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Technology for the Treatment/Reuse of Refinery Wastewater

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Biological Treatment
Typical Applications and Operating Conditions

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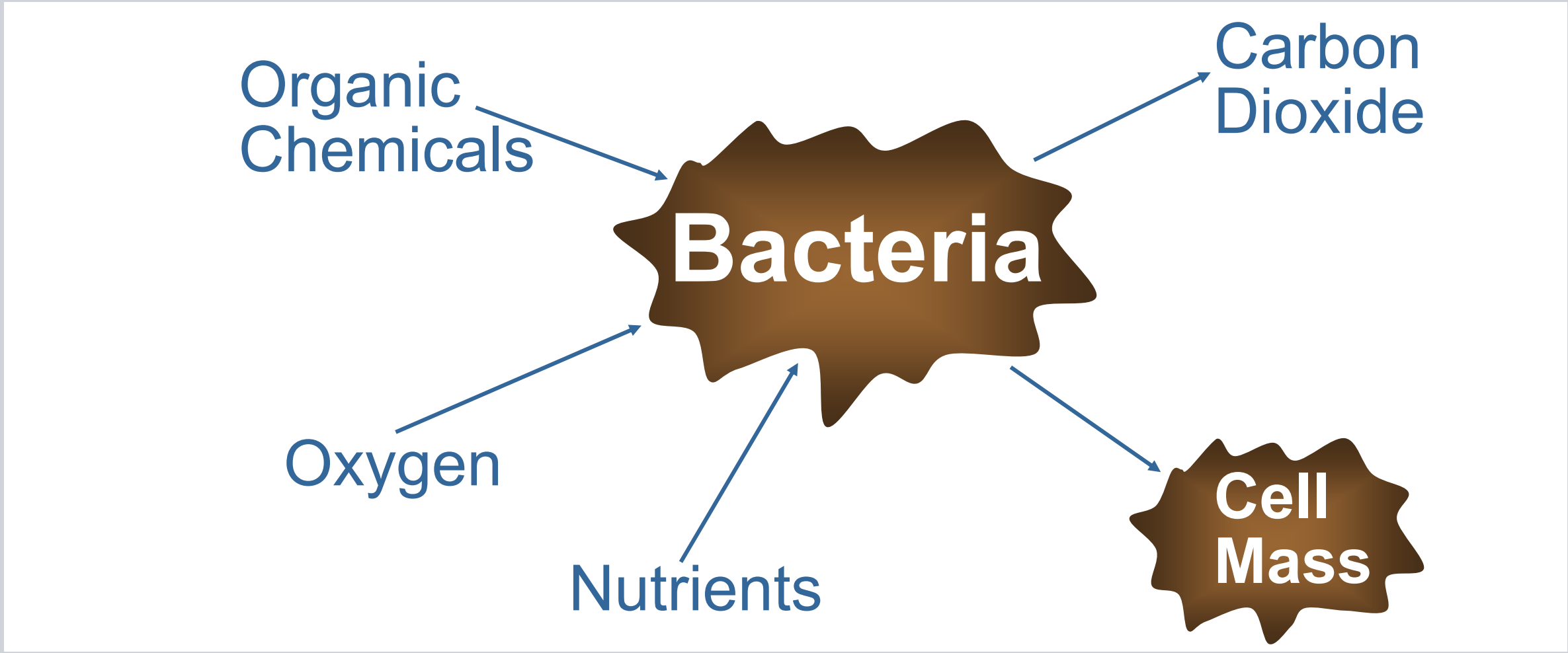
- Designed primarily for removal of biodegradable organic matter, nitrogen and phosphorus compounds
- Normally applied after primary treatment where inert solids and oils are removed from the wastewater
- Used to achieve effluent BOD and TSS concentrations of 30 ppm or less
- Effluent COD concentrations are dependent upon the application.



Biological Treatment
Principals of Operation

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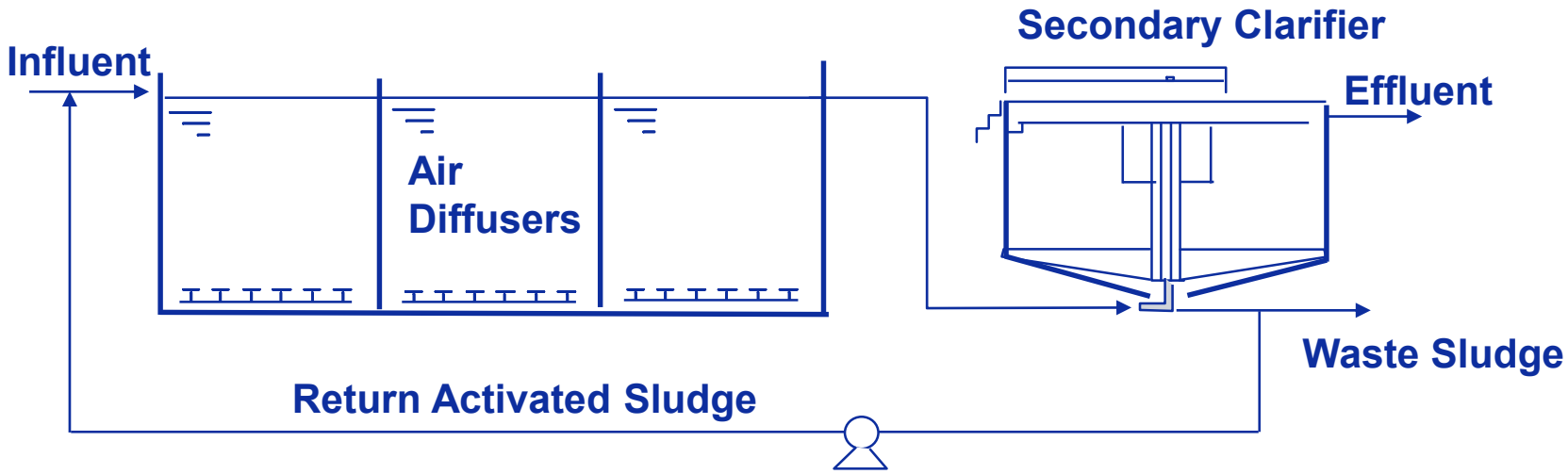


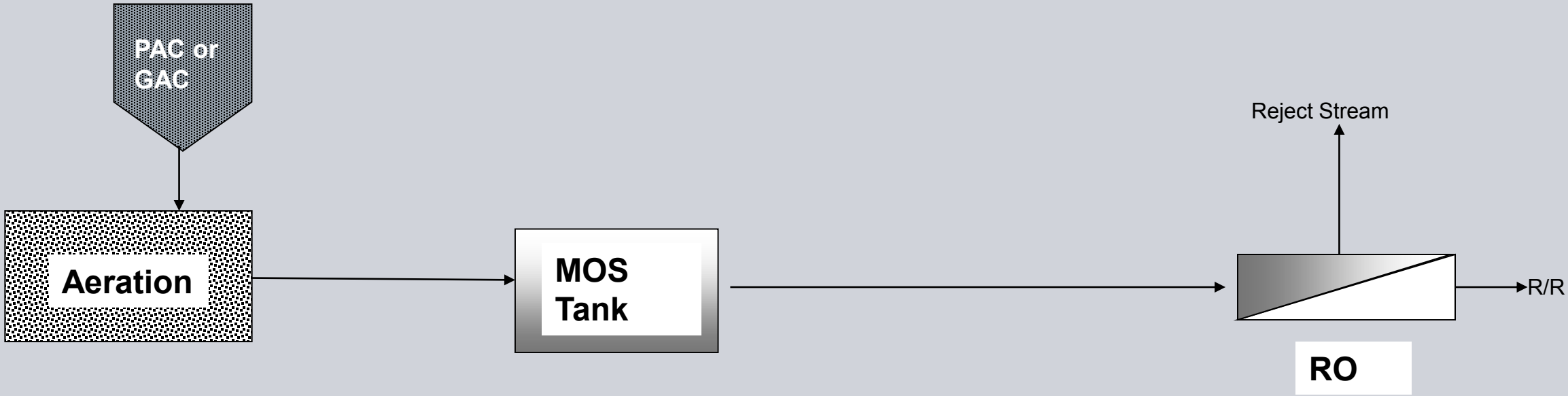
Market Dynamics - Background

- Industrial Wastewater
  - Treatment of Refractory Organics
  - Need for water conservation/sustainability
- Wastewater discharge regulations tightening
- Water shortages
- Existing technology not reliable / too costly

Needs

- Increased contaminants removal efficiency
  - Existing or stricter discharge standards
  - Reuse of wastewater:
- Reliable, small footprint

From PACT® to MBR Alternatives



Petro™ MBR Technology = Siemens O&G MBR Design

Petro™ PAC MBR = Powdered Activated Carbon in Aeration + MOS Tank

EcoRight™ MBR = Granular Activated Carbon in Aeration Tank ONLY

Advantages

Carbon assisted MBR Advantages

- Small footprint
- High COD and TOC removal efficiency
- Bio-refractory organics removal
- No gravity clarification
  - More stable – less upsets
- Wastewater reuse pretreatment
- Lower capital, operating & maintenance costs for equivalent effluent quality

Saudi Aramco Powdered Activated Carbon PAC (MBR) Testing

- Complex refinery WW
  - Highly variable
  - High concentrations of refractory organics
  - Effluent compliance difficult
- Side-by-side test with MBR

Testing

PAC MBR Pilot Test Unit

Testing

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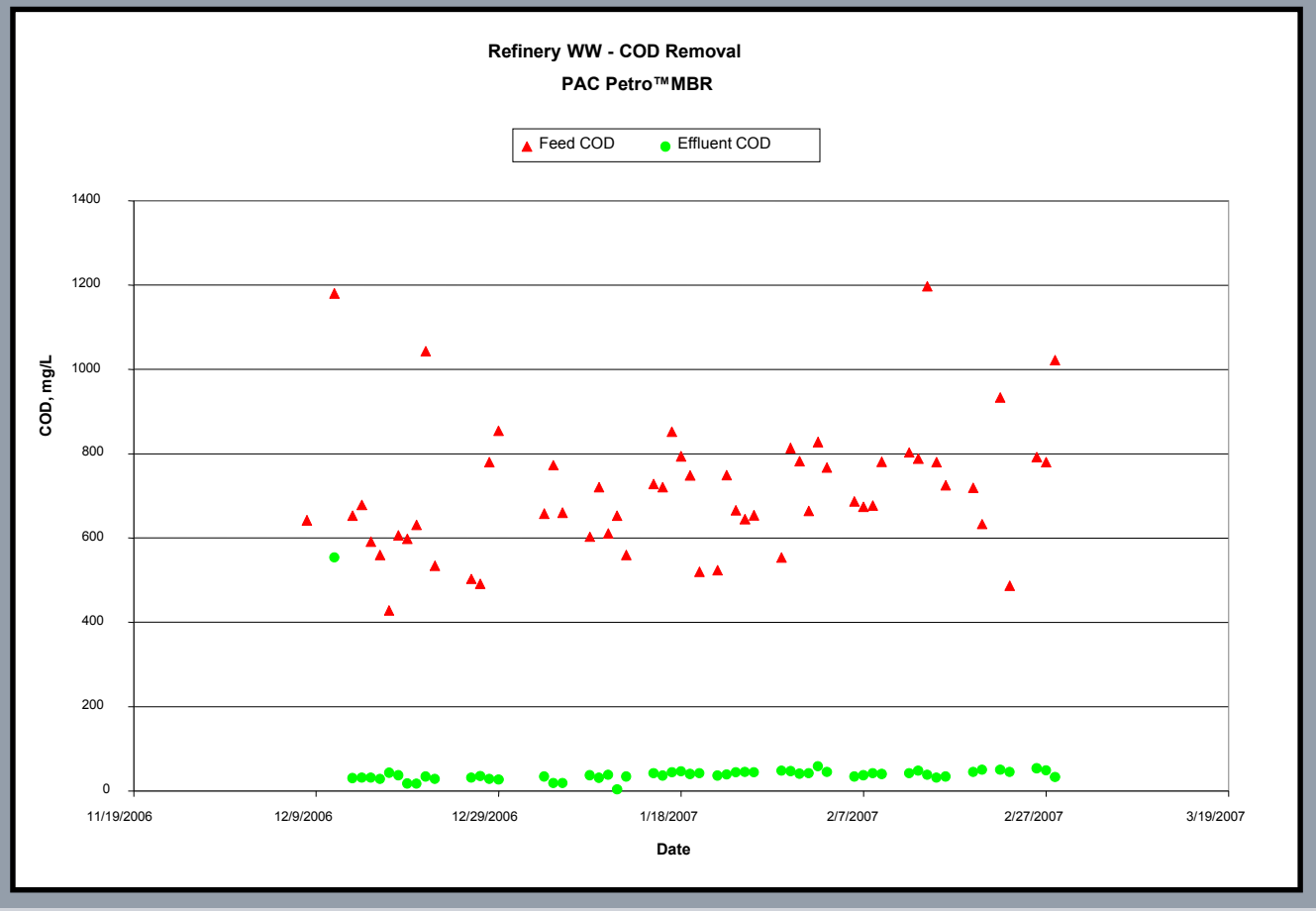
COD – Influent and Effluent



Testing

Test Results	Feed	MBR Removal %	PAC MBR Removal %
BOD	~400 mg/L	(~4 mg/L) 99%	(~5 mg/L) 99%
COD	~750 mg/L	(151 mg/L) 81%	(46 mg/l) 92%
TOC	~200 mg/L	(27 mg/L) 86%	(11 mg/L) 94%

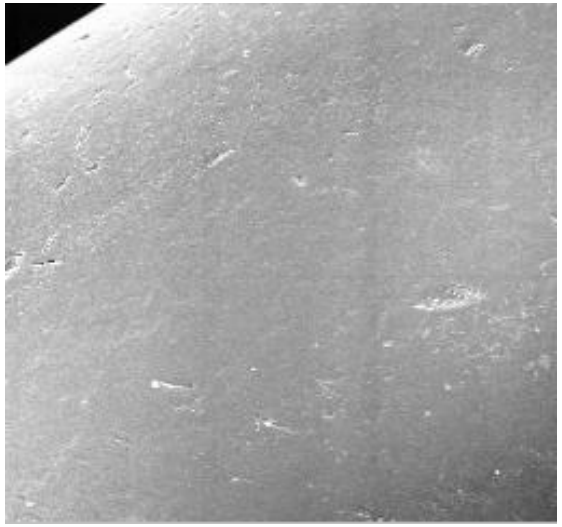
PAC MBR Results - Summary

- Excellent refractory removal
- Excellent effluent quality – feed to an RO
- Very stable
- No MBR membrane fouling
- Significant abrasion
  - Up to 40% reduction in life expectancy

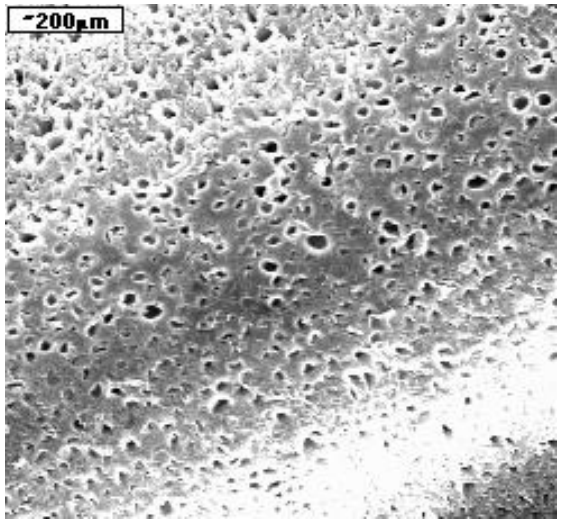
Testing

Membrane Abrasion*

New 125X

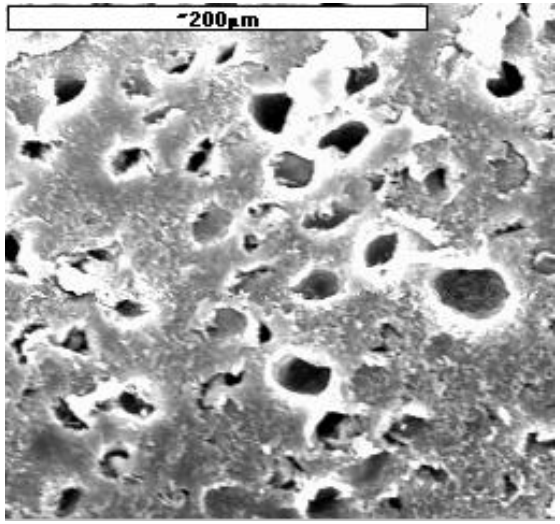


30 days



125X

30 days



500X

* Improvements in membrane materials have reduced, but not eliminated, membrane abrasion.

Testing

Saudi Aramco invented & patented GAC MBR

All advantages of PAC MBR

Solves the problems

- GAC vs. PAC
  - GAC can be pre-separated from membrane tank – No membrane abrasion from carbon contact
  - GAC attrition is minimized

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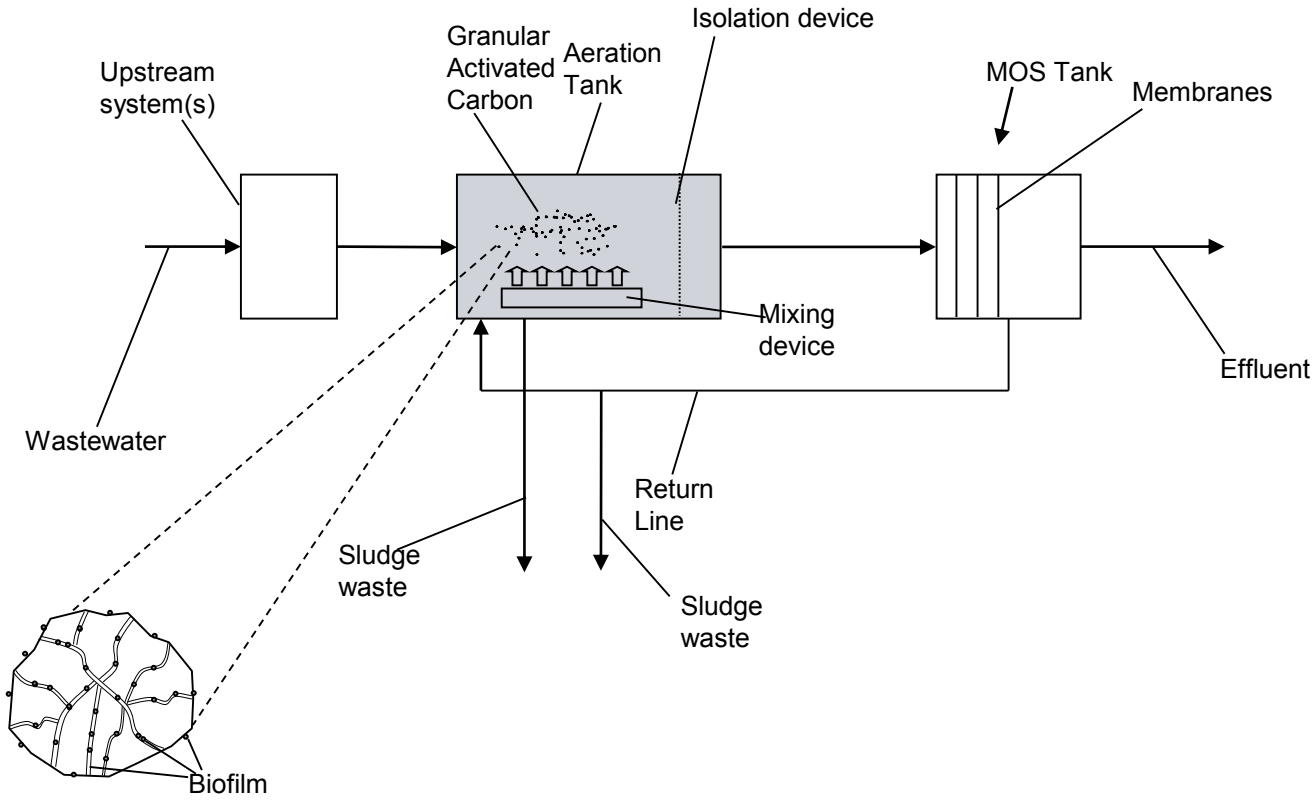
EcoRight™ MBR How it works



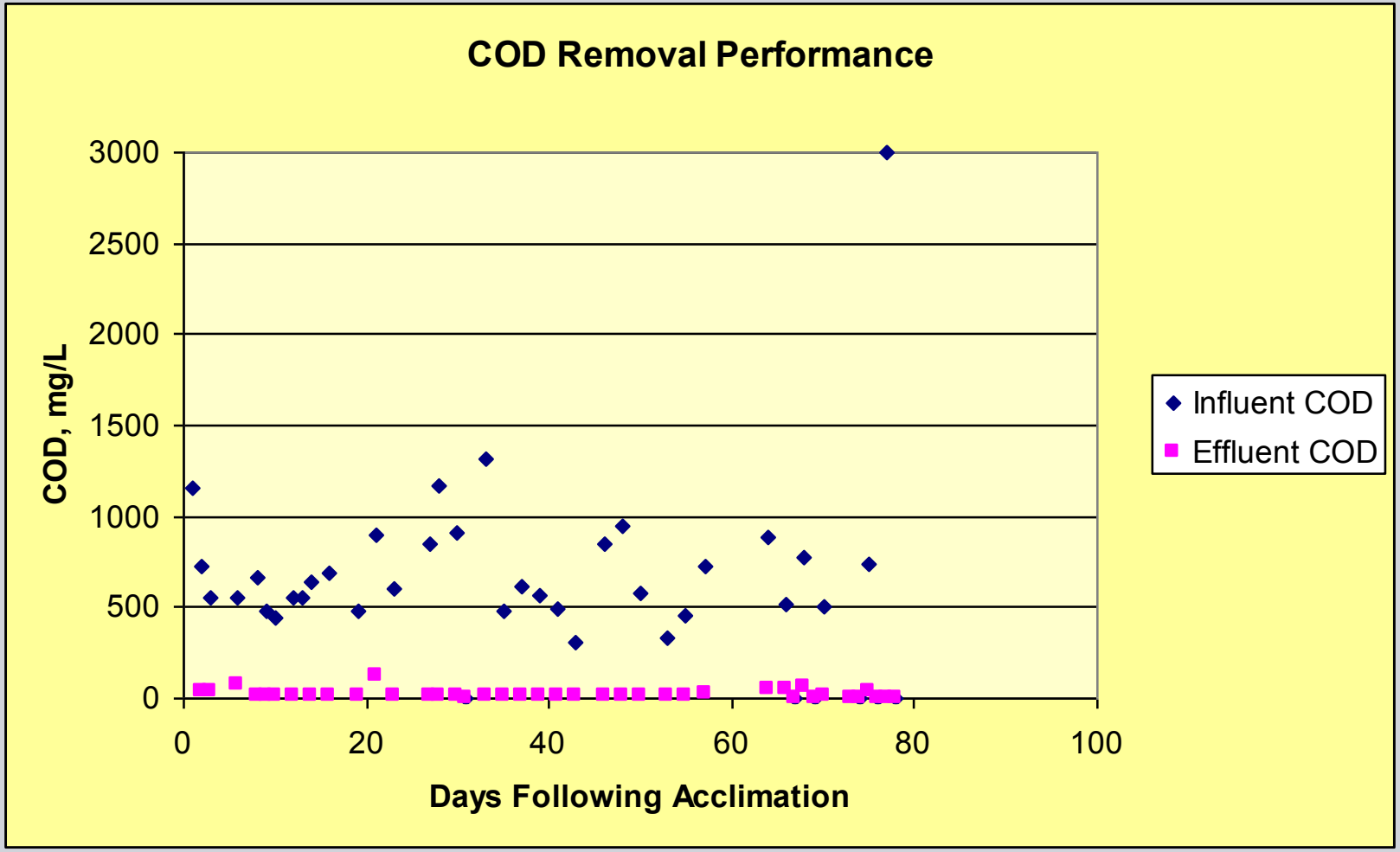
Testing

EcoRight MBR Pilot Unit

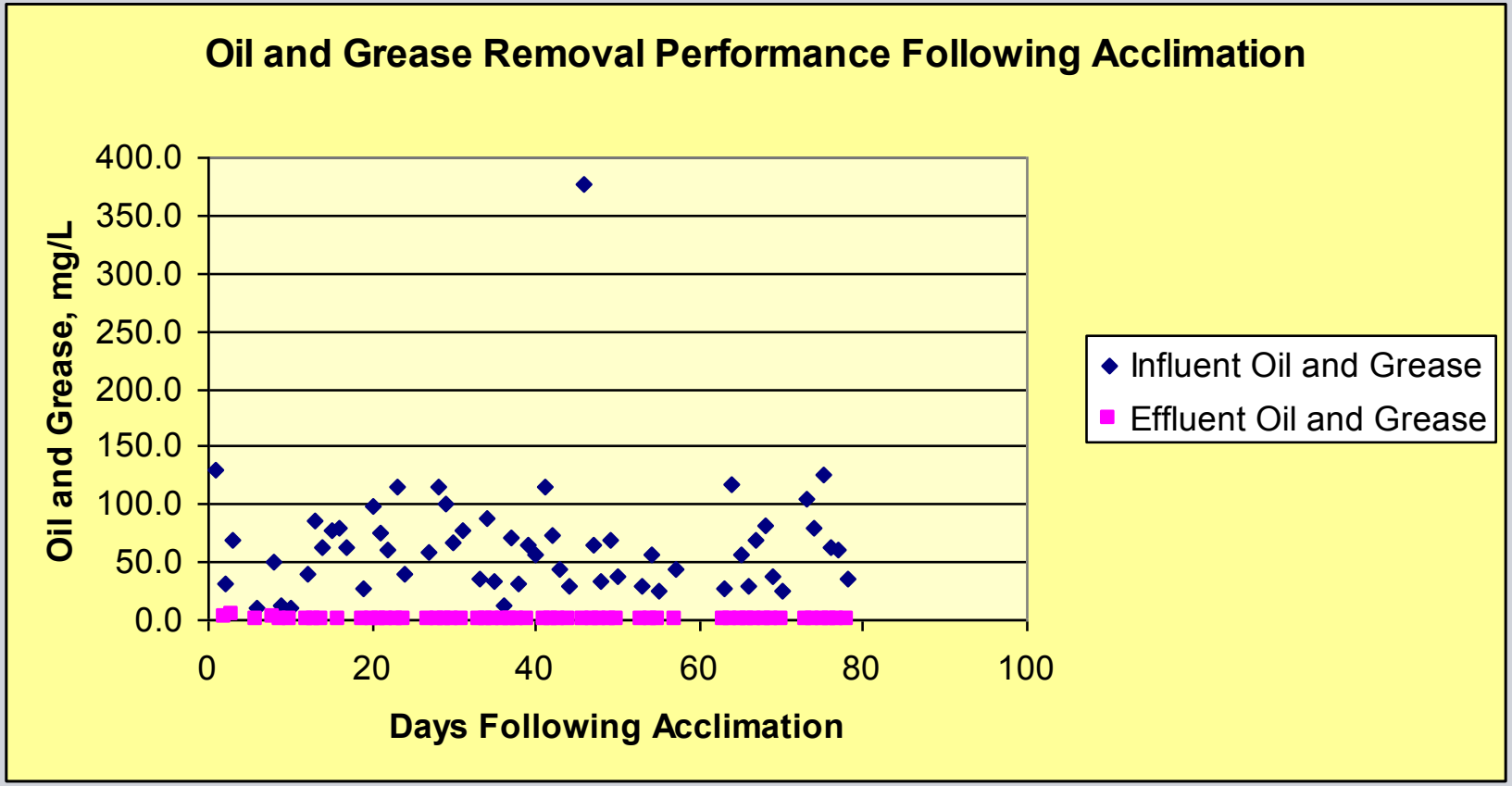
Testing

EcoRight™ MBR Pilot Samples

Testing
EcoRight™ MBR Pilot Testing COD Removal Performance Following Acclimation



Testing
EcoRight™ MBR Pilot Testing Oil and Grease Removal Following Acclimation



Note - EcoRight MBR appears to respond much better to higher influent oil concentration than conventional biological treatment systems

Testing - EcoRight™ MBR Pilot Testing RO (Single Pass) Performance*

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Date	Data Collection Time HH:MM	Product Flow (gpm)	Reject Flow (gpm)	Cartridge Filter Inlet Pressure (psig)	Cartridge Filter Outlet Pressure (psig)	RO Inlet Pressure (psig)	RO Outlet Pressure (psig)	Feed TDS Readout (ppm)	Product TDS Readout (ppm)
06/28/11	197	0.45	1.5	166	160	240	160	6386	73
06/29/11	198	0.5	1.5	166	160	240	160	5221	54
06/30/11	199	0.5	1.5	166	160	240	160	4927	49
07/08/11	201	0.5	1.5	160	151	280	180	1489	47
07/03/11	202	0.5	1.5	160	151	260	180	5348	50
07/04/11	203	0.5	1.5	160	150	260	160	6348	75
07/05/11	204	0.5	1.5	155	150	260	160	4434	44
07/06/11	205	0.5	1.5	160	150	260	180	3979	34
07/12/11	211	0.5	1.5	160	150	260	180	4441	25
07/13/11	212	0.5	1.5	160	150	260	160	4510	35
07/14/11	213	0.5	1.5	160	150	260	160	9011	48
07/16/11	215	0.5	1.5	170	160	260	160	6834	7.7
07/19/11	218	0.45	1.5	170	160	240	140	6833	92
07/20/11	219	0.45	1.5	170	160	240	140	6385	104
07/21/11	220	0.45	1.5	170	155	220	140	6251	102

* Operating since June 28th with one maintenance cleaning cycle.

Testing

EcoRight™ MBR Testing

- Refractory organic feed
- Same operational advantages as PAC MBR
  - MBR – no clarifier
  - Improved refractory removal efficiency
  - Stable Operations - GAC acts as a buffer, adding stability to the system operation Lower EPS concentrations
  - Biological regeneration of the GAC

Testing

Development together with Saudi Aramco

- Field pilot confirmation
  - Completed at the Ras Tanura Refinery and Juaymah Gas Plant in Saudi Arabia (both SA facilities)
- Applications (Refinery/ Gas plant)
  - Eliminate /reduce surface discharge
  - Reuse WW – reduce desalination costs
  - Reduce groundwater consumption

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Thank you for your attention!