OPPORTUNITIES FOR WATER SAVINGS AND WATER QUALITY IMPROVEMENT IN THE BAYER PROCESS

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Abstract

Water is a critical resource for all alumina producers and increasingly, water is also being recognized as a valuable and scarce resource. Appropriate use, control and management of water within refinery operations are key areas of concern for refinery operators. This paper outlines specific technologies focused on water control and management across refinery sites with case studies on improved water management practices and opportunities for further development.

1. Introduction

Water is a critical raw material for all alumina refineries. Within refineries, operators try to carefully manage and control the application and quantities of water used across a wide variety of process areas. The water balance in refineries is a critical function of the process and a reduction in the available input can have a stark impact on a number of key aspects, such as red mud washing efficiency (soda recovery) and lead to the requirement for greater evaporation (higher energy costs). Indeed, it is hard to imagine another raw material, apart from water, that can so acutely influence plant activity across all the areas of safety, productivity, product quality, energy efficiency, equipment operation, maintenance, cleaning and even general housekeeping. Water, in various guises and quantities, is used within refineries to address all these issues and more. Despite this, or perhaps because of its ubiquitous nature within refineries, water has often not been well recognized and valued as highly as other process input materials. This is becoming less common due to the increasing value placed on water by both process operators and communities in general.

Increasing populations and changing community attitudes to water, often as a result of drought experiences, means that governments, communities and families, are increasingly viewing water as a commodity of value. As a result, industrial users of water are coming under increasing scrutiny and, in many cases, additional regulation and cost. This has led many industrial users to consider the opportunities provided by the use of poor quality waters such as grey water, seawater or water from hyper-saline aquifers, in their facilities. Such sources can be used to supplement or even replace traditional fresh water sources and applications in the areas of pre-treatment technology and/or advances in the use of such poor quality water "in-process" are well established and are continuing to progress.

While the use of such alternatives to fresh water may be considered, industrial users, and in particular, large water users such as alumina refineries, are increasingly looking for new ways to save, manage and more efficiently use their water resources, regardless of the source.

While the economic and social benefits of saving water are obvious, in some cases the necessity for water savings may be forced on refinery operations. Drought conditions over the past few years in a number of regions where Australian refineries operate has had a substantial impact on plant operations. A fundamental lack of available water has, at times threatened to, or has actually hindered, refinery activities. In such cases, water saving measures have been an essential part of refineries continuing to operate.

Clearly then, opportunities to save water are important for a variety of reasons. However, depending on location, seasonal factors and climate, some refineries may at times alternatively suffer from an oversupply of water. In such cases, the potential for disposal and/or discharge of water of appropriate quality is also an issue of operational concern.

In such an environment, new methods or processes used by other industries to better manage the quantity of water utilized and/or the quality and nature of the water used are necessarily of vital importance to all refinery operators. As a service provider to a range of industries where water is a key resource, Nalco has developed a range of processes and products to address a wide range of water issues related to water management, A number of these may be applicable to alumina refinery operations and in some cases, have already been implemented. The aim of this paper is to review the state of the art in water management and consider how the most recent advances in usage and quality management could be best applied in Bayer process operations.

2. Opportunities for Water Savings

It is likely that judicious use and more careful management of water in almost every part of the Bayer process has the potential to deliver water savings. Given the pervasive use of water within the circuit, the list of possible opportunities is therefore likely to be both long and varied. Operators are generally well aware of some of the larger and more significant opportunities to reduce water, however, substantial savings can also be obtained by utilizing new technologies now available across a range of applications. In particular, water use in utilities such as cooling towers and powerhouse boilers has been the focus of a number of recent developments in automation technology and control. While these facilities are relatively small users of water within the Bayer process, the available savings are nonetheless significant and valuable.

Additionally, cooling towers and boilers are not unique to Bayer process plants and as a result, technologies applied to such facilities and proven in other industries can be readily transferred to alumina refineries with some confidence.

Specifically Nalco has developed the 3D-Trasar® control system for water management in such facilities that provides a system of automated assessment, delivery and control of a range of critical water management parameters including corrosion, microbiological activity and scale inhibition.

The concept of the 3D-Trasar technology is based on Nalco's early breakthrough of "tagging" chemicals with a fluorescent dye that allows detection of a chemical's concentration in solution. [Hoots *et al*, 1994]. By incorporating a so-called "Trasar®" tag onto a treatment chemical (for example, a scale inhibitor) the amount of product actually in solution can be monitored and the dosing adjusted to ensure that the appropriate concentration of product is present at all times. Early forms of "traceable" materials simply used a blended mixture of a dye with the product but further development [Fong and Hoots, 1992] resulted in the dye functionality being incorporated into the actual molecules and polymers of a broad range of water treatment chemicals.

This technology has now further developed from the original concept of a static monitor of product concentration to incorporate specific advances in the area of automation and process control. The initial ability to accurately determine the amount chemical in solution has been coupled with a number of sophisticated process measurement probes. Coupled with appropriate process logic, this provides the core of the 3D-Trasar technology which is based on:

- **Detection** – of the critical process parameters such as pH, dissolved solids, microbial activity together with the existing concentration of control chemicals in solution
- **Determination** – of the concentration of control chemical required to optimize the process,
- **Delivery** – of the specific amount of chemical required.

This process can be fully automated with delivery of monitoring results and chemical usage to remote locations if required. Additionally, 3D-Trasar units can be used to rapidly detect upset conditions in utilities that may result from unavoidable issues upstream or downstream of the facility itself. Using the internal logic systems, the unit then determines and delivers the most appropriate corrective action and communicates this with system users. In this way, facilities that operate at the limits of their capacity – a common condition in many alumina refineries – can be more effectively managed since operational excursions are more rapidly detected and controlled.

In itself, the ability to better control the quality and condition of the water in a facility together with the addition of treatment chemicals does not directly save water. Indeed, the most noticeable effect of the implementation of 3D-Trasar technology is typically a reduction in the amount and cost of treatment chemicals used. However, more rapid and more consistent control of the water chemistry in utilities can and does lead to genuine and significant water savings. This is most notably achieved through the reduction and extent of excursions from ideal conditions. Such excursions typically require substantial blow-off and replacement of water within the facilities.

2.1 Cooling Towers

Clearly the 3D-Trasar technology, as applied to cooling towers, can be used across a variety of industries, not just alumina refineries. As a result, the uptake and installation of 3D-Trasar units in a range of industrial applications has progressed substantially and on a global basis. These units are now providing cooling tower operators across a broad range of industrial applications with significant benefits in terms of reliability, cost of operation and water savings. At the same time, there have also been a number of installations of 3D-Trasar units in operating alumina refineries.

Examples of the impact of using 3D-Trasar technology can be seen in figures 1-3. Figure 1 shows the variation from target conductivity in a cooling tower over an operational period of some weeks. The implementation of 3D-Trasar technology results in much greater process control with less variation in conductivity. This is significant since excursions in conductivity are normally controlled by increasing the blow-down on the tower – effectively removing the salts by dumping some of the water in which they are dissolved and replacing with fresh water. By reducing the excursions (and thereby amount of water "disposed") significant water savings are achievable.

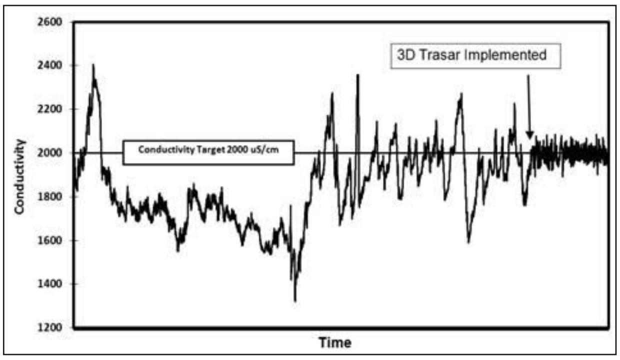

Figure 1. Variation in conductivity over time (3 months data is shown) as measured in an operating cooling tower. Implementation of 3D-Trasar technology results in much tighter process control.

Figure 2 gives an indication of such water savings across two separate facilities, each with three separate cooling towers, where 3D-Trasar units were installed on all towers. Prior to the implementation, average annual water usage across all the towers was monitored and measured. The reduction in makeup water usage of up to 20% was achieved across the facilities cooling tower systems after the implementation of 3D-Trasar units. Together the total water savings resulting from installation of the 3D-Trasar units across these two plants was more than 460,000m^3 per year.

Additionally, these water savings were achieved with a reduction in overall cost of chemicals used to service the cooling towers. More direct control of the input (and less blow-down excursions) results in lower chemical usage (figure 3) and more targeted and effective application.

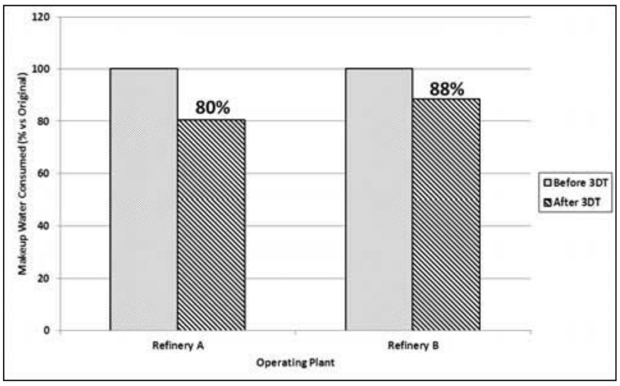

Figure 2. Water savings from implementation of 3DT technology on a series of cooling towers at two separate refineries. Amount of makeup water required before and after implementation of 3D-Trasar technology is plotted relative to the original amount of makeup water used.

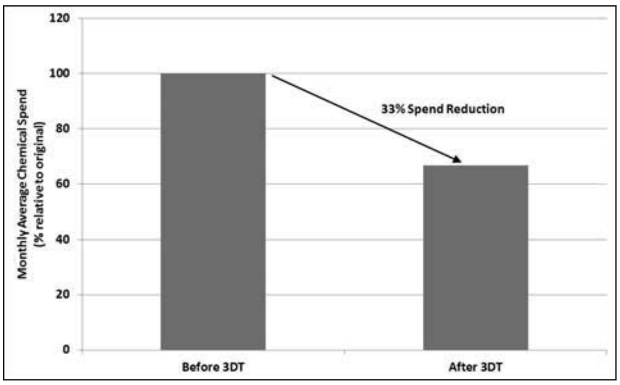

Figure 3. Chemical savings achieved through the implementation of 3DTrasar technology on a single cooling tower from refinery A above. Average monthly spend relative for the 9 months after 3D-Trasar installation plotted relative to average spend for 12 months prior.

The more effective control that 3D-Trasar technology delivers can also result in additional benefits to operators. In particular, the improved control of water quality can result in the potential to utilize sources of water that may be otherwise unacceptable. An example of this was the use of Bayer process condensate in a series of cooling towers built and commissioned as part of a refinery expansion. The original estimates for water usage across the expanded facility included substantial use of fresh water would be required to appropriately operate the new cooling towers. Installation of a series of 3D-Trasar units meant that Bayer process condensate could be used instead of fresh water. This resulted in savings of 2.2 million cubic metres of fresh water per year.

While it is understood that the process condensate could have been used in the cooling towers without the implementation of 3D-Trasar technology, it is well established that such conditions – without the improvement in water quality and treatment control – would result in substantial costs in terms of chemical usage, water usage, scale formation, maintenance down time and corrosion.

2.2 Boilers

The original application of the 3D-Trasar technology to cooling towers was relatively straightforward since these facilities typically operate at relatively low temperatures and atmospheric pressure. More recently Nalco has been able to overcome the substantial technical hurdles associated with determining water properties (e.g. pH, Oxidation-Reduction Potential or ORP) under the high temperature and pressure conditions typically found in operating boilers.

While the technical challenges compared to cooling tower monitoring are greater, both the water savings potential and the consequences of poor operating conditions are commensurately more significant in boilers. Additionally, the impact of operational upsets often occur more quickly at the elevated temperatures and pressures associated with boiler operation. As a result, the need for rapid and constant monitoring of operating conditions is even greater. Consequently, the use of 3D-Trasar technology in boiler operations provides even greater opportunities for water savings.

Despite the complexities of boiler operation and monitoring, Nalco has developed a range of measurement and application tools that can be incorporated into the control systems of a 3D-Trasar unit. These include a corrosion stress monitor to minimize pre-boiler corrosion, together with an automated management system to optimize and control boiler blowdown. As well as providing water savings, such control increases heat efficiency and reduces energy requirements resulting in more efficient operation of the asset.

Again, while individual boilers have specific nuances, the general trends in operation are often consistent across industries. As a result, examples from outside the alumina industry can be indicative of potential uses within refineries. One example comes from the petrochemical industry where a refinery implemented 3D-Trasar technology on their boiler system and subsequently identified annual savings in energy and water of more than $US370,000 [Nalco, 2011].

3. Opportunities for Water Recovery

The recycling of water or utilization of low quality water again provides refinery operators with opportunities for direct savings. Typically, the main issues related to poor quality water can be addressed by one of two ways:

a) Reduce the impact of less than ideal water quality, or
b) Improve the quality of the water through processing (e.g. RO)

The use of 3D-Trasar to control the impact of poor quality water has been outlined in examples above. The use of (lower quality) condensate in place of fresh water provides substantial savings of water input and can increase the sustainability of refinery operations.

Improving the quality of process water that is available, through recycling or upgrading of the water is also an alternative. The installation of recycling systems such as Reverse Osmosis (RO) units is not extensive across the alumina industry but a number of processors have implemented such technology for specific purposes. Nalco has recently coupled the principles of 3D-Trasar technology (in terms of better operational control through detection, determination and delivery of control) to the operation of RO and membrane systems. This coupling is likely to provide more consistent operation of such units and as a result, may well open such recycling systems to more widespread application across the industry.

4. Opportunities for Contaminant Removal

Re-use of water is often dictated by the presence of undesirable contaminants. Additionally, while discharge of water is not often contemplated by alumina refineries, climatic conditions are not controlled by refinery operators and as a result, excess water, and the necessity to reduce the amount held within plant areas, may occasionally occur.

Across a number of industries, one of the key limitations to water discharge is the presence of heavy metals in solution. Some options for the environmental management of mercury in particular, both within and exiting alumina refineries have been recently considered [Minma *et al*, 2011]. Additionally, control of mercury, along with zinc and a broad range of other heavy metals in solution can be managed by use of polymeric chelant such as Nalmet® 1689 which binds, precipitates and flocculates the ions from solution. These products have a broad affinity for heavy metals as outlined in table 1.

Table 1. The range of heavy metals removed from solution by Nalmet 1689. Elements are listed in the order of preferential removal from solution by the application of the product.

Element	Specific Species*
Mercury	Hg
Silver	Ag
Cadmium	Cd
Copper	Cu
Lead	Pb
Zinc	Zn
Nickel	Ni
Cobalt	Co(II)
Iron	Fe(II)
Manganese	Mn(II)

* All water soluble species unless specified

Additionally it has been shown that control of zinc and mercury in Bayer liquor directly, and/or in condensates, can be achieved by application of specific dithiocarbamate and/or dithiocarbonate products [Malito, 2002].

Control and removal of such heavy metals from solution presents Bayer plant operators with appropriate and sustainable options to improve water quality. This can enable reuse of otherwise contaminated and unacceptable water sources within refineries, which accordingly affords savings in fresh water. Alternatively such treatment can facilitate disposal of water of acceptable quality when conditions of excess supply or limited capacity necessitate such action.

5. Conclusions

Appropriate use and application of water is a critical parameter for all alumina refinery operators. The increasing cost (both environmentally and in dollar terms) of water resources means that plants are increasingly considering ways to reduce water inputs and/or more effectively use and manage water within refinery operations.

The requirement to reduce water input and more effectively use current resources is not specific to Bayer plants and a broad range of industries are seeking the same outcomes. Nalco has recently developed and improved a range of technologies aimed at more effective and efficient water use across a broad range of industries. These include the application of Nalco's 3D-Trasar control technology which enhances water quality management by detecting data on critical operating parameters, determining the appropriate action and delivering the required control remedy. Application of this philosophy, together with sophisticated measurement technologies and logic control, has been implemented for cooling systems, boilers and most recently, membrane and water recycling applications.

Since this technology is not industry specific, the use in alumina refineries is viable and a number of specific examples (particularly in the area of cooling towers) are readily applicable to plant facilities. Due to the generic nature of many applications, examples of proven savings both from both outside and inside the alumina industry can be considered as relevant indicators of the potential benefits and savings available.

While the 3D-Trasar technology provides substantial improvements in the capacity of facility operators to manage water, the ability to recycle and re-use water that is somehow contaminated from the process is another option for plant operators to consider as a means of improving efficiency. Within the area of recycling technology Nalco has developed a number of state of the art technologies to deal with a range of contaminant issues.

Together, there now exists a broad range of water control tools that have the potential to deliver substantial and significant water savings for alumina plant operators. While all aspects are unlikely to be utilized in any one plant, the wide range of technologies now available, and, in many cases, their proven application in other industries, provides operators with the appropriate tools to implement specific water savings programs for individual plants

6. Acknowledgements

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