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Cost Impacts from high flux rate, small footprint, and operation simplicity

A competitor to **RSL Membranes™** is a UF membrane product sold by Koch Membranes. The product is known as Puron-mp Ultrafiltration membranes. Puron membranes , like **RSL Membranes™**, operate in the dead end filtration mode (i.e no cross flow) and there by concentrate solids in the membrane housing. The layout of the Puron module and the footprint was assessed. Koch sells models that vary in size from 6 membrane housings to 64 housings

The estimated floor area for this Koch Puron system is 12 ft by 5 ft for a capacity of 15 m3/hr based on 50 lmh flux rate. Koch claims that these membranes can operate at flux rates as high as 100 lmh or 200000 gpd (30 m3/hr) on the 6 housings. Each housing has 50 m2 of membrane area. In the assessment, a key limitation on the development of a floor area was consideration of using a sea container as the shipping and weather protecting enclosure for the process unit. In the design of the **RSL Membrane™** treatment systems, all models fit into a 8.3 m (27ft). One of the issues with the Puron design is that the housings are too high for a sea container, specifically as it is placed on a skid and support rack. As a result, if the Puron system was designed for sea container enclosure, the housings height would have to be reduced by 400 to 500 mm (20 to 25% reduction in capacity)

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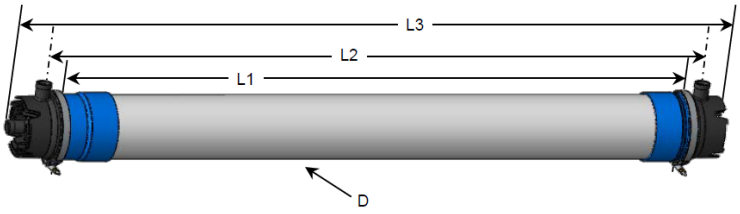
NOMINAL DIMENSIONS



Model	D		L1		L2		L3	
	inches	(mm)	inches	(mm)	inches	(mm)	inches	(mm)
PURON® MP 8081-102	8.6	(220)	81	(2,060)	84 9/16	(2,148)	91 9/16	(2,326)

The typical design parameters for UF membranes is shown in the following table 6 (Wikipedia Ultrafiltration Membranes) which is referenced in the Bromley,2021 paper "**The differences between Conventional Low-Pressure Membranes and RSL Membranes™** "

Table 6 Process Characteristics - Manufactuers Recommendations

Operating Parameters	UF Hollow Fibre	UF Spiral-wound	UF Ceramic Tubular	RSL Membranes™
pH	2–13	2–11	3–7	2-13
Feed Pressure (psi)	9–15	<30–120	60–100	0-10
Backwash Pressure (psi)	9–15	20–40	10–30	air 75-90
Temperature (°C)	5–30	5–45	5–400	1-400
Total Dissolved Solids (mg/L)	<1000	<600	<500	<250000
Total Suspended Solids (mg/L)	<500	<450	<300	<5000
Turbidity (NTU)	<15	<1	<10	<3000
Iron (mg/L)	<5	<5	<5	no limit
Oils and Greases (mg/L)	<0.1	<0.1	<0.1	<2000
Solvents, phenols (mg/L)	<0.1	<0.1	<0.1	unknown

In addition, as much as there is an ability to operate pressurized UF membranes at flux rates of 50 to 100 lmh, pretreatment of the water is essential. {Quote: *Compared to submerged membranes, pressure UF membranes can operate with TMPs as high as 500 kpa (75 psi). As*

result flux rates will be higher at 50 to 100 l/m2/hr. To accomplish these higher flux rates, feed water to the membranes has to have water clarity < than 3 NTU (Swiezbin 2017)}

The largest Puron unit is a 64-housing model as shown below. This unit would have the most efficient use of floor space

The estimated floor area for this large Puron Unit using the housings as specified above is 6.7 m (22 ft) by 1.5 m (5 ft). The capacity is up to 2 MGD (300 m3/hr). This size arrangement is for the housings only. The actual footprint needs to include the support infrastructure (CIP. CEB and tankage). To accommodate the support infrastructure, the footprint was doubled to fit into one 12.2 m (40 ft) sea container. This equates to a maximum capacity of 300 m3/hr/30 m2=10m3/hr/m2. However, the typical design would be 50 lmh or 150 m3/hr =5 m3/hr/m2. Based on standard industry practice, there is a high probability that pretreatment will be necessary to lower the turbidity to <3 NTU or reduce oil to <0.1 ppm. Koch however claims pretreatment is not necessary. The calculations in this document are based on no pretreatment requirements. **RSL Membranes™** do not require pretreatment.

RSL Membranes™ can fit a minimum of 80 m3/hr system up to 200m3/hr into a 27 ft sea container (20 m2) or 10 m3/hr/m2. In reality, the normal flux rate for RSL membranes™ is 430 lmh =100 m3/hr or 5 m3/hr/m2.

As a result, floor area for the two technologies are **potentially** the same. It is worth noting, however, that there was a recent comparison of UF membranes using a sheet membrane format with dead-end filtration (https://www.technologycatalogue.com/product_service/oilpaq-water-treatment-system) vs an **RSL Membranes**™ application, to treat oil and gas produced water. The difference in footprint for the two technologies is significant. The UF technology floor space for

a 35 m3/hr treatment system was in a 40 ft (12.2 m) sea container vs the 100 m3/hr **RSL Membranes**™ system in a 27 ft (8.3 m) sea container. The footprint per 1 m3/hr water treatment rate is 1.2 m2 for the UF membrane system vs 0.2 m2 for the **RSL Membranes**™.

In the event that pretreatment is required, the floor area advantage for RSL membranes improves drastically. The **RSL Membranes**™ footprint advantage results in significant overall cost saving in capital and operating costs. The high flux rate provides the cost benefit on the membrane tubes and the housing but the overall reduced footprint and simplicity in operation creates significant cost improvement in capital and operating costs.

Recently a consultant's cost evaluation was undertaken on a 50 m3/hr conventional UF membrane potable water treatment system which was compared to an **RSL Membranes**™ potable water treatment system. The water quality feeding the membrane was a high-quality surface water with NTU less than 2 NTU. The **RSL Membrane™** system was combined with an NSF certified UF disposable cartridge system. This configuration, with the **RSL Membranes**™ as the lead filtration technology, provides longevity in the certified barrier technology which relies on disposable cartridges. Table 1 below shows the total capital cost of construction of a 50 m3/hr. water treatment plant in USD $. The comparison is based on a conventional UF membrane with multimedia pretreatment. **RSL Membranes™** have no pretreatment but use a UF disposable Cartridge system to provide the certified barrier. Table 2 compares the Operating Costs

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Table 1 Potable Water Treatment Plant

Capital Cost USD 50 m3/hr	UF Membranes	RSL- UF Cartridges
Floor Area incl water process, pumping, lab, B/W and membrane cleaning (m2)	180	90
Excavation and Backfill	$13,591	$7,020
Rock Excavation Allowance	$8,580	$6,240
Concrete for Footings	$164,736	$124,800
Building (above grade)	$561,600	$280,800
Site Requirements/Hydro	$62,400	$62,400
RSL Membrane	$0	$468,000
UF Cartridges	$0	$234,000
Watertreatment equipment	$877,500	$0
Overflow/Rejectwater	$39,000	$39,000
Outfall line structure	$78,000	$78,000
Chemical Feed System for disinfection	$42,900	$42,900
Mechanical Equipment (piping ,valves,gauges,Fittings	$312,000	$156,000
Heating and ventilation Equipment	$156,000	$117,000
Electrical and Control Panel	$390,000	$156,000
Standby Diesel Generator	$152,100	$152,100
Miscellaneous Appurtenances	$39,000	$39,000
Backwash pumping & backwash effluent management	$273,000	$78,000
Decommissioning of Existing WTP	$117,000	$117,000
Radio Path Study	$19,500	$19,500
Comunication system	$156,000	$46,800
Install Septic Tank	$23,400	$23,400
Locate and Connect to Existing Watermain	$5,850	$5,850
Construct Access Road	$354,900	$354,900
Provide 3 phase power	$331,500	$331,500
		$0
Construction subtotal	$4,178,557	$2,940,210
Miscellaneous Construction Cost(7%)	$292,499	$205,815
Construction Total	$4,471,056	$3,146,025
		$0
Engineering (15%)	$670,658	$471,904
Contingency (10%)	$447,106	$314,602
TOTAL	$5,588,820	$3,932,531

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Table 2 Annual Operation and Maintenance Costs

Annual Operation and Maintenance Costs		
Item	UF Membranes	RSL- UF-cart
1. Allowance for routine maintenance	$3,900	$3,120
grounds, grass, snow	$0	$0
2. Allowance for Building maintenance	$9,693	$4,680
cleaning , minor repairs	$0	$0
3. Building Heating	$7,800	$3,900
4a Electricity-RSL-kw/m3 =0.1 kw/m3	$0	$3,416
4b Electricity- NF and other	$27,300	$3,416
5. Allowance- Equipment maintenance	$11,700	$9,360
equip replacmt-10 years, inspection, testing	$0	$0
6. WTP Operator	$0	$0
Primary 40hrs/wk 1 x Secondary 30hrs/wk	$81,120	$70,980
7. UV bulb replacement	$3,120	$3,120
8a. Chemical Cost- RSL $0.06/m3	$0	$20,498
8b. NF cartridge cleaning	$10,296	$0
8c Cartridge Disposal	$3,900	$0
9a. Membrane replacement RSL 5 yrs	$0	$12,480
9b Membrane replacement NF 5yrs	$39,000	$3,900
10. Membrane service contract	$7,800	$7,800
11. Settling Tank Cleanouts	$6,240	$3,120
12. Sludge tank cleanouts	$27,300	$0
13. Road Maintenance	$3,120	$3,120
TOTAL cost per year	$242,289	$152,911

Recently, there has been a detailed assessment of the CAPEX and OPEX between and **RSL Membranes™** system and a DAF system to treat industrial waste water. The table below shows the operating cost comparison between the two technologies. With regards to the Capex difference, **RSL Membranes™** are more expensive but based on a 5 year depreciation the extra cost per m3 of waste water treated is approximately $0.26. However the treated quality of the wastewater using the RSL Membrane is a significant improvement (i.e < 5 ppm oil and < 1 NTU in clarity vs > 20 ppm oil and > 15 NTU in clarity for the DAF technology).

Table 3 OPEX Cost Comparison for Industrial Water Treatment DAF vs RSL

		Fixed Site - $ USD /m3		Mobile-$USD/m3	
		DAF	RSL	DAF	RSL
Labor		$0.322	$0.049	$0.322	$0.194
Subsistance		$0.032	$0.016	$0.032	$0.016
Maintenance		$0.014	$0.061	$0.014	$0.061
Powder		$0.000	$0.189	$0.000	$0.189
Coagulants		$0.119	$0.000	$0.119	$0.000
Peroxide		$0.265	$0.265	$0.265	$0.265
Polymer		$0.256	$0.000	$0.256	$0.000
Fuel		$0.000	$0.000	$0.095	$0.095
Air Compressor		$0.015	$0.015	$0.015	$0.015
Generator		$0.000	$0.000	$0.013	$0.013
Electricity		$0.028	$0.014	$0.000	$0.000
Sludge disposal		$0.378	$0.126	$0.680	$0.227
Sub Total		$1.427	$0.733	$1.808	$1.073
Contingency	10%	$0.143	$0.073	$0.181	$0.107
Total Cost		$1.569	$0.807	$1.989	$1.180