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Economic Study for Green Nanoceramic Membrane Production

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Abstract

This research evaluates the cost of manufacturing nanoceramic membranes unit based on waste produced from ceramic industry. Membrane system is cost competitive with conventional and advanced vehicle membranes to gain the market-share required to influence the environment and reduce the cost of the membrane units for water treatment. This study depends on conceptual design for ceramic membrane production process and the estimated housing for these membranes. The economic study indicates that production of ceramic membranesusing recycling waste from ceramic industry reduced the cost of membranes filter to be 2.2 $/m^2$ of ceramic membrane. While the economic calculations indicate that the original capital investment of small project in this side will be recovered after approximately one year.

Keywords:Water security, Ceramic wastes, Ceramic membrane, Economic study.

1. Introduction

In fact, water shortage is one of the key challenges to the Egyptian government, so it is important to find an alternative to overcome that problem. Water desalination is one of the most attracting solutions to resolve the problem of water scarcity [1]. Membrane technology is a suitable technique for water treatment. Membrane could be classified according to used raw material into organic membrane such as polymeric membrane, and inorganic membrane as ceramic membrane [2–3]. Ceramic membrane is prepared from inorganic ceramic materials such as titania, zirconia, and alumina. Generally, Ceramic membrane consists of numerous layers of one or more ceramic materials [4]. Recently, ceramic membrane became one of the best significant ceramic products as of their various applications. Many studies were carried out to prepare ceramic membranes with adjusted properties by changing in used raw materials [5–6] or incorporating waste with the production procedure [6–15]. The suitable waste might be invaluable waste and supporting reducing pollution with eco-friendly aspect and economic condition [7].

Ceramic industry is considered one of the principal industries in Egypt. However, wastes generated from this industry are becoming an increasing environmental problem [8]. The increasing of ceramic waste amount although the safety measures were forced the world to adjust and control waste management. Hence, these wastes must be controlled thanks to active research fields, which attracted many disciplines for instance research of environment. Many efforts were carried out to combine/incorporate such wastes in ceramic forms for minimizing the formed wastes along with keeping natural resources [9–10]. Ceramic wastes incorporation was proposed with the purpose of reducing the energy requirements and production cost. For instance, some researchers have incorporated ceramic wastes as replacement of coarse aggregates in concrete [11–12]. The fabrication of ceramic membranes from industrial ceramic waste has been taken in some research [13–14].

The purpose of this paper is to identify the cost of portal ceramic membrane system. A prototype

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unit for ceramic membrane production has been designed, to facilitate production of large size of nanoceramic membrane, and the preliminary economic study has been proposed.

2. Conceptual Design

The design procedure includes design of membrane and its support. The economic study is based on the following principles:

a) Develop a productive facility of 20000 ceramic flat membrane sheets /month (240000 CM/year) capacity for feed of raw materials 1 ton/month. Or 2400 CM/year for feed of raw materials 10 kg/month. The flat ceramic size (1 cm thickness x diameter 5 cm).

b) The facility is working 340 d/year, 8 h/day for 1 shift of 8 h.

c) The production rate 1000 ceramic membrane (CM)/day for feed of raw materials 1 ton/month.

d) The maintenance of machines will be carried out monthly.

3. Estimation of capital and processing cost

3.1 *Capital Cost*

Table (1) illustrates prices of individual apparatus [15–19].Fixed capital cost greatly depends on total equipment cost. Table (2) shows the detailed fixed capital cost parameters [15–19].

3.2. Operating Cost

Operating cost consists of raw materials, maintenance, and labour costs. The total monthly salaries for operating labour are displayed in Table (3).

Table (1): Approximate equipment prices [15–19]

Apparatus	Quantity	Description	Price ($)	Size
Storage Tank: Raw material	1	• 316-L Stainless steel • Shop fabricated vessel with angle legs	1000	10 m^3
Storage Tank: NaOH 10 M	1	• 316-L Stainless steel • Shop fabricated vessel with angle legs	1000	10m^3
Storage Tank: HCl 0.1 N	1	• 316-L Stainless steel • Shop fabricated vessel with angle legs	1000	10m^3
Storage Tank: Polymer PVA solution with 4% concentration	1	• 316-L Stainless steel • Shop fabricated vessel with angle legs	1000	10m^3
Storage Tank: Distilled water	1	• 316-L Stainless steel • Shop fabricated vessel with angle legs	1000	10m^3
Storage Tank: Final treated powder	1	• 316-L Stainless steel • Shop fabricated vessel with angle legs	1000	10 m^3
Mixer	5	• LCD Display of Speed & Torque • Propeller in SS 316, Digital Speed indicator & speed regulator. • Portable Clamp and Flanged Mounted Mixers	15000	2 × 25 m^3 3 × 10m^3
Membrane Holders	1	316-L Stainless steel	1000	
Autoclave	1	• Operating Temperature: 200 – 500°C • Capacity: 50–70 kg/cycle	200000	
Filter	3	Separate powder from water	2500	
Dryer	3	Fluid: Compressed Air/Gas	12000	
Ball Mill	1	Automated System	20000	
Extruder	1	• With different modules **Automatic Operation with Printer** • Automatically and continuously monitor and record dates, time, load, I.D no. and Operating parameters.	90000	

		• LCD Display		
Press	1	• One automated 100 MPa Hydraulic press, with multi ended pressing • Max. Capacity: 50 MPa (Tolerance +/- 1 Ton or 12-15 Kg/sq.cm.) • Max. Ram Stroke: 15 mm • Daylight: 90 mm • Pump type: automatic operated. • Platen Size: 1 m	85000	
High Temperature Furnace	1	• Maximum working temperature 1600 degree Celsius, programmable. • Full size Pressure Relief Valve • Pressure indicator locally mounted • Control Power On/Off Switch	104000	
Die	Many	Die Body: Hardened Alloy Steel - hardened & ground with vacuum nozzle with different shapes and sizes.	20000	
Packing System	1		5000	
Storage Coding System	1		1000	
Membrane Storage	1	Shelving Unit	5000	
Total Cost			**566500**	

Table (2): Fixed capital cost for ceramic membrane production [15–19]

Items	**Cost ($) Input 1000 Kg/month**
1-Purchased Equipment (PCE)	566500
2- Purchased Equipment Installation (15%PCE)	84975
3-Instrumentation and Controls(5% PCE)	28325
4- Piping (10% PCE)	56650
5- Electrical (10% PCE)	56650
6-Building Including Services (10%PCE)	56650
7-Yard Improvements (2.5% PCE)	14162.5
8-Service Facilities (10% PCE)	56650
9-Land (2.5%PCE)	14162.5
Total Direct Plant Cost (DPC)	**934725**
10- Supervision and Engineering (5%PCE)	28325
Total Direct and Indirect Plant Cost	**963050**
12-Contractors Fee 2.5% (DPC)	46736.5
13-Contingency 5% (DPC+IDC)	48152.5
Fixed Capital Investment (FCI)	**$1057939**

Table (3): Monthly plant labor costs (OPC)

Item	Cost (LE/ month)
1. Engineer	5 × 2000
2. Chemist	3 × 1750
3. Workers Supervisor, and Lab Technician.	3 × 1500
4. Skilled Labor	10 × 1250
Total in Egyptian pound	**32250**
Total in USD (1 USD = 20 Egyptian pound)	**1612.5**
Year ($) labor Cost/ Year	**19350**

The raw materials cost is one of the main cost items in membrane production. The total production cost and raw materials are illustrated in Table (4). The total production cost is calculated supposing that the raw materials cost is around 50-100% of the production cost/product unit, it supposed to be 75%.

Table (5) shows the estimation of total processing cost. The operating labor cost is assumed equal to the utilities. Repairs and maintenance are supposed 5% of the apparatus price (Table 1).

Operating supplies is assumed 15% of repairs and maintenance. The laboratory charge is supposed 10% of the operating labor cost [20]. Fixed charges contain depreciation that is assumed 10% of (FCI), local taxes represent 2% of (FCI) and insurance that represents 1% of (FCI). Furthermore, general expenses combine of administrative costs that are calculated 20% of (OPC). Selling costs and distribution is an equal OPC and development and research cost are about 2% of OPC.

3.3 Payout Period (τ)

Payout period is "defined as the shortest length of time required to get back the original capital investment in the form of the cash flow to the project". The estimation of payout period describes that the original capital investment will be recovered after approximately one year. Assuming the surface life of the equipment is 25 years. The payout period has been determined from equation (1) [20]:

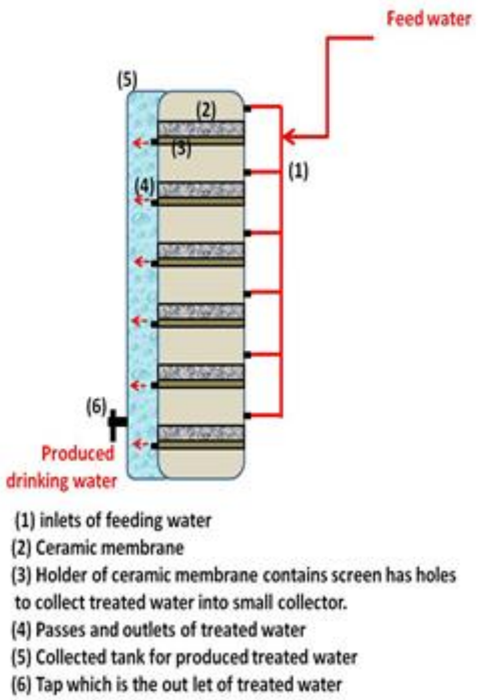
$$\tau = \frac{FCI}{x+y} \qquad (1)$$

Where:

- Fixed capital investment (FCI) in dollars= 1057938.75 $
- Working capital investment (0.2 FCI)= 211587.75 $
- Total capital investment = 1269526.5 $
- Total production cost (TPC)= 526259.118 $
- Total Income =total capital investment+ TPC= 1795785.62 $
- Annual equipment depreciation= 26959.4513 $
- Gross earning cost =Total Income – TPC= 1269526.5 $
- Net Profit = Total Income –All Expenses = 1717603.21 $
- General (all expenses)= 78182.4086 $
- Annual cash flow= (1 – Tax Rate) [(Total Income) – (All Expenses)] + Depreciation= 1026248.41$
- Average annual profit= Annual cash flow – Annual depreciation cost= 999288.962 $
- Payout Period= 1.03 year

From the economic study the price of produced ceramic membrane = 2.2$/m^2

The estimated housing of flat ceramic membranes is shown in Figure (1). Which has PVC housing, and the flat ceramic membrane are placed on perforated screens with collector from bottom to collect the treated water from each ceramic membrane. The feed water enters in channels from the top of the housing each channel connects to one membrane, where the feeding flow through the ceramic membranes then the treated water is collected from each bottom of the holders of the ceramic membranes which have collecting channel to collecting tank. Cross flow mode was used in this study because this mode reduces the concentration polarization phenomena, which leading to reduce the fouling of membranes and reducing washing or backwash for the membrane unit [20–21]. For cleaning the back wash can be carried out weakly to clean the ceramic membrane surface. However, the tubular ceramic membrane by the same raw materials was fabricated which can be applied in commercial housing as shown in Figure (2).



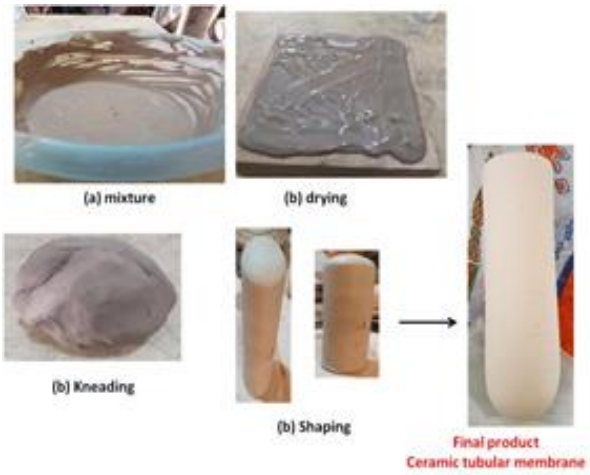


Fig.(1): Estimated flat ceramic membrane housing Fig.(2): Fabrication of tubular ceramic membrane

Table (4): Raw materials cost of ceramic membrane production per year

Chemicals	Unit Cost ($/ Unit of Chemical)	Dosing Rate	Specific Cost ($)
Alumina Waste	1 ($/Kg)	5 gm	0.005
NaOH (8–10 M)	10 ($/L)	40 mL	0.4
HCl (1N)	10 ($/L)	100 mL	1
Distilled Water	20 ($/L)	200 mL	4
Polymer {PolyVinyl Alcohol (PVA)}	1 ($/Kg)	0.75 gm	0.00075
Raw materials cost per one membrane fabricated membrane			5.41
Total raw material cost for produced ceramic membrane (CM) per year (240000 CM/year)			**1298400**

Table (5): Estimation of Total Processing Costs [15–19]

Items	Input (1000 Kg/month)
Manufacturing Cost = {Direct Production Costs + Fixed Charges + Plant Overhead Costs}	
Direct Production Costs	**Cost, $**
Raw materials	129840
Operating labor (OP)	19350
Direct supervisory and clerical labor (0.1 OP)	1935
Utilities (0.1 OP)	1935
Maintenance and repairs (0.1 FCI)	105793.875
Operating supplies (0.1 Maintenance)	10579.3875
Laboratory charges (0.1 OP)	161.25
Direct Production Costs	**269594.5125**
Fixed Charges	

Depreciation (0.1 Production Cost)	26959.45125
Local taxes (0.1 FCI)	105793.875
Insurance	5289.69375
Total Fixed Charges	**138043.02**
Plant overhead costs (0.15 Direct Production Costs)	40439.17688
Manufacturing cost (Direct Production Costs + Fixed Charges + Plant Overhead Costs)	448076.7094
General Expenses = Administrative Costs + Distribution and Selling Costs + Research and Development Costs	
Administrativecosts (0.04 Total Product Cost)	10783.7805
Distribution and selling costs (0.1 Total Product Cost)	26959.45125
Research and development costs (0.1 Total Product Cost)	26959.45125
Financing (0.05 Total Product Cost)	13479.72563
Total	**78182.40863**
Total Product Cost (TPC)	
TPC = Manufacturing Cost + General Expenses	**526259.118**
Price of Ceramic Membrane (CM)	**2.192746325 $/m^2**

4. Conclusion

The economic study indicated that the price of produced ceramic flat sheet membrane was 2.2 $/m^2.The produced ceramic membranes using waste powder from ceramic industries provides a cheaper and economical substitute for the commercial membranes. This economic study indicates that the establishment of small factory to produce this kind of ceramic membranes can recover the original capital investment after approximately one year and the average annual profit will be 999288.962 $. Two kinds of housing can be estimated for this kind of produced ceramic membranes depends on the shape for flat sheet ceramic membranes and tubular ceramic membranes.

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