Protecting the Adriatic Sea with advanced technologies

WATER TECHNOLOGIES

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The Rimini Santa Giustina WWTP protecting the Adriatic Sea with advanced technologies.

Lucio Boverio EWT, Technical Sales Manager Italy
Gerin James, EWT Global Product Manager Memcor MBR

The Italian scenario
Tourism in Italy attracts people from all over the world with its history, villages, monuments and beaches. To protect the environment the European Union sets strict rules to prevent and mitigate pollution in rivers, lake and seas. Also, municipalities have an interest to improve these limits in order to be able to promote their investments and attract more tourists and a tangible monetary gain. Nutrient removal, strict effluent requirements and lack of space all combine together as drivers that have contributed and are contributing to the success of the MBR technology in Italy.

Rimini plant background
Rimini is located in the famous “Riviera Romagnola” in Italy. The effluent is discharged at the end of the river Marecchia feeding the closed Adriatic Sea whose coasts are full of beaches both in the Italian side and in the other side (Croatia, Greece, etc.). The territory is well vegetated with mountains and hills, which gives the area its beautiful landscapes. However, construction of infrastructure is difficult and costly.

The Rimini WWTP plant is operated by HERA, one of the biggest water companies in Italy. HERA designed the upgrade of the conventional activated sludge plant, in order to increase the original capacity, 220,000 P.E., up to 560,000 P.E. (maximum capacity in summer season). The new MBR plant was inaugurated on the 23rd of June 2015 as the biggest WWTP with MBR technology in operation in Europe.
This increase in capacity was to allow the demolition of some existing WWTPs in the area like “Rimini via Marecchiese” (230,000 P.E.) and “Bellaria-Igea Marina” (70,000 P.E.) in order to centralise the wastewater in a unique high-performance WWTP.

The existing plant
The existing plant, kept in operation during the upgrading, is a conventional activated sludge (CAS) plant with the following process scheme:

- Coarse and fine screening
- Sand/grit removal
- Primary clarifiers
- Biological tanks with nutrient removal (pre-denitrification — oxidation/nitrification)
- Secondary clarifiers
- Tertiary filtration (sand filters)
- UV disinfection (added in 2015)

The MBR plant
The process scheme of the MBR plant is the following:

- Sand/grit removal (dedicated line)
- Flow split
- Existing primary clarifiers (can be used as lamination volume)
- Punch holes 1.5 mm fine screens

- Pre-Denitrification (n°3 lines)
- Oxidation-nitrification (n°3 lines)
- Membrane tanks (n°8)
- Clean-in-place (CIP) system (sodium hypochlorite and citric acid)
- Chlorination tank

Figure 1. The Rimini Santa Giustina MBR plant.

The membrane operating system (MOS) comprises eight membrane tanks fed by gravity from a common channel, in order to be able to feed each MOS tank with any biological tank.
The membranes are a monolithic hollow fibre type made from PVDF with nominal pores 0.04 microns arranged into modules.
Membrane modules are installed into a rack with 41 racks per tank, the total filtration area is approximately 150,000 m^2 (MEMCOR® membranes type B40N).

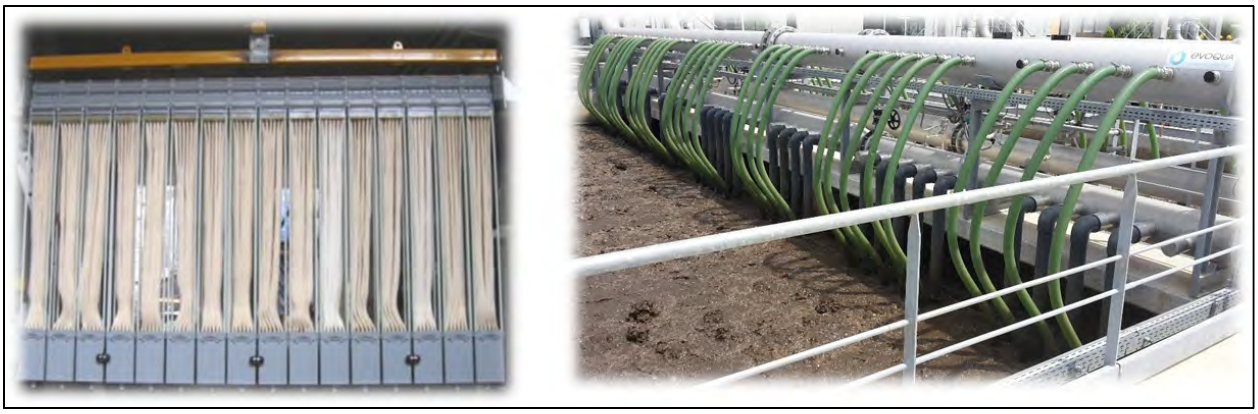


Figure 2. Membrane rack (on the left) and MOS tank in operation (on the right).

Membrane tanks are fed from a common channel that is divided into eight feeding channels (one per MOS tank) enabling distribution of the feeding flow through the long side of the tanks. This keeps the mixed liquor concentration inside the membrane tanks homogeneous.

Centrifugal pumps (8) extract filtrate from membranes (filtration out-to-in).
Typically every 12 minutes filtration is stopped and the membrane allowed is to 'relax'. This step, combined with the air scouring, prevents and removes fouling on the surface of the fibres and the formation of a filter cake. No backwashing of the membrane is used or needed.

Positive displacement blowers (8) feed air to a common manifold and then split it into the membrane tanks. The logic is controlled via a pressure transmitter placed in the common manifold and modulating valves + air flowmeters placed in the pipes feeding the MOS tanks. The air flow from the blowers is continuous but, thanks to MemPulse® devices at the base of each membrane module, the continuous airflow is converted into irregular pulses of air. This results in an increase in scouring effectiveness, and an overall reduction in air scour energy consumption.
The MemPulse devices introduce large bubble slug flow air and mixed liquor into the bottom of the membrane modules through an "airlift effect". The air bubbles blend with the mixed liquor and rise up into membrane fibres, providing effective scouring to the membrane surface and refreshing it to prevent solids concentration polarisation. The two-phase cross-flow reduces air energy for scouring. No moving parts are added to the system, decreasing operation and maintenance costs.

A portion of the mixed liquor is not filtered and overflows in four channels (two per MOS tank) feeding a recirculation sump with submersible recirculation pumps (8).

The cleaning system is automated and there is no requirement to remove membranes from their tanks.
Two types of cleanings are operated: Maintenance Clean (MC) and Clean-In-Place (CIP).
The MC is used to clean the membrane fibre through the lumens of any bio-film that has accumulated during operation. It is typically performed every week, the duration is less than 1 hour per tank. It can be scheduled automatically or manually initiated by an operator.
A CIP is typically required every 3 to 6 months to remove any foulants that have not been removed during normal relaxation and MC. The CIP provides further stability to the operation of the membranes at nominal and peak flows.
A biocide (NaClO) is used for all cleans and the use of an acid (citric acid) is necessary for inorganic fouling (less frequently).
A CIP takes typically 5–6 hours mainly depending on the water temperature that influences the soaking time. Sequences are automatic and there is no removal of the membranes or manual handling of chemical at any time.
The CIP/MC system is made of: dedicated draining pumps, dedicated CIP/MC pumps (for tanks filling and recirculation), pneumatic dosing pumps, chemical storage tanks, piping, valves and instruments.

Data

Design data and effluent requirements

Rimini WWTP is located in a tourist area, consequently the flowrates are variable from summer to winter, as reported in the table here below.

Table 1. Design flowrates

Parameter	m.u.	Summer scenario (WWTP)	Other months (WWTP)	Summer scenario (MBR)	Other months (MBR)
People Equivalent (P.E.)	N°	560,000	370,000	340,000	260,000
Average daily flow	MLD	125.5	78.0	76.2	54.8
	MGD	33.1	20.6	20.1	14.5
Peak daily flow (Q_{16})	m^3/h	7,848	4,874	4,765	3,425
	gps	576	358	350	251
Peak hourly flow to biological treatment	m^3/h	10,464	7,798	6,353	5,479
	gps	768	572	466	402
Minimum temperature	°C	20	12	20	53.6
	°F	68	53.6	68	68

The effluent limits requested to the MBR line only are stated from the combination of the Italian laws for discharge in surface water (D. Lgs. 152/2006), for reuse (D.M. 185/2003) and, as far as some parameters are concerned, stricter limits (for some parameters e.g. BOD_5, different limits are required in summer and in other seasons), as summarised in Table 2 below.

Table 2. Effluent requirements

Parameter	m.u.	Value			
		Inlet (design data)	Outlet (152/06)	Outlet (185/03)	Outlet (required)
BOD_5	ppm	248-265	≤ 25	≤ 20	≤ 3.5-5.5
COD	ppm	n.a.	≤ 125	≤ 100	≤ 25-35
TSS	ppm	400-427	≤ 35	≤ 10	≤ 10
TN	ppm	53-57	≤ 15	≤ 2	≤ 10
$N\text{-}NH_4$	ppm	n.a.	n.a.	≤ 2	≤ 2
TP	ppm	4.4-4.7	≤ 5,000	≤ 100	≤ 0.5
Escherichia coli	CFU/100 mL	n.a.	≤ 25	≤ 25	≤ 100

Start up

Installation of membrane modules in the N°8 tanks, after piping and ancillaries installation, started on August 2014 and finished on November 2014. Once each MOS tank installation was completed, proper operation of ancillaries and automatic procedures were tested.
On November 2014 the first MOS tank was put into service (in filtration). Due to the size of the plant and in order to allow proper growth of activated sludge in the biological tanks, the startup was divided into 3 steps. With additional days for authorisations to proceed, the total commissioning time was 170 days.

For each step, the MBR line had to comply with the following effluent values:

Table 3. Effluent requirements during startup

Parameter	**m.u.**	**Value**		
		1st phase	**2nd phase**	**3rd phase**
BOD_5	ppm	75	50	25
COD	ppm	375	250	125
TSS	ppm	105	70	35
TN	ppm	30	20	10
TP	ppm	3	2	1
Escherichia coli	CFU/100 mL	5,000	1,000	100

The MOS system during the startup phase had to face the following unexpected operating conditions:

- Incomplete rainflow buffer tank (30,000 m^3)
- Incomplete additional buffer tanks (former primary clarifiers, 6,000 m^3)
- Flow splitting not yet automated
- Maintenance works operated on existing CAS line biological tanks (higher flows to be treated by the MBR line)

As a consequence of the variable flow to the plant, the MBR line during startup was not operating with balanced flow. Instead the plant ramped up and down to treat flows several times operating at peak capacity.
The plant was able to cope with these conditions and due to a constant control of biological and MOS systems, the duration of the startup procedure was significantly decreased, taking 130 days totally: the MBR line startup finished at the end of March 2015.
At the end of the startup phase, each MBR line successfully completed a performance procedure of two consecutive cycles, each constituted by 5 hours at rain peak flow conditions (6,353 m^3/h - 466 gps) followed by 26 hours at peak daily flow (4,765 m^3/h — 350 gps).

Results
The effluent data for the first 6 months of operation are summarised below.

Table 4. Effluent data

Parameter	m.u.	Value			
		Inlet (design data)	**Inlet (actual)**	**Outlet (required)**	**Outlet (perf. test)**
BOD_5	ppm	248-265	183 (av.) 379 (MAX)	≤ 3.5-5.5	≤ 4
COD	ppm	n.a.	413 (av.) 712 (MAX)	≤ 25-35	11
TSS	ppm	400-427	250 (av.) 616 (MAX)	≤ 10	≤ 4
TN	ppm	53-57	30 (av.) 45 (MAX)	≤ 10	≤ 5
NH_4	ppm	n.a.	28.5 (av.) 49 (MAX)	≤ 2	1.9
TP	ppm	4.4-4.7	5 (av.) 9 (MAX)	≤ 0.5	0.5
Escherichia coli	FCU/100 mL	n.a.	n.a.	≤ 100	≤ 2

Remarks:
BOD_5 detection limit = 4 ppm
TSS detection limit = 5 ppm
TN detection limit = 5 ppm
Escherichia coli detectable limit = 2 FCU/100 ml

With regard to energy consumption, the operating data relevant to the whole MBR line (including fine screens, biological blowers, mixers, automatic valves & penstocks, SAS pumps, sludge thickening, etc.) shows an average specific energy consumption of less than 0.35 kWh/m^3 of treated water.
Further evaluations and field data collection will be carried out in this way in the near future; anyway, during startup phase, data kept by MOS power analysers have shown the following values:

Table 5. Specific power consumption (kWh/m^3 treated water)

Filtrate flow per MOS cell	Filtrate pumps	Air blowers + RAS pumps	Total
332.5 m^3/h	0.035 kWh/m^3	0.037 kWh/m^3	0.072 kWh/m^3
272.5 m^3/h	NA	NA	0.083 kWh/m^3
292.5 m^3/h	NA	NA	0.078 kWh/m^3

It is noted that due to low headloss and low flow (filtrate pumps are centrifugal pumps sized for 870 m^3/h @ 10 m.w.c.) during startup filtrate pumps delivery valves were being throttled: as a consequence the relevant power absorption was higher than necessary.

Summary

The MBR plant built at Rimini is meeting or exceeding all of the strict requirements for discharge into surface water and the effluent is also compliant with re-use requirements. The technology chosen to be installed within the plant, such as the compact hollow fibre MBR technology, allowed the upgrade of the plant to occur without acquisition of new land; while the energy consumption for the MBR plant and the MOS is below industry benchmarks thanks to good design and the pulsed aeration. It will be interesting to follow the plant during its life to check these results after years of operation.

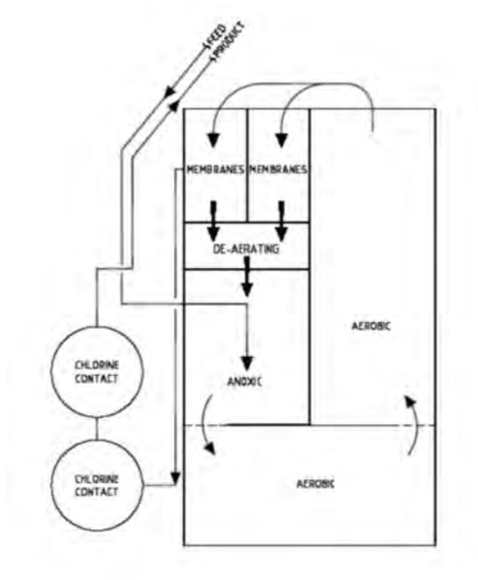
Closer to home

Globally there are many wastewater plants that are taking advantage of the MemPulse system and the latest B40N membranes. Recently the MBR plant at North Head STP was upgraded to B40N membranes and MemPulse systems after over almost 10 years of operation. The upgrade allowed the plant to increase membrane capacity by over 25%, using the same footprint while also decreasing scour energy costs.

The background: A low maintenance solution with high water quality output for water conservation

North Head Sewage Treatment Plant (STP) is one of the largest wastewater treatment facilities in Sydney. In 2005, the Sydney Water Corporation (SWC) sought a viable alternative to reduce the STP's potable water demand. As the plant is located in a scenic and environmentally sensitive area, a compact high-quality treatment process with little impact on the surrounding area was required. A membrane bioreactor (MBR) system from Evoqua was chosen for the recycled water plant due to its ability to provide consistent high-quality water, within a small footprint at lower capital and operating costs.
Constructed and commissioned by CHJY Freshwater, a joint venture between CH2M Hill and of John Young Kelvinhaugh, the MBR system comprises separate aerated, anoxic and solids separation zones.

The process



Screened settled sewage is pumped into the anoxic zone and mixed with a mixed liquor return. Flow then passes into the aerobic zone. Pumps draw from the aerobic zone and deliver mixed liquor to the membranes in the Membrane Operating Systems (MOS), with the return activated sludge overflowing to a de-aeration zone prior to the anoxic zone.
High-quality filtrate is produced by pumps providing a vacuum to hollow fibre membranes (0.04 µm nominal pore size). The filtrate is dosed with sodium hypochlorite to provide a chlorine contact time (CT) of at least 30 mg/L min. and re-used within the plant.

Performance that exceeds expectations

Since the integration of MBR technology in 2005, the North Head STP has produced over 700 ML/yr (185 US MG/yr) of high-quality recovered water.
Two detailed studies have been conducted on the MBR system to determine its effectiveness in removing microorganisms. The results show log reduction values (LRV) in the range of 4.7 – 6.2 for F-specific RNA bacteriophage, 5.4 – 6.7 for E. coli and 3.7 – 5.2 for somatic coliphage.
The MBR also reduced Cryptosporidium, Giardia and human enteric viruses present in the influent to below detectable levels. These log reduction values exceeded most of the LRV range given for membrane filtration in the 2007 Australian Guidelines for Water Recycling (AGWR), despite being limited by the number of microorganisms present in the influent, proving that the MBR system is an effective and beneficial solution for pathogen removal, as well as high-quality water output.

Increased capacity in the same footprint

In 2013 Sydney Water recognised the need for additional recycled water and began to develop options. Evoqua Water Technologies conducted an audit of the MBR and found that it was possible to increase the MBR capacity up to 3 ML/d by upgrading to the latest generation B40N+MemPulse systems.
The upgrade was completed in 2014 with minimal disruption; the plant was kept in operation throughout the upgrade.

Parameter	Initial design	Upgrade Phase 1
Average capacity [ML/d / MGD]	2.0 (0.53)	2.25 (0.60)
Peak capacity [ML/d / MGD]	2.2 (0.58)	2.6 (0.69)

Membrane type	B10R+MemJet	B40N+MemPulse
Nominal pore size [µm]	0.04	0.04
Tanks	2	2
Racks per tank	4 + 1	4 + 1
Module per tank	160	56
Total membrane area [m^2 / ft^2]	3232 (34789)	4211 (45327)
Average net flux [L/(m^2*hr) / gfd]	26 (15.3)	22 (13.0)
Peak flux [L/(m^2*hr) / gfd]	30 (17.7)	26 (15.3)
Hydraulic retention time, HRT [hrs]	5.5	4.6

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Every day, millions of people and thousands of companies rely on Evoqua Water Technologies to help them meet their needs for clean water.