

An MBR System For Aquapolo Ambiental S.A.

Unprecedented Project Curbs Industrial Use Of Freshwater



The need for advanced wastewater treatment and reuse is increasing in all parts of the world; this is especially true in the São Paulo region of Brazil, where there is a growing demand for high quality water for industrial processing as well as for clean drinking water.

By Christoph Kullmann, Darren Lawrence & Emyr Costa

The Aquapolo Ambiental water reuse venture was created to address new regulations to restrict industrial use of potable water in São Paulo. Aquapolo is the largest wastewater reuse project in the Southern Hemisphere, and the fifth largest of its kind in the world. Upon completion, this ground-breaking facility will free up enough drinking water to continuously supply a population of 350,000 inhabitants, with the potential capacity to reach 600,000.

Membrane bioreactor (MBR) design has been identified as the most cost-effective solution to upgrade the existing wastewater treatment plant to meet São Paulo's pressing demand for industrial wastewater reuse. The new Aquapolo facility will employ Koch Membrane Systems' (KMS) innovative PURON™ MBR technology as well as MegaMagnum® reverse osmosis (RO) membranes.

Construction started in April 2010; the water treatment portion of the project is following an aggressive schedule for start-up in November 2011.

Public & Private Sectors Join Forces

The State of São Paulo, with close to 41 million people, is the world's seventh most populous urban area and is considered the economic, financial, and technical hub of Brazil. The region

contains nearly one-fourth of the country's population but less than 2% of Brazil's water.

Resources for drinking water are becoming increasingly scarce in São Paulo. The state government, recognizing the importance of safeguarding drinking water for the region's inhabitants, recently issued new regulations to restrict the industrial use of potable water, forcing factories to look for ways to reuse their wastewater, or obtain recycled water from another source.

Aquapolo Ambiental emerged from a unique business structuring and project financing arrangement known as a Specific Purpose Partnership (SPP) between Foz do Brasil, the engineering division of Odebrecht Group, and Sabesp, a Brazilian state-owned utility that provides water and sewage services for residential, commercial, and industrial use in the municipalities of the state of São Paulo.

The SPP signed a 15-year finance contract with the Brazilian Development Bank (BNDES), a federal public company that provides long-term financing for private infrastructure projects that contribute to the development of the country, such as water and sewer systems. To build this project, the SPP will rely on the expertise of the Brazilian engineering and construction firm Construtora Norberto Odebrecht working under a three year Engineering, Procurement, and Construction contract.

The new treatment plant will be built on the grounds of the ABC Sewage Treatment Plant (ABC STP) of Sabesp, located on the boundary between São Paulo and São Caetano do Sul counties. Effluent from the ABC Plant will be treated and pumped to the Mauá Petrochemical Complex and sold to other factories in the region for use in industrial processes.

The initial 2012/2014 phase will produce 56,160 m³/day (650 L/s) of reuse water, eventually reaching a capacity of 86,400 m³/day. Sixty-five percent of the plant output has already been sold under a 34-year contract to Quattor, a petrochemical company located within the Mauá petrochemical complex—Aquapolo’s target market. Other potential users are companies located along the 10-mile steel pipeline being built to carry water to the complex.

Feasibility Study Evaluates Options

Water is used in virtually every industrial and manufacturing process. The recycled water used in industry for processes such as cooling, making steam, and cleaning requires removal of particular substances as well as a reduction of suspended solids and conductivity. Several critical discharge parameters of the current ABC STP operation seriously compromised the ability to reuse the existing effluent, including chemical oxygen demand (COD), biochemical oxygen demand (BOD), suspended solids, ammonium, total phosphorus and conductivity. The facility was built in the 1990s and has an installed capacity of 3000 L/s but it only operates at 50% of its design capacity.

KMS conducted a comprehensive feasibility study to identify the most cost effective strategy to upgrade the existing plant infrastructure. This study evaluated the amount of high quality water needed for reuse, which parts of the existing wastewater

treatment structure could potentially be used in the upgraded facility, alternative system configurations, and the capital and operating costs of each configuration.

RO is typically the technology of choice for producing the quality of water needed for industrial reuse. RO involves forcing pressurized water through the membrane to remove salts and organic molecules, producing high quality water. In the case of the ABC STP facility, an evaluation of current effluent quality and future water reuse targets determined that it was not possible to solely add RO directly after secondary clarifiers to meet reuse quality parameters.

The poor performance of the secondary clarifiers, suffering regularly from bulking sludge, was a major potential threat for any RO solution. Even the installation of either sand filtration or direct ultrafiltration (UF) would only move the problem upstream, but never eradicate it. Another point to address was the high ammonia level still present in the secondary effluent from the plant, varying between 10 and 25 mg/L NH₄-N. As the current plant was only designed for carbonaceous removal, nitrification was impaired because the sludge retention time was too short, resulting in high ammonia effluent values. RO technology alone will not be able to meet strict reuse criteria of <1 mg/L NH₄-N year average. While RO remained an essential part of the treatment process to reduce total dissolved solids and make the water clean enough for reuse, the RO system needed to be coupled with an effective pretreatment system.

KMS engineers concluded that an upgrade of the existing biological treatment was necessary. Four different potential upgrade scenarios were evaluated. All four options involved submerged MBR technology. Depending on raw water conductivity, which varies significantly seasonally, the water produced by the MBR could either be reused directly, or be blended with RO permeate to meet the conductivity target level.

The first three scenarios involved retrofitting existing concrete structures. Using this approach required careful consideration of the current infrastructure and accommodation of future expansion. The fourth option considered was to make use of the existing plant operation and infrastructure and use the effluent of the secondary clarifier as feed water to the new MBR installation. It was clear that the nutrient deficient design

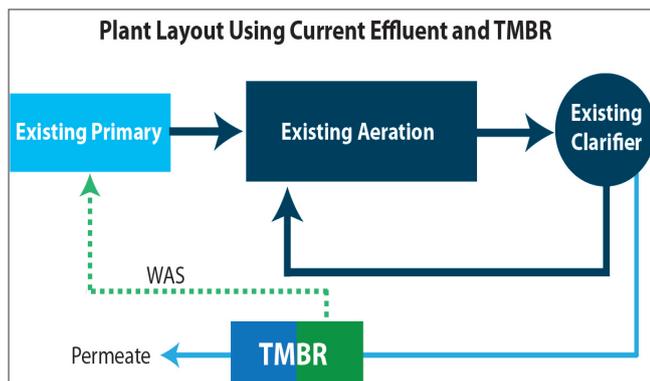


Figure 1: Approach 4 with TMBR Concept

Parameter	Unit	Effluent of ABC STP	Effluent of ABC STP
Average Flow	Lps	1600	650
Temperature	°C	15 to 30	15 to 30
BOD	mg/L	20 - 60	10
COD	mg/L	50 - 120	20
TSS	mg/L	40 - 100	2
Ammonia Nitrogen	mg/L	20	1
Total Phosphorous	mg/L	5	0.5
pH	mg/L	5 to 9	6.5 to 7.5
Total Iron	mg/L	2	0.3
Sulphide	mg/L	1	0.1
Turbidity	NTU	50	1
Conductivity	µs/cm ²	650 - 1500	720
Total Hardness	mg/L	100	100
Aluminium	mg/L	0.5	0.2
Phenol	mg/L	0.2	0.1
Copper	mg/L	0.2	0.01
Surface Active Agents	mg/L	5.1	1
Free Chlorine	mg/L	-	1

Table 1: Water Quality

of the existing plant would be a challenge biologically, but could be developed as a greenfield enhancement to the existing site operation without direct interaction with the site operation.

“Also, the choice for a greenfield solution will surely avoid many unknown risks derived from interfaces or adaptations on the existing structures,” says Giancarlo Ronconi, Foz do Brasil project leader. For this unique combination of existing conventional biological treatment with a new MBR system, the new MBR system was designated as a Tertiary Membrane Bioreactor (TMBR).

Pilot Study Proves TMBR Is the Solution

After a careful evaluation of each scenario, the KMS team concluded that adding a TMBR system to the existing plant infrastructure was the best solution for the new Aquapolo facility. In total, the Aquapolo project will encompass the construction of a new pretreatment step, installation of a chemical dosing system, and the construction of a 700 lps TMBR utilizing 94,500 m² of membrane area. The TMBR offers lower operating costs, lower process risk, greenfield design, and negligible interaction with current plant operations and equipment.

The TMBR is a polishing MBR process. It will treat water coming from the existing secondary clarifiers and further treat it in a newly built biological step using membranes as the final separation process. Some of the TMBR effluent will be further treated by RO membranes to meet conductivity goals for water reuse.

To validate the TMBR approach, a one-year pilot study was conducted to confirm the design parameters, optimize the system operation, and evaluate operating costs. A standard MBR pilot plant was used to exactly simulate the TMBR design concept. The membrane modules used were KMS hollow fiber submerged UF membranes. All flows were according to the feasibility design and Dissolved Oxygen, pH and mixed liquor suspended solids (MLSS) were closely controlled.

The pilot was operated between 2 and 6 g/L MLSS and start up and daily plant operation was simulated. The feed flow was controlled to a fixed value and all maintenance cleaning and down time was reflected in the operational flux of the membranes. The pilot plant output was 775 L/h net flow. The biological system design was simulated with a hydraulic retention time of ~3 hours and a sludge retention time of between 12 and 20 days.

According to Mr. Ronconi, “The main challenge during the pilot phase was the organic load variation but by developing the adequate approach to those situations, the Aquapolo team streamlined the learning curve regarding the wastewater behavior on ABC STP.”

A number of operational tools were developed to stabilize the operation and improve the biomass quality. Up until seven

months into the pilot study, primary feed was occasionally bypassed to the TMBR and occasionally ethanol was dosed to the TMBR. This proved useful to stabilize the biological system, but more importantly to stabilize the nitrifier population and alkalinity balance. After that time an additional operational tool was added in the form of ferric dosing.

This had two advantages; first, the total residual phosphorus was precipitated out to meet the discharge criteria and secondly, the biomass became marginally more flocculated and easier to control for the nutrient removal processes. Using these operational tools the target COD of 20 mg/L was achieved.

The TMBR pilot demonstrated that the submerged membranes benefited from the optimized biological system. Average flux rates of >25 L/m²h were achieved and daily maintenance cleaning was found to enhance the UF performance. Recovery cleaning returned the UF membrane to the original process permeability.

A standard RO pilot also was used to simulate the RO design concept of the proposed full scale system for 200 L/s feed water. The pilot trials were setup in three well-defined phases, a simple batch mode, a modified batch mode and a continuous mode. The RO system was able to produce an excellent water quality. The final water quality for reuse was achieved via blending the TMBR permeate and the RO permeate.

Together, both phases of this pilot study demonstrated a viable full scale solution for water reuse under difficult operational conditions.

Meeting Stringent Water Reuse Requirements

KMS was chosen for the Aquapolo project for its superior technical support and biological design, the availability of MBR and RO pilot plants, its vast experience with water-recycling projects, and ability to meet an extremely accelerated delivery schedule. KMS scope of supply included sixty-three (63) PURON PSH1500 membrane modules, two MegaMagnum MM9 RO units, system design and controls, and after-market support and service.

“Koch Membrane Systems’ willingness to work with us as our technological partner was a key factor in our decision to award them the contract,” said Emyr Diniz Costa, Senior Project Director at Odebrecht. “They offered a comprehensive engineering solution and dedicated extensive pre-engineering man-hours to produce the most reliable design and the state-of-the-art technology for our project. The availability of a pilot plant convinced us their solution was the best one.”

PURON submerged membrane modules produce high-quality effluent that meets stringent water reuse and recycling requirements while significantly reducing the treatment system footprint. PURON modules are energy-efficient, with the lowest energy demand of all commercially available MBR modules. The system is easy to operate, with features that are designed to provide significantly lower lifecycle costs, including a single header design that provides better solids management in the module, braided fibers to reduce the risk of fiber breakage, and highly effective air scouring method that virtually eliminates sludging.

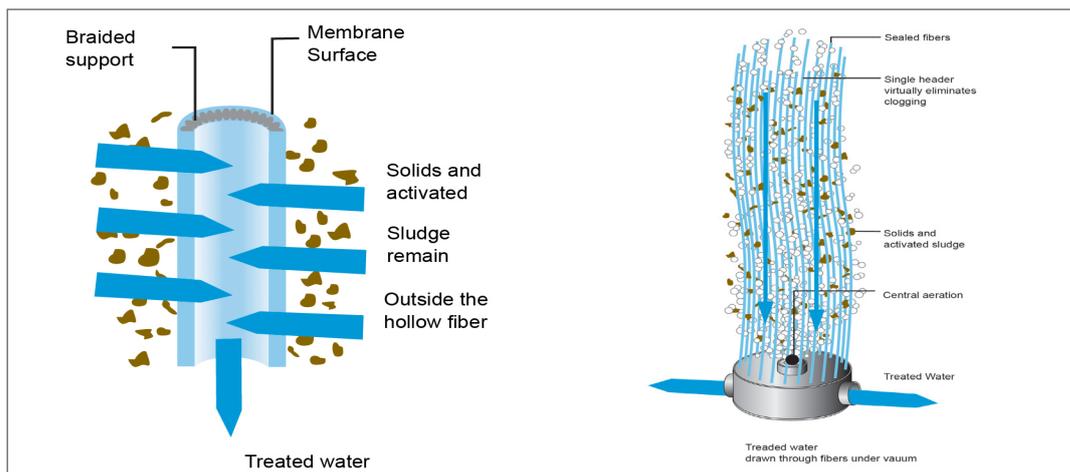


Figure 2: A Close-Up Of The Free Floating Tip Design Of The PURON Module And Its Outside-To-Inside Flow Pattern

Parameter	Units	Rebuild System 1	Rebuild System 2	Rebuild System 3	TMBR
Coarse Screen	-	Existing	Existing	Existing	Existing
Sand & Fat removal	-	Existing	Existing	Existing	Existing
Primary Clarification	-	Existing	Converted to DN	Existing	Existing
Fine Screens (2 mm)	-	New- after primary clarifier	New- before primary clarifier	New-after primary clarifier	New-after secondary clarifier
MBR Design					
Volume DN	%	0	19%	19%	6%
Volume N	%	74%	74%	56%	17%
Volume Membrane	%	7%	7%	7%	10%
Total System Volume	%	81%	100%	81%	33%

Table 2: Design Differences

An important advantage of the patented PURON module is the use of a single header with reinforced hollow fibers that are fixed only at the bottom. The sealed upper end of the fiber is allowed to float freely. The free floating tip design eliminates the build-up of hair and fibrous materials that typically clog the upper ends of membrane fibers in MBR module designs that employ both top and bottom headers.

Solids and particulates, including bacteria, are retained by the membrane and remain on the outside, while permeate is drawn through the membrane to the inside of the fibers. The outside-to-inside flow pattern provides optimal solids management and a high flow-rate. The Aquapolo facility will use the 1,500 m² PURON module, which was specifically designed for large-scale MBR projects. Features such as an optimized permeate extraction manifold and air supply lines reduce the number of piping connections during installation. For additional flexibility, the new product line enables users to easily retrofit the advanced PURON technology into systems with comparably sized modules.

The PURON module features greater packing density, lower energy costs for aeration, and simplified installation while providing even greater compatibility with other commercially

available systems. In addition to the PURON modules, the large diameter MegaMagnum RO elements will complete the custom-designed system. Each of the MM9 systems chosen for Aquapolo has a flow capacity of 1.7 MGD/day and 6,500 m³/day.

The MegaMagnum elements are the world’s largest commercially available spiral wound RO elements. Each MegaMagnum spiral element used for the project contains 3,050 square feet of membrane surface area, compared to 400 square feet in commonly deployed 8-inch products.

The MegaMagnum systems significantly reduce overall footprint as well as the cost of producing high-quality water through pre-engineered packaged systems for fast installation and start-up and fewer connections and seals for greater reliability.

About The Authors

Christoph Kullmann and Darren Lawrence work for Koch Membrane Systems, while Emyr Costa works for the Odebrecht Group. Koch Membrane Systems, Inc. has developed innovative membrane technologies that serve a diverse range of industries and applications around the globe. www.kochmembrane.com