. This increased the cost of regenerant chemicals by a factor of 7 - 10. In order to keep up with plant consumption, demineralizers were run past their optimum regeneration point. This produced a lower treated water quality which required more boiler water treatment chemicals.

The New Wales Plant has seven demineralizer trains. Each train has a bed of strong acid cation resin followed by a bed of strong base anion resin. The resin in each bed was checked, and resin samples were analyzed for ion exchange capacity. Most of the beds had below the design resin volume. The resin also showed a significant loss in ion exchange capacity. It was decided to do a complete resin replacement in the two trains that had the lowest capacity. The resin removed from these trains was used to top off the resin levels in the remaining five trains.

The combined effect of changes in the RO system and the demineralizers increased the demineralizer run lengths on the trains with new resin to 900,000 gallons. As the water quality has improved, the run lengths have increased to 1.3 MM gallons. The remaining demineralizers, which have lower caustic efficiency, are operated on a stand-by basis.

The water quality produced consistently meets or exceeds the requirements of IMC-Agrico's water treatment vendors.

COOLING TOWER OPERATION

The operation of heat exchange equipment is critical to the production process. Premature scaling of heat exchange equipment can result in production rate restrictions or excessive downtime for cleaning. Previous experience had shown increased scale formation associated with high calcium and phosphate levels in the cooling tower water. This was one of the prime concerns in the initial discussions with the water treatment vendors.

The cooling tower cycles of concentration were reduced from 3.0 to 1.8 to reduce the concentration of scale-forming components in the cooling water. Any further reduction in the cycles of concentration would approach once-through cooling and become unacceptably expensive.

New Wales has typically divided its water treatment business between two water treatment companies. At the time of the earlier cooling tower water high phosphate levels, one company had the program for the three cooling towers and the other had the program for the boiler and steam systems. The company with the cooling towers had taken the conservative approach of maintaining the dispersant and corrosion inhibitor levels while increasing blowdown to lower the cycles of concentration. The second vendor, based on prior experience with high phosphate levels, recommended that IMC-Agrico lower the pH control target to 5.8 - 6.2 to lower the potential for scale formation. This recommendation was based on the fact that higher phosphate levels provided additional corrosion protection. The treatment of one cooling tower was transferred to the second vendor on a trial basis. This approach proved successful and was eventually extended to the two remaining cooling towers.

As mentioned earlier, IMC-Agrico was in the process of rebidding a portion of the New Wales account. Although the phosphate levels from the sinkhole event were much higher than earlier experience, two vendors thought that the low pH approach would work. The vendors admitted that their company had not had any experience operating with the phosphate levels that IMC-Agrico was encountering. The vendors also indicated that some additional downtime might be required for cleaning.

Short of pretreating the cooling tower make-up water, IMC-Agrico agreed that this was probably the best approach.

The primary concern that IMC-Agrico had with the lower pH treatment programs was the possibility of increased corrosion. Short-term corrosion meters and longer term corrosion coupons were installed by the vendor and have shown no problem with corrosion rates.

OTHER WATER USES

In the past, New Wales has had excellent water quality. Because of this quality and its lower temperature, well water was used for a variety of cooling and seal water applications. Third Train was the first phosphoric acid plant at New Wales to receive its cooling water and seal water from a cooling tower. As the water quality deteriorated, the phosphate concentration in the well water reached levels previously seen only in cooling towers. However, the well water contained no dispersants to prevent scale formation. As a result, the East and West Train phosphoric acid vacuum pumps began to experience problems with lost capacity due to scale formation. The Third Train vacuum pumps experienced no such problems. After several chemical cleanings of the vacuum pumps, the cooling water header at Third Train was extended to supply the vacuum pumps at East and West Trains and the scaling problem was corrected.

OPERATION OF A-11 POND

New Wales has a NPDES discharge permit. The excess non contact water is stored in the A-11 pond, an old clay settling pond. To reduce well water consumption, IMC-Agrico's Minerals division uses water from this pond in the Kingsford mining operation. By NPDES permit, this water cannot be discharged to Kingsford if the pH is below 6.0 or the monthly average phosphorus concentration is above 35 ppm. Since the phosphorus concentration in well water used at New Wales was predicted to reach 130 ppm, it was anticipated that the phosphorus level in A-11 would exceed 35 ppm. The A-11 pond had to be operated to maintain the New Wales surge capacity and not violate the pH and phosphate limits of the NPDES permit.

The A-11 water was sampled and found to meet pH and phosphorus limits. The boards were removed to discharge this water to Minerals and provide maximum storage volume for water from New Wales. The discharge of A-11 pond was then boarded up in August 1994 to prevent any discharge of this water to Minerals.

A-11 water was used at New Wales to replace well water for some applications during the sinkhole crisis. Care was taken not to drop below the minimum deep well flow rate recommended to maintain the zone of capture. Use of A-11 water at New Wales extended the storage time in the A-11 surge pond.

All of the water streams discharging to A-11 were sampled during the crisis and analyzed. The stream with the most concentrated impurities (RO concentrate) was diverted to the gypsum cooling pond for a period of time to reduce the amount of phosphorus entering A-11 pond.

As expected, the phosphorus content of the water collected in A-11 pond exceeded the 35 ppm limit for reuse. The level actually reached 42 ppm.

Previous work by others indicated that soluble phosphorus levels could be lowered by increasing the water's pH. Bench scale tests confirmed that this effect was also true for the water collected in A-11 pond. A lime slaker was rented and a temporary liming station was set up to increase the pH and lower the soluble phosphorus content of water being discharged to A-11. Operation of the temporary liming station continued for four months at a cost of $1100/day. When the water in A-11 reached acceptable phosphorus levels, it was again discharged into the Minerals system.

FUTURE PROGRAMS

As the well water quality improves, IMC-Agrico will optimize the operation of the water treatment programs. Tools developed during the recent crisis will allow us to anticipate potential problems as we attempt to lower costs. The normalized performance data programs for the RO system will be used to track performance as we begin to increase recoveries and pH. Heat transfer programs being developed for the sulfuric acid heat exchangers will allow us to track potential scaling problems as we begin to increase cycles of concentration and pH.

SUMMARY

The formation of a sinkhole, a natural occurrence common to Florida, produced a rapid change in the quality of water used at the IMC-Agrico New Wales Plant. The suddenness of the change and its expected limited duration precluded the use of conventional water pretreatment for the plant cooling water and steam systems. Consultation with water treatment experts and close monitoring of water treatment systems' performance enabled IMC-Agrico to survive this crisis in water quality with no production restrictions or environmental impacts. The high capital and operating costs of pretreatment systems were avoided.