A Phosphate Plant Process Water Treatment System

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Abstract In 2004 Hatch partnered with one of the world's leading fertilizer manufacturers to develop a cost effective and sustainable treatment method for phosphate fertilizer plant process water. Through extensive research, laboratory testing and pilot testing, a Phosphate Plant Process Water Treatment System (PPPWTS) was developed. The key objective of the process was to over come the high chemical cost of the traditional two-step liming and ammonia scrubbing process and recover phosphate values otherwise lost in the lime precipitates. The developed multi-step membrane process removes contaminants such as fluoride, ammonium and phosphates, as well as significantly decreasing the total dissolved solids content, to meet the requirements for discharge. In 2008 Hatch was awarded a contract to build a PPPWTS plant. This plant is currently in the start-up phase, and the discharge quality has been well below design discharge limits.

Key Words Membrane Water Treatment, Phosphate Fertilizer

Introduction

During the manufacturing of phosphate fertilizers contaminated process water, also known as "pond water", is produced. This water is a very low pH brine with total dissolved solids (TDS) content up to 40,000 mg/L (FIPR 2004a). The process water contains a broad spectrum of organic and inorganic material, including high levels of phosphate, fluoride, sulphate, silicon, sodium, calcium and ammonium, many at super-saturated conditions. Process water from the manufacturing process is sent to a large storage pond contained within a phosphogypsum stack which is formed by the precipitation of solids from the water. Some of the water evaporates and the water cools as it sits in the pond. The cooled water is continuously pumped back to the manufacturing process and used for a variety of purposes. A large phosphate manufacturing facility may hold several billion gallons of process water in its storage pond, and can have many tens of thousands of gallons per minute circulating between the manufacturing process and the pond.

Many phosphate fertilizer manufacturing plants maintain a process water balance. That is, the fresh water input to the plant and process water generated in the process roughly equal the amount of water lost by evaporation in the process water storage pond. However, changes in fertilizer production levels can result in a relative increase in the water generated, and severe storm events can result in large quantities of rainwater entering the storage pond, both of which can raise the pond surface level and increase the potential for accidental discharges or other environmental problems. Therefore, the ability to treat process water so it can be taken off site, discharged, or reused within the fertilizer plant is very important to overall fertilizer plant operations.

Currently, there are a number of technologies utilized to treat surplus process water, such as double liming, but most of these are relatively expensive and produce waste by-products that also require disposal. For years, the phosphate industry has looked for an economical long term solution (FIPR 2004b) for treating process water to allow it to be discharged to the environment or reused in place of fresh water in the fertilizer process. A broad spectrum of technologies has been assessed by the industry, and some of those have been based on membrane separation (Jardine et al. 2005).

In 2004, Hatch was contacted by a leading phosphate producer in the U.S. The phosphate producer was interested in partnering with Hatch's wastewater treatment specialists to develop a membrane-based process for the treatment of process water to produce water suitable for above ground discharge to Florida Class III waters. A primary goal of the process development would be that no secondary waste liquids or solids would be generated that would require separate disposal, and fresh water would not be required for dilution prior to discharge, which is the case with most traditional treatment processes. In response, Hatch initiated a structured development program to assess the feasibility of achieving needed objectives, and subsequently developed and pilot-tested the PPPWTS. This work was based on studies undertaken in other industries (Macintosh et al. 2001).

In 2008, Hatch was awarded a contract to design, construct, and operate an PPPWTS plant. Currently in the final phase of commissioning, the plant is designed for a treatment capacity of 1.44 MGD (63 L/s), and has produced over 100 MG (378 million litres) of treated process water suitable for discharge since start-up.

Development of the Process Water Treatment System

Hatch's approach to the development of a membrane process to treat process water involved the following:

- Extensive research and development, including obtaining an in-depth understanding of the phosphate fertilizer manufacturing process and process water properties, understanding the strengths and weaknesses of prior treatment technologies that had been applied, and conducting an assessment of membrane treatment process economics and process sustainability.
- Extended laboratory testing with numerous membranes in a range of process water conditions, which included studying the influence of seasonal impacts.
- Pilot testing at three different facilities in order to understand the similarities and differences in process water characteristics at each plant. A final process optimization test, undertaken during the design phase, was used to study long term operational issues, including the behaviors of different types of membranes at varying pond water and process conditions, and the effect of different cleaning chemicals and regimes on membrane productivity. At the end of this stage, final design engineering tasks were performed and contract CAPEX and OPEX costs were refined.
- Throughout the development of the PPPWTS and continuing during plant operations, Hatch and client engineers worked together in a true partnership in which all technical aspects of the project were developed, reviewed, and verified in an open forum, which advances the process technology forward as rapidly as possible.

Specific design and operating features of the PPPWTS are patent-pending or proprietary and cannot be disclosed at this time. Some general features of the process design are:

- Most of the equipment and systems manufacturers involved in the project were selected based on their ability and willingness to customize equipment to Hatch's specifications, and critical suppliers have entered into non-disclosure agreements with Hatch to protect the proprietary nature of the process.
- The design requirements for the membranes used in the process were developed during pilot testing, and specific membranes that can survive in the aggressive process conditions have been manufactured to Hatch's specifications. Membrane recoveries and scale inhibitors used have been optimized to minimize scale formation and maximize membrane life.
- Specialized cleaning chemicals and regimes were developed during piloting and have continued to be modified during operation to improve membrane performance.

Construction and Operation of the Process Water Treatment Plant

The construction project for the PPPWTS plant was a true partnership between the client and Hatch. Each company had separate scopes, accountabilities, and deliverables, with a joint management team overseeing the project execution. Hatch's scope of services included the design engineering, procurement, and construction management of the major equipment and control systems, including membrane skids, tanks, piping, instrumentation, ancillary equipment, SCADA, and the MCC, operator, and warehouse buildings. Hatch engineers and operators were also responsible for commissioning and plant start-up. The client was responsible for site civil works, electrical installation, and construction outside the PPPWTS plant limits.

Hatch's operations and maintenance contract scope includes the overall supervision and management of the plant, including hiring and training Hatch operators, providing engineering support, and handling the supply of all membranes, chemicals, spares parts and consumables. The PPPWTS plant operates 24/7 with two operators per shift, maintenance technicians, shift supervisors, and engineering support.

Figure 1 *PPPWTS NF membrane system*

Figure 2 *PPPWTS RO membrane skids*

Figures 1 and 2 show the PPPWTS membrane equipment.
Process water characteristics, design criteria, and PPPWTS effluent quality during start-up and commissioning are shown in Table 1. Data displayed is average operating data from December 2009 through April 2010. The discharge quality has met contract limits approximately 99% of on-stream time.

Specific key process indicators (KPI) in the discharge stream flowing to the product water tank are measured continuously during operation, and if the KPI do not meet the process control limits, the discharge stream is automatically diverted back until the KPI return to their control limits.

Conclusions

The PPPWTS plant has undergone several improvements during commissioning, including the installation of improved pre-filtration equipment, improved membrane construction, and upgraded clean-in-place (CIP) systems and regimes. The quality of the PPPWTS discharge has been slightly better than expected based on pilot plant results, but improvements continue to be made to the process design to reduce operating costs. It is expected that these improvements will decrease the construction and operating costs and improve the operability of the next-generation PPPWTS.

***Table 1** Process water Characteristics and PPPWTS Discharge Quality*

Parameter	Process water (Average)	PPPWTS Discharge Range (Average)	Contract Limits (24-hr Composite)
pH	1.4	7.5 – 8.5	6.5 - 8.5
Conductivity (µS/cm)	24,600	30 - 110 (70)	1,275
Phosphorus (mg/L)	6,000	ND - 0.5 (0.07)	10
Fluoride (mg/L)	6,900	1.0 – 8.6 (4.5)	10
Ammonium (mg/L)	890	ND – 0.02*	0.02*

* Free ammonia, calculated by using ammonia/ammonium conversion chart
ND = non-detectable

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