21

Economics of membrane treatment process

Mark Wilf*

21.1 Cost components

Composition of water cost in membrane desalination system will depend in some extend on method of project delivery. For example, water cost could have a different structure in a turn key project and different in a system that is being developed by a private entity as design build operate (DBO) project. Although, process reliability and operating cost is important in both cases, usually the turn key project is designed and built to conform to standards imposed by the client. This could include use of equipment type being used in other systems operating by the client or configure the units to provide high level of convenience for the operators. In DBO method of delivery, the design–operator of the plant has more freedom to implement cost saving measures, he carry full responsibility for system operation during the duration of the operating contract.

Product water cost is contributed by capital cost and operating and maintenance (O&M) cost, where each one is a composite of the following components:

Capital cost

- Project development cost
- Project engineering services
- Direct construction cost

^{*}Director, Membrane Technology, Tetra Tech Inc., 10815 Rancho Bernardo Rd., San Diego, CA 92127, USA e-mail: mark.wilf@tetratech.com

- Project financing cost
- Contingency

O&M Cost

- Variable O&M cost
 - Power
 - Chemicals
 - Replacement of membranes and cartridge filters
 - Concentrate and waste disposal
- Fixed O&M cost
 - Labor
 - Maintenance
 - Regulatory monitoring
 - Indirect O&M cost

In more details the capital cost is composed of direct cost, directly related to system construction and indirect cost originated from financial and administrative activities within the project.

Representative structure of capital cost components is listed below:

Direct cost

- Site preparation and building
- Intake and outfall (brackish wells and concentrate disposal)
- Pretreatment
- RO trains
- RO membrane elements
- Piping
- High pressure pumps and power recovery turbines
- Electrical (MCC)
- Permeate post-treatment, storage and delivery
- Membrane cleaning system
- · Instrumentation and control system

Indirect cost

- Contingency
- Engineering
- Owners cost
- Interest during construction

Cost of wastewater reclamation system is a composite of direct cost of treatment steps used in the process and indirect cost of engineering and project management. The cost of wastewater reclamation project tend to be much higher then the cost ob brackish system of a similar capacity. The wastewater reclamation system includes additional treatment steps. In addition to RO unit,

Ch. 21 Wilf / Economics of Membrane Treatment Process

TABLE 21.1

Cost of GWR facility, Orange County, CA.

Construction contracts	Estimated cost, \$M
Microfiltration, reverse osmosis, UV and hydrogen peroxide disinfection system	305,3
21 km (13 mile) pipeline from Fountain Valley to Anaheim	64.2
Barrier facilities	17.1
GRW phase one facility	20.6
Integrated information system, wells, workshop, insurance	16.9
Design	30.9
Construction management	13.8
Administration	15.6
Program contingency	2.5
Total	486.9

it includes membrane filtration pretreatment unit and extensive product water disinfection unit. The RO unit operates at lower flux than the brackish system, therefore, larger number of RO membrane elements and pressure vessels is required. Although, this is a low pressure process and regular construction materials could be used for piping and components, system cost could be close to cost of seawater desalination system of similar capacity.

The cost of Ground Water Replenishment System at Orange County California, as reported by Orange County Water District [1] is listed in Table 21.1. The system includes 310,000 m³/day (82 MGD) membrane microfiltration pretreatment unit followed by 265,000 m³/day RO unit and similar capacity advanced oxidation process (AOP) unit.

21.2 Calculation of components of product water cost

The components of O&M cost belong to two categories: variable and fixed cost The variable cost is related to quantity of product water produced and on line time. The fixed components of operating cost represent fixed periodic expenses required to maintain plant operating status.

The capital cost contribution to product water cost represents amounts paid to recover capital spent on project development, according to Eq. 21.1.

Interest charges =
$$I + i/[(1 + I/100)^n - 1]$$
 (21.1)

Where: I is interest (%) and n-projected system useful life (years)

Example #21.1

Calculation of capital cost.		
System product water capacity, m ³ /day (MGD)	40,000	(10.6)
Total project cost, \$	30,000,000	
Interest rate, %	6.0	
Projected system life, years	20	
Plant load factor	0.95	

Interest charges: $6+6/[(1+6/100)^{20}-1] = 8.72\%$

Contribution of capital cost to water cost: $(30,000,000 \times 8.72/100)/(40,000 \times 365 \times 0.95) = \$0.189/m^3 (\$0.71/kgallon)$

Operating cost components will include:

Chemicals

- · Chemicals used in membrane pretreatment system
 - Flocculant
 - Chlorine
 - Chemicals for CIP
- Chemicals used in the RO system
 - Acid
 - Scale inhibitor
 - Ammonium chloride (if ammonia concentration level is too low)
 - Chemicals for CIP
- Chemicals for product water treatment
 - Caustic
 - Hydrogen peroxide (if AOP is used)
 - Chlorine
 - Ammonia (to form chloramines)

Cartridge filters replacement

Membrane replacement (MF/UF)

Membrane replacement (RO)

Power

- Raw water delivery
- Pretreatment
- High pressure pumps

Permeate pumps
Auxiliary
Maintenance and spare parts
Operation (labor)
Monitoring and reporting

The cost structure of wastewater reclamation plant that utilizes membrane technology differs from a brackish RO plant. The pretreatment in wastewater reclamation plants is more extensive, as it includes membrane filtration vs. cartridge filtration in brackish plants. The post-treatment, in addition to CO_2 removal and alkalinity adjustment, could include advanced oxidation process (AOP), applied to break down micropolutants (pharmaceutical and personal care compounds) in the product water.

Additional cost components are contributed by extensive monitoring of product water quality, which could be either imposed by local health regulations or implemented by the plant operating entity as a safety measure

21.3 Present worth value

Various alternatives of system configuration or operational approach is evaluated based on p[resent worth (PW) value. The calculation of PW value is conducted to determine cost beneficial alternatives among process design or various modes of operation. The PW express the present value of future payments required according to budget for system operation.

The PW can be calculated according to Eqs. 21.2 and 21.3, as provided in reference [2].

$$PW = A_1 \frac{1(1+e)^n (1+i)^n}{(i e)}, \, i\pi e$$
(21.2)

$$PW = \frac{nA_1}{(1+i)}, \, i = e \tag{21.3}$$

$$PW = A_1 \frac{1(1+i)^n}{i}$$
, $e = 0$ (no price escalation)

where: A_1 is the current value, n is projected system life, i is interest rate and e is price escalation rate

625

Exampl	е	#21	1.2
--------	---	-----	-----

Calculation of present value of selecte	ed components of the operating cost.
System product capacity	40,000 m ³ /day (10.6 mgd)
Recovery rate	80%
System on line factor	90%
Projected system life	20 years
Permeate flux rate	17 l/m ² /hr (10 gfd)
Element membrane area	37 m ² (400 ft ²)
Number of membrane elements	2646
Membrane element warranty period	5 years
Interest rate	5% (0.05)
Price escalation	3% (0.03)
PW factor (without price escalation)	12.46
PW factor (with price escalation)	15.96
Specific energy use	0.70 KWhr/m ³
	(2.65 KWhr/kgallon)
Cartridge filters capacity rating	4.0 m ³ /hr/1m catridge
	(17.6 gpm/cartridge)
Number of annual replacements	6/year
Acid dosing rate	20 ppm
Scale inhibitor dosing rate	2 ppm

Results in Table 16.9 illustrate contributions of various components to the operating cost. When evaluating individual contribution it is evident that changes of operating parameters or warranty terms, could affect the operating

Results of calculation of PW of selected components of operating cost.					
Cost component	Quantity per year	Unit cost, \$	Annual cost, \$	PW (w/o escalation), \$	PW (w escalation), \$
Energy, KWhr	9,198,000	\$0.10/kWhr	919,800	11,460,708	14,480,008
H2SO4	328.5 t	\$150/t	49,275	2,024,781	786,428
Scale inhibitor	32.9 t	\$2600/t	85,540	1,065,828	1,365,218
Membrane elements	530	650/element	344,500	4,292,470	5,498,220
Cartridge filters	3120	\$10/cartrige, 1m long (40")	31,200	388,752	497,952
Total			1,410,815	19,232,539	22,627,826

TABLE 21.2

Ch. 21 Wilf / Economics of Membrane Treatment Process

TABLE 21.3

Distribution of product water cost

Product water cost component	\$/m3	\$/kgallon
Capital cost, including land fee (25years@ 6.0% interest)	0.150-0.250	0.568-0.946
Electric power (\$0.060/kWhr)	0.050-0.080	0.189-0.302
RO membrane replacement (5 years membrane life)	0.010-0.012	0.038-0.0.45
Chemicals	0.010-0.020	0.038-0.076
Maintenance and spare parts	0.015-0.020	0.057-0.076
Labor	0.015	0.057
Other cost and contingency	0.020-0.030	0.038-0.113
Total cost	0.27–0.43	1.00–1.63

cost. If for example it would be possible to operate the RO system at higher feed pH at somewhat higher dosing rate of scale inhibitor, reduction of sulfuric acid dosing rate could provide overall reduction of operating cost. An increase of membrane warranty period from 5 to 7 years could significantly reduce membrane replacement cost contribution to the product water cost.



FIG. 21.1 Representative distribution of water cost components in low salinity RO applications.

Representative distribution of water cost in RO system treating low salinity feed is shown in Table 21.3 and Fig. 21.1.

References

- 1. Publication of Orange County Water District
- 2. A. Badiru, Engineering Economics http://ef.engr.utk.edu/ef402-2007-01/eng_econ/econrevnotes.pdf