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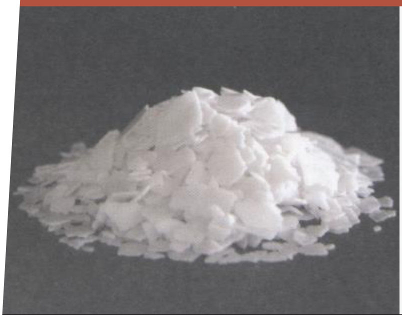
CHLORINE INDUSTRY:



ECONOMICS OF CONVERSION IN INDIA

CHLORINE INDUSTRY:
ECONOMICS OF CONVERSION IN INDIA

Toxics Link
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Study by:
Toxics Link, New Delhi

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TOXICS LINK

Toxics Link is an environmental organization, engaged in disseminating information to help strengthen campaigns against toxic pollution, provide cleaner alternatives and bring together groups and people concerned with, and affected by, this problem.

Toxics Link
for a toxics-free world

"We are a group of people working together for environmental justice and freedom from toxics. We have taken it upon ourselves to collect and share information about the sources and dangers of poisons in our environment and bodies, as well as about clean and sustainable alternatives for India and the rest of the world."

This current report was undertaken in the wake of the global phase out of mercury from chlorine and caustic soda producing Chlor-alkali plants. The challenges were brought to light in the voluntary transformation of mercury based electrolysis cell with membrane cell in the country.

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ZERO MERCURY WORKING GROUP

zero Hg
mercury working group

The Zero Mercury Working Group (ZMWG) is an international coalition of more than 94 public interest environmental and health non-governmental organizations from 52 countries from around the world formed in 2005 by the European Environmental Bureau and the Mercury Policy Project.

The ZMWG strives for zero supply, demand, and emissions of mercury from all anthropogenic sources, with the goal of reducing mercury in the global environment to a minimum. Its mission is to advocate and support the adoption and implementation of a legally binding instrument which contains mandatory obligations to eliminate, where feasible, and otherwise minimize, the global supply and trade of mercury, the global demand for mercury, anthropogenic releases of mercury to the environment, and human and wildlife exposure to mercury.

www.zeromercury.org
Contact: mercury@eeb.org

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Contents

List of Tables and Figures

Tables

Figures

Executive Summary

'Chlor Alkali Plants' which manufactures chlorine, hydrogen gas and sodium hydroxide or caustic soda by applying direct electric current to a brine (water and salt) solution, dates back to 1959 in India. The various technologies, which are being used in the Chlor-alkali industries, include mercury, membrane cell and diaphragm cells. Indian industries, initially adopted the Mercury cell technology and many years later made a conscious decision to shift to Membrane cell technology, which can be attributed to environmental concerns and economic gains as two of the most significant drivers.

The Indian Chlor alkali sector was predominantly using mercury based technology, supplied by a German technology provider UHDE and an Italian Company DE NORA. The industry was ageing and its profitability was also being affected adversely, coupled with the pressure of stricter environmental norms led to a strategic decision on the part of the industry. The industry and government (MOEF) collaboratively formed the Charter on Corporate Responsibility for Environmental Protection (CREP) in 2003 and decided to voluntarily make a technological shift towards a mercury free technology. The industry announced that slowly and gradually it would shift their existing plants to an alternate technology and complete the process of shifting by 2012. Initially, UHDE started providing membrane cell based technology; though later on, a Japanese company, named Asahi Kasei Chemicals Corporation, introduced membrane cell based technology in India.

A total of 36 plants are in the operational stage with total production capacity of approximately 3.2 million MTPA of caustic soda, out of which, approximately 3.04 million MTPA production capacity is under membrane cell technology and the rest 0.16 MTPA production capacity is under the mercury cell process. According to a discussion with AMAI on July 2011, CREP implementation and conversion is expected to incur an investment of up to 15000-16000 million rupees. In addition to CREP recommendations, the other major factors behind technology shifting in India include:

a.) Economic benefits due to net energy savings of 24% by shifting from mercury to membrane cell technology;

b.) Expansion of existing plant capacity;

c.) Addressing environmental concerns such as:-

    1. Generation of completely mercury free gas or other end products, thereby causing no mercury contamination;
    2. Reduction of the amount of carbon foot print;

Two separate case studies have been done to establish the economic benefits of technology shifting; the study has considered a 300 TPD capacity plant which is in operation for a total of 350 days in a year and a capacity utilization of 75%. The data inputs have been sourced from various existing plants in operation in the country and are close to the actual figures. The study has revealed the following findings:

- Net annual savings in energy cost is 6930 million rupees approximately;
- Payback period for conversion of the plant without any capacity expansion (300 TPD) would be seven years;
- Payback period for conversion of the plant with 20% capacity expansion (360 TPD) would be five years;

In addition to the above mentioned economic benefits, some other miscellaneous benefits can also be achieved, which include:

- Avoidance of all those costs associated with regulatory compliances to be met in case of mercury cell technology;
- Decrease in legal liability and improvement in community relations;
- Improvement in public/investor image of the company and improved attractiveness of the company as a place to work (employee satisfaction) etc;
- Good quality, mercury free subsidiary products as it has demand in the downstream sector, especially in food or pharmaceutical sector.

1. Introduction

Chlor Alkali Plants in India dates back to 1959, when Dhrangadhra Chemical Works (DCW), a reputed Soda Ash factory commissioned a new Chlor-alkali plant at Sahupuram in the southern state of Tamil Nadu. The plant manufactures chlorine, hydrogen gas and sodium hydroxide or caustic soda solution. The Chlor alkali process is the main process for manufachuring of caustic soda and chlorine production all over the world. The process involves the application of direct electric current to a brine (water and salt) solution that results in producing caustic soda and chlorine. Chlorine is produced and collected at the positively charged electrode (anode), whereas the hydrogen and caustic soda are produced and collected at the negatively charged electrodes (cathode). India has a large number of these plants and many are located close to the coast line due to the easy accessibility of sea water. The state of Gujarat in India has the maximum number of such plants. These plants belong to the category of large industries that attract investors on a large scale. The Indian Chlor alkali industry has overall performed well even though it faced some difficult times while negotiating the global economic recession in 2008.

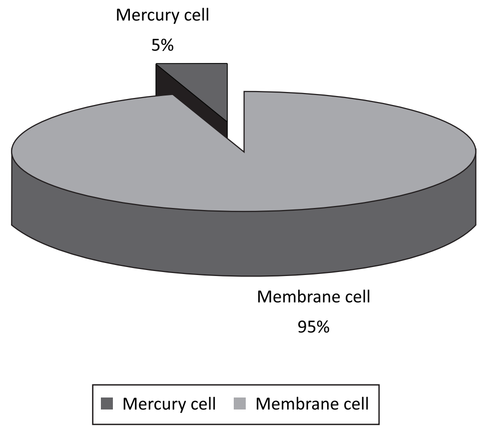
In its initial phase the industry adopted the Mercury Cell Technology and many years later made a conscious decision to shift to the Cell Membrane Technology. The path and process charted during this shift is interesting and can be attributed to environmental concerns and economic gains as two of the most significant drivers behind the shift.

The main production process used for chlorine is electrolysis, i.e. passing an electric current through brine (salt water – mainly sodium chloride or, to a lesser extent, potassium chloride, KCl). The major end products obtained in the process are caustic soda (sodium hydroxide) (or potassium hydroxide for KCl production), hydrogen and chlorine. These products are considered reactive; therefore technologies have been developed to separate them within the electrochemical reactor.

The various technologies, which are being used in the Chlor-alkali industries, include mercury cell, membrane cell and diaphragm cells. The function of each of these technologies is to keep the chlorine separated from the hydrogen and caustic soda.

In India, mercury and membrane cell technologies are widely used for caustic soda production, as the diaphragm cell process was not being able to find its market in the country. The following (**Figure 1-1**) shows the percentage share of the two different technologies in terms of the current production capacity in India in the year 2011.

Figure 1-1: Technology share in India as on date



1.1 Evaluation of Technologies

Three types of technologies which have been used in different regions across India, with varying degrees of success include Diaphragm technology (U.S based), Mercury Cell technology (Europe) and Cell membrane technology (Japan).

The Indian Chlor alkali sector was predominantly using mercury based technology, supplied by a company that provides German technology, UHDE and they enjoyed a good relationship with the industry. UHDE also had an office in India and continues to have one in Mumbai. Another Italian Company, named DE NORA was also supplying their mercury based cell technology to India through the concept of Phased Manufacturing Programme (PMP/PMT). It was post 1990 that the Indian economy started opening up which led to the welcoming of new technologies and partnerships. During the post economic liberalization period, the Chlor Alkali industries initiated the process of a technology shift on account of environmental concerns and an ageing industry. UHDE in conjunction with De Nora later established a joint venture Company UHDE and Uhdenora, which was then the only provider for membrane cell based technology to the industry. They enjoyed an almost monopoly status which was also one of the reasons for the technology costs being higher. It was much later that a Japanese company, named Asahi Kasei Chemicals Corporation, brought out their membrane cell based technology in India. Initially, the technology costs were approximately 15- 18 million rupees/ton, however as the technology evolved and as the volumes grew and multiple vendors entered the competition, a reduction in the cost of technology was observed. The membrane cell technology cost has gradually reduced to 10 million rupees/ton and experts suggest that currently, the cost has further reduced to only 8 million rupees/ton of caustic soda production. A quick glance at the cost reveals that the costs have almost reduced to half since the initial days of conversion of the first few units in India. There was also a marginal cost reduction in technology on account of reduction in duties levied by the government. In order to encourage a shift in technology and to address environmental concerns, the government of India reduced the import duties on cell membrane technology from 40% to 5%, thereby cutting down the overall cost. The current import duty continues to be 4% but now there are multiple vendors and a fair competition, leading to a lowering of technology costs.

A brief outlook

- Use of three different types of technologies;
- Wide use of Mercury and Membrane cell technology in India;
- Initial procurement of mercury as well as membrane technology from German based company, UHDE;
- Monopoly of UHDE in Indian market, is caused due to the lack of other suppliers & competitors, thereby leading to higher pricing of the technologies;
- Liberalization of the Indian economy and emergence of new technologies and partnerships;
- Emergence of new suppliers & technological evolution leading to subsequent reduction in cost;
- Government concessions on import duty for cell membrane technology;

The various technologies are described in this section are:

1.1.1 Mercury Cell Process

In this process, the mercury cell cathode comprises of a slowly flowing layer of mercury across the cell bottom. In this, sodium ions at the cathode are converted into sodium, which forms an amalgam with the mercury at the cathode. The amalgam reacts with water in a separate reactor called a decomposer, where hydrogen gas and a caustic soda solution of 50% concentration are produced. Chlorine, which is also produced as a byproduct in the process, is collected separately and then cooled, dried, compressed and liquefied. Mercury is pumped back into the cells. As the brine is usually re-circulated, solid salt is required to maintain the saturation of the salt water. The brine is first de-chlorinated and then purified by a precipitation-filtration process.

1.1.2 Membrane Cell Process

In the membrane cell process, the anode and the cathode are separated by an ion exchange membrane that selectively transmits sodium ion and some amount of water but restricts the hydroxyl ions from the cathode section into the anode section.

Diluted brine is fed into the anode compartment, where chlorine gas is generated and sodium ions migrate into the cathode section through the membrane. In the cathode section, hydrogen is evolved at the cathode, leaving behind hydroxyl ions, which along with sodium ions, producing caustic soda. The caustic solution leaves the cell with about 30-33% concentration. This 33% caustic soda is further concentrated to 50% at a later stage as per the market requirement. The chlorine gas, generated from this process contains some oxygen and must be purified by liquefaction and evaporation. The brine is de-chlorinated and re-circulated. Solid salt is usually needed to re-saturate the brine. After purification by precipitation-filtration, the brine is further purified with an ion exchanger.

1.1.3 Diaphragm Process

A diaphragm cell contains a porous diaphragm, which is used to separate two halves of the cell, to allow a flow of brine and to prevent chlorine and hydrogen gas from mixing. The brine is introduced into the anode compartment and flows through the diaphragm into the cathode compartment. Chlorine gas is formed at the anodes, whereas the sodium hydroxide solution and hydrogen gas are formed directly at the cathode.

A diluted caustic brine leaves the cell, after which the caustic soda must usually be concentrated to 50% and the salt be removed by an evaporative process. The salt separated from the caustic brine can be used to saturate diluted brine. It is estimated that, approximately three tons of steam is required for each ton of caustic soda. The chlorine gas generated contains oxygen and must be purified by liquefaction and evaporation. This process also uses asbestos which has serious environmental implications.

2. Background to Shifting Study

2.1 Shifting from mercury to membrane cell technology

The mercury cell process is one of the oldest processes for producing chlorine and caustic soda; however, it poses a serious threat to human health and the global environment. The United Nations Environment Programme (UNEP) has initiated a Global Mercury Partnership programme with an objective of protecting human health and the global environment from the release of mercury and its compounds. This is achieved by minimizing and where feasible, ultimately eliminating global, anthropogenic mercury releases to air, water and land. During this period all the mercury based Chlor-alkali plants in India were ageing and their plant life was gradually shortening. The increasingly stringent environmental regulations and decreasing profitability of these plants led to the shifting of the mercury cell process to membrane cell technology in line with the global trend.

Chlor alkali production units, being large companies require huge investments, for which money is sourced from financial institutions or by raising public money, in case the funds of the companies are insufficient. The industry being aware of the shareholders sentiments and their investment which require protection found one of the options available to make these companies more profitable, was to expand and adopt new technology. The industry took a very conscious decision of making a shift in the technology, so as to remain economically viable.

Various steps have been taken by Indian industries through commitment & voluntary initiatives for responsible care of the environment alongside the economic development of society. The formation of the Charter on Corporate Responsibility for Environmental Protection (CREP) is one such step, initiated by the Ministry of Environment and Forest (MoEF) and agreed on by Indian Chlor-alkali Industry. CREP came into force in the year 2003 with the Thirteen Points Time Bound Action Plan. From its' very outset the CREP for Chlor-alkali industries proved to be an instrument for drastically reducing mercury consumption and emission in the environment. Like other industries handling hazardous substances, mercury cell based Chlor-alkali plants are also facing pressure to shift towards membrane cell technology due to the hazardous effects of mercury. Conversion of mercury cell to membrane cell is the most important action point under this regulation and the Alkali Manufacturer's Association of India (AMAI), on behalf of all the Chlor-alkali plants of India, have agreed to make this conversion complete by the year 2012. A Task Force has also been constituted for continuous monitoring and a rigorous follow up to monitor the progress of the implementation of CREP Recommendations.

3. Emission Standards for Chlor-Alkali Plants

In India, the Chlor-alkali plants, which are operational, follow certain guidelines, specified by Central Pollution Control Board (CPCB). As per the Rules, G.S.R. 913(E), dt 24th Oct., 1989 under Environmental Protection Act (EPA) Notification, CPCB has issued certain emission standards for Chlor-alkali plants, which are given in the **Table 3-1.** CPCB has also issued certain waste water discharge norms for Chlor-alkali plants, under the EPA Notification (S.O. 844(E), dt., 19th Nov., 1986), which is explained in **Table 3-2.** Under this partnership program the government did not permit setting up of any new plant with mercury cell technology, also it did not allow capacity expansion of the existing plants without technology shifting.

Table 3-1: Chlor-Alkali (Caustic Soda) Emission Standards

Sl No.	Process	Pollutants	Emission limit (mg/ Nm^3)
a.	Mercury Cell	Mercury (from hydrogen gas holder stack)	0.2
b.	All processes	Chlorine (from hypo tower)	15
c.	All processes	Hydrochloric vapour and mist from (hydrochloric acid plant)	35

Source: Central Pollution Control Board

Table 3-2: Caustic Soda Industry – Wastewater Discharge Standards

Parameter	Concentration not to exceed Limits, mg/l (except for pH & flow)
Total concentration of mercury in the final effluent*	0.01
Mercury bearing wastewater generation flow	10 kl /ton of caustic soda produced
pH	5.5-9.0
*Final effluent is the combined effluent from Cell house, Brine plant, Chlorine handling, Hydrogen handling & Hydrochloric Acid plant	

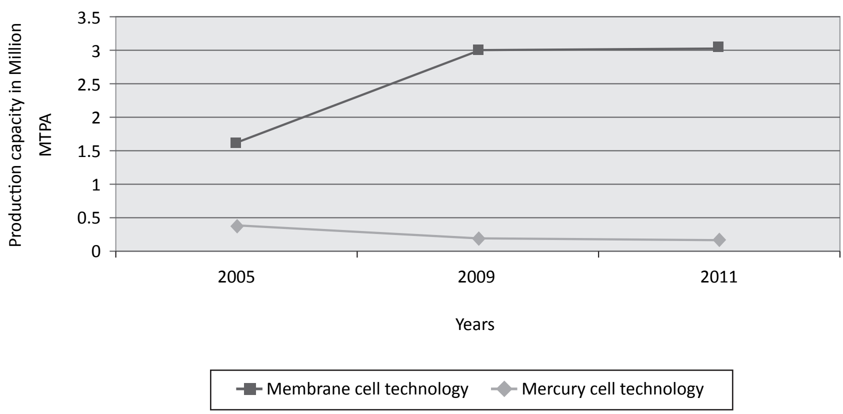
Source: Central Pollution Control Board

4. Current Indian Scenario

In Indian Chlor-alkali sector, the technology shift started with the CREP initiative, which dates back to March, 2003. Right from the very beginning, the Chlor-alkali plants had decided to complete the shift by 2012.

In India, a total of 36 Chlor-alkali plants are in operational condition in various states with a total production capacity of approximately 3.2 million MTPA of caustic soda. Out of this production capacity, currently approximately 3.04 million MTPA is being produced by membrane cell technology; whereas the rest of the production capacity (0.16 MTPA) is being produced by mercury cell technology. In 2008, the total production capacity was 3.2 million MTPA, out of which the mercury and membrane based production capacity was 0.2 million MTPA and 3.0 million MTPA respectively. In 2005, the total production capacity of caustic soda was 2 million MTPA, out of which 1.6 million MTPA was by membrane cell technology, whereas the 0.4 million MTPA production capacity was by mercury cell technology. The following graph in **Figure 4-1** shows a gradual shifting trend in the production capacity from mercury to membrane cell technology.

Figure 4-1: Trend of Technology Shifting



Among a total of 36 plants, 29 plants shifted to membrane cell technology by the year 2009. In the year 2010, two plants shifted to membrane cell process that are located in Orissa (shifted in November, 2010) and Gujarat (shifted in December, 2010) respectively. Till 2009, Indian Chlor-alkali plants had made an investment of approximately 12600 million rupees (***source: AMAI***) towards the implementation of the CREP programme and for a shift towards the new technology. The following **Table 4-1** shows a detailed break up of this investment made by the industries.

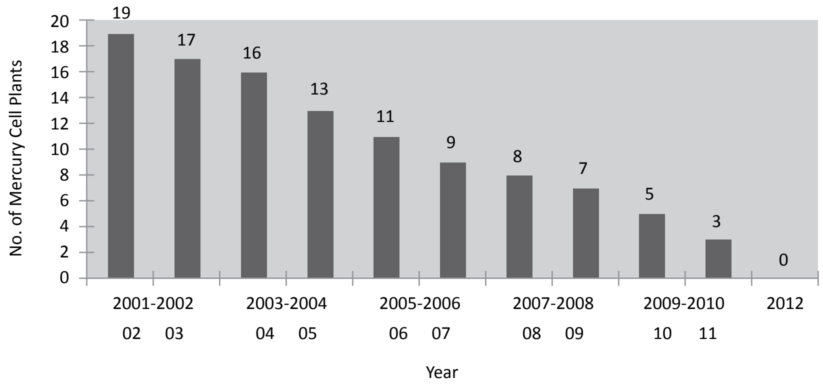
According to the latest discussion (July, 2011) with AMAI (Alkali Manufacturer's Association of India), this investment towards CREP implementation and conversion is expected to go up to 15000-16000 million rupees.

A gradual trend of technology shift and subsequent change in the mercury consumption pattern in the Chlor-alkali plants of India is shown in the following graphical representation, **in Figure 4-2** and **Figure 4-3** respectively.

Table 4-1: Investment made by Industries for CREP Programme & Conversion

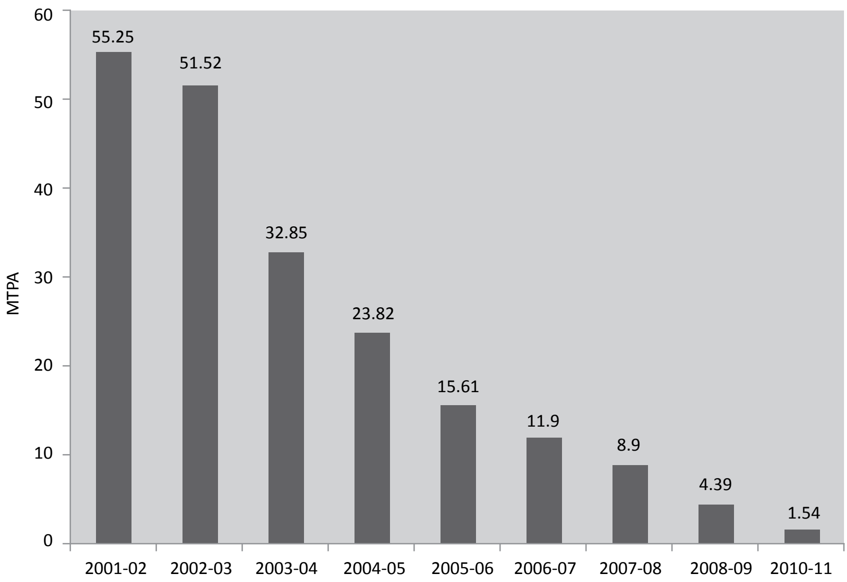
S.No.	Name of the unit	Investment for implementing crep programme (Rs. Million)	Investment for conversion (Rs. Million)	Date of conversion
1	Atul	7.5	NA	December, 2010
2	Aditya Birla Chem.	13.6	1211.7	February, 2006
3	Chemplast Sanmar	26.51	1500	March, 2007
4	DCW	44.2	(Est. 1950 million)	April, 2008
5	DSCL	5	840	March, 2005
6	Durgapur	14.148	1000	November, 2008
7	Grasim	25.4	2000	September, 2006
8	Hindustan Heavy	Fixed - 6.3, Operating -13.5 pa	Plan not given	Latest by 2012
9	Hindustan Paper	Data not available	NA	2010
10	HJI - Prop : Gmmco Ltd.	27.49	NA	2012
11	Jayshree Chemicals	22.4931	250	November, 2010
12	Kanoria Chemicals	Fixed - 50.3, Operating -2.2 pa	1920	Phase-I conversion in 2006, phase-II conversion in 2008 & Full Coversion by March, 2012
13	Solaris Chemtech	22.112	NA	2012
14	Standard Industries	NA	NA	Unit Closed in May,2004
15	The Andhra Sugars	17	100	30.06.2005
16	TCCL	0	500	Dec,2006
	Total	**376.2531**	**12171.7**	
		Approx.400 million rupees	**Approx.12200 million rupees**	

Figure 4-2: Mercury Phase-out trend in Chlor-alkali plants in India



Source: Alkali Manufacturer's Association of India (AMAI)

Figure 4-3: Mercury consumption by Chlor-alkali plants in India



Source: Alkali Manufacturer's Association of India (AMAI)

In India, two plants are still operating with mercury cell technology, which either have decided to close down their operation or to shift to the membrane cell process by 2012. **Table 4-2** shows a glimpse of the current status of these plants.

Table 4-2: Status of Mercury Cell based plants in India as on July, 2011			
Sl No.	Name of Plant	Current Status	Future plan
1	Hindustan Heavy Chemicals	Production stopped in November 2010	-
2	Hindustan Paper of Nagao and Cachar	Currently operating at 60 TPD capacity	Will reduce to 30TPD by 2012
3	Hindustan Jute Industries	Shifted half of their plant to membrane cell process	Rest will convert by 2012
4	Solaris Chemtech Industries Ltd. of Goa	Not yet decided, whether to sell it off or convert it. Currently it has stopped production	In case of further continuing the operation, it would be converted by 2012
5	Kanoria Chemicals & Industries Limited, U.P	Taken over by Aditya Birla Group, which has stopped mercury cell operation in 2011	Initiated the process of conversion & will be converted by 2012

Source: Alkali Manufacturer's Association of India (AMAI)

4.1 Factors influencing technology shifting

The investment costs of conversion from mercury to membrane technology is a highly variable factor, which have been identified through conversations with AMAI and companies that have already converted or are planning to convert and also the technology experts who have been involved in these shifts.

Indian Chlor-alkali plants have proven the benefits of the shifting from mercury to the membrane cell process, which actually affects the production cost of caustic soda and chlorine. In addition to the CREP recommendation, Indian Chlor alkali plants have some major reasons for shifting to membrane cell technology, which are as follows:

d) Reduction in energy consumption & its cost

e) Expansion of existing plant capacity

f) Addressing environmental concerns

a) Energy prices and efficiency

Given the fact that Chlor-alkali production relies on energy intensive electrochemical technology, approximately 70-75% of the production cost primarily comprises of energy costs in case of mercury cell based technology. On the other hand in case of membrane cell technology, there is a significant reduction in energy consumption and the total energy cost only constitutes 60% of the production cost. Therefore, immediate reduction of production cost of about 24% can be achieved by technology shifts.

In India, the cost of the average unit of electricity is high with an average cost of Rs.5/unit. As per the facts taken from a study on Green Rating Project (***refer: Annexure II***), carried out by the Center for Science & Environment (CSE), energy requirement for the mercury cell process is approximately 3000 kWh/Ton (kilowatt hour per tone) of caustic production, where as in case of the membrane cell process, it goes down to 2200 kWh/Ton.

On the basis of the information obtained, it has been observed that approximately 3000 kWh/Ton of energy are required for the production of caustic soda by using mercury cell technology. Considering the current unit electricity rate of Rs.5, the electricity cost for producing one ton of caustic soda is approximately Rs.15,000/-.

In case of membrane cell technology, the average specific energy consumption is approximately 2200kWh/Ton. Therefore, considering the unit electricity cost of Rs.5/unit, the total electricity cost for producing one ton of caustic soda is approximately Rs. 11,000/-. Thus, shifting to membrane technology would help in reducing the energy cost by Rs. 4000/-approximately. However, in the case of membrane cell technology, additional steam is required to concentrate the caustic lye from 33% to 48%, as it is demanded by almost every purchasing unit of caustic soda in India and it again demands an additional energy requirement of approximately 66kWh/ton (**Source:** Central Pollution Control Board; **Basis:** Rs.330/ton of caustic lye concentration and electricity price @ Rs.5/kWh). Therefore the membrane cell technology would require 2266kWh/ton of electricity, thereby leading to a net energy saving of 734 kWh per ton of caustic soda produce. The net savings of approximately 24% in energy will help in reducing the cost by Rs.3670 per ton. Therefore, reduction in energy requirement has a strong influence in the decision making process.

Case Study

In order to understand this issue of cost saving by lowering energy consumption, we have calculated the annual savings in energy cost by technology shifting, after discussions with the AMAI, technology experts and industrial expertise reached the following conclusions:

a. The capacity of the plant - 300 TPD
b. Capacity utilization – 75%
c. Working days a year – 350

In the case of shifting from mercury to membrane cell technology, a net energy saving of about 24% will be achieved, which will amount to Rs. 3670 per ton of caustic soda.

Total plant size: 300 TPD

Plant running capacity: 75%, i.e. 225 TPD

Plant running a year: 350 days

A. Energy requirement per day by mercury cell

: (3000*24) kW

: 72000 kW

Energy Cost per day @ Rs.5 per kWh

: (72000*5)

: **360000 rupees**

B. Energy requirement for membrane cell

Including additional steam per day

: (2266*24) kW

: 54384 kW

Energy Cost per day @ Rs.5 per kWh

: (54384*5)

: **271920 rupees**

C. Net energy cost savings per day

: (360000-271920) rupees

: 88080 rupees

D. Net energy cost savings annually

: (225 * 88080*350)

: 693, 63, 00,000 Rupees

: **6930 million rupees approximately**

In the case of membrane cell technology, the net savings in power reduction again goes down gradually, due to the current density. At the initial stage of the technology invention, the current density was lower, resulting in lower electricity consumption per ton of caustic soda produced, which results in lower operating costs. However, it demands more electrolyzer, thereby increasing the fixed cost.

On the other hand, as and when the technology was being developed, more caustic soda was produced from the same number of electrolyzers, but with higher current density, i.e. with higher electricity consumption. This cumulatively increases the operating cost and reduces the plants' fixed cost.

In Indian Chlor-alkali plants, high level of energy requirement has lead to the dependency on captive power plants. Out of the total Chlor-alkali plants in India, 99% plants are using the captive power, as the power sourced from the state electricity grid often causes interruption in production, thereby lowering the product quality. It has been observed that, for Chlor alkali plants, having their own captive power is less expensive, than depending on grid power. The dependency on captive power would ensure uninterrupted power supply and good quality end products. These captive power plants have an average capacity of 40MW and most of them use coal as fuel.

Initially, these captive power plants were run by residual fuel oil (RFO) or heavy fuel oil (HFO) that was less expensive; however, the increase in its supply cost led these plants to shift to gas based power generation. Gradually, the cost of gas also increased forcing the entrepreneurs to shift to coal based power generation. Most of the Chlor alkali production units are supported by coal based power generation units in India. This shift to coal based captive power supply would also result in a marginal saving, on account of efficient captive power generation cost in the overall assessment however is difficult to give any accurate figure.

b) Expansion of existing plant capacity

In the Indian scenario, most of the Chlor-alkali plants are a source of raw material for the associated industries; therefore the increase in market demand for end products (chlorine and caustic soda) establishes the need for increased production of either chlorine or alkalis.

In India, caustic soda is used as a raw material in rayon and pulp industries, aluminium, textiles, soap & detergents, fertilizers, refineries and petrochemicals industries. However, the demand for chlorine is usually less in India as it is mainly used as a raw material in PVC production and India is not very well-known for manufacturing PVC. Hydrogen is one of the bi-products of the caustic manufacturing process, which is used in Hydrogenation. - Shifting to membrane cell process gives mercury free hydrogen as a byproduct, which is a saleable product in the Indian market.

The demand for caustic soda and chlorine has been growing in the Indian economy, resulting in accelerated production by these units. However, due to the ageing of plants, the Government refuses to sanction the use of mercury cell technology on account of environmental concerns. Capacity expansion was another major factor responsible for the technology shift, and both the cost of technical manpower and the cost of land being fixed, did not add to the cost of shifting.

It was ideal for plants to undertake the shift with capacity expansion as it amounted to cost savings on fixed assets and manpower. These factors have lead to the current increase in production of approximately 3.2 million MTPA of caustic soda. The increased production requirement can also support additional capacity investment that may favour conversion simultaneously. Out of the total production capacity of 3.2 million MTPA, approximately 3.04 million MTPA production capacity is membrane cell technology, while the rest of the 0.16 million MTPA production capacity is mercury cell technology as on date. In order to cater to the CREP requirements and to convert the plant up to this extent, Indian Chlor-alkali plants have made an investment of approximately 15000-16000 million rupees (***source: Alkali Manufacturer's Association of India***).

c) Raising environmental concerns & benefits

In India, an increasing awareness of the adverse impact of mercury usage and mercury based products was also one of the major factor behind conversion. Alongside, CREP recommendation on Chlor alkali plants, named Thirteen Points Time Bound Action Plan came in the year March 2003. From the very beginning, CREP for Chlor-alkali industries proved to be an instrument to drastically reduce mercury consumption and emission into the environment. Like other industries, handling hazardous substances, mercury cell based Chlor-alkali plants are also facing a serious shift towards membrane cell technology due to the hazardous nature of mercury. Conversion of mercury cell to membrane cell is the most important action point under this regulation and the Alkali Manufacturer's Association of India (AMAI), on behalf of all the Chlor-alkali plants of India, has agreed to have this conversion completed by the year 2012. A Task Force has been constituted for continuous monitoring and rigorous follow up, thus monitoring the progress of the implementation of the CREP Recommendations. The Indian industry has voluntarily taken this initiative to convert through this CREP Programme and no financial incentives were provided to them by the Indian Government.

Environmental benefits

Indian Chlor-alkali plants have achieved huge benefits through this technology shift, which are tabulated below:

1. The membrane cell plant is an environment friendly and energy efficient technology. Any end products or gas, generated from this plant are completely free of mercury with no chances of mercury contamination to the soil or water;
2. The membrane cell based plant would ensure no emission of mercury into the air;
3. No chances of negative impacts on humans as well as the environment remains as the mercury itself is a toxic element;
4. Net energy saving of about 24 percent, thereby reducing the amount of carbon foot print;

The total reduction in CO_2 emission to the environment has been calculated by using the United States Environmental Protection Act (US EPA) Greenhouse Gas Equivalencies Calculator, which uses the Emissions & Generation Resource Integrated Database (EGRID) U.S. The details of total energy consumption per unit production of caustic soda by the Indian Chlor-alkali plant has been taken after discussions with AMAI technology manufacturers and a secondary study, done by CPCB. The recent total production of caustic soda in India has been obtained from AMAI.

It is estimated that, approximately 1569024.824 MT of CO_2 emissions to the environment can be avoided by shifting to membrane cell technology.

In addition to the above mentioned benefits of reduced carbon foot print, some others tangible and intangible benefits are there, which are as follows:

- ***Regulatory compliance and other benefits of conversion***:

Mercury cell chlor-alkali plants are subject to special regulations due to the use of mercury. Converting to a mercury free process will lead to the savings of several relevant costs, which in approximate order of economic significance include:

- Avoiding costs of recycling, retorting, transporting, inventorying and/or disposing of mercury wastes;
- Elimination of the mercury wastewater treatment facility;
- Reduced labor costs due to reduced need for maintenance;
- Reduced labor costs due to reduced need for monitoring mercury emissions and occupational exposures, health testing, reporting and abatement measures;
- Avoidance of costs of storage of residual mercury;
- Elimination of mercury monitoring equipment, as well as equipment for cleaning mercury from product streams, flue exhausts, other clean-up related costs (spillages) etc;

- ***Miscellaneous benefits***

- This can not be easily quantified; however, at least 5% of the total benefits listed above, can be achieved, which include, improved community relations, decreased legal liability, improved public/investor image of the company, improved attractiveness of the company as a place to work (employee satisfaction), reduced energy demand during the time of raised energy consciousness, reduced CO_2 emissions related to energy demand etc.
- Reduced costs on medical testing of workers and relevant insurances as well as costs related to potential need of rehabilitation in case workers had to take time off.

d) Market Demand

The requirement of good quality products that are not contaminated with mercury is also a big factor behind technology shifting. In the downstream, the specific needs of the customer for mercury free chlorine and caustic soda is a major factor, as some units like the food or pharmaceutical sectors might demand a feedstock with an extremely low mercury content.

4.2 Economics of technology shifting

In India, very old mercury based Chlor alkali plants have shifted to membrane cell technology. In this sector, two types of shifting can be achieved; one is complete shifting of the entire plant and the other one is conversion of the electrolyzer from mercury to membrane cell.

A. PLANT FIXED COST

On the basis of secondary studies and discussions with experts in the field, we have found that, in India, the average plant size is 150-200 TPD. The conversion of electrolyzer to membrane cell would cost approximately 6-7 million rupees per TPD of caustic produce, provided the capacity remains same.

According to Mr. P.N. Arora, Technical Consultant, in case of establishing a completely new plant, the project cost would be approximately 9 -10 million rupees per TPD of caustic produce, which includes power intake, utilities, land development etc; however, the land purchasing cost would be in addition to the above mentioned cost, as it is subject to regional variations.

In the case of technology conversion as well as capacity expansion of up to one and a half times of the existing plant, approximately 50% of an entirely new establishment cost is required to be invested additionally, i.e. 50% of 10 million rupees/TPD, which comes to approximately 5 million rupees/TPD of caustic produce. Therefore, the total project cost for conversion would depend on the total production capacity of the plant.

In most of the cases, the plant may require a complete conversion, as almost every part of a plant gets contaminated by the use of mercury.

B. OPERATING & MAINTENANCE COST

Raw materials

In the case of membrane cell technology, comparatively pure brine is required; hence one additional unit of secondary brine treatment and analyzer is required to be installed, which involves a further investment of Rs. 0.5-0.6 million rupees. In addition, the salt costs approximately Rs. 1600/ton and other chemicals go upto Rs. 2000/ton (on the basis of a discussion with a plant operator).

Manpower

In recent years, the Chlor-alkali plants are being operated automatically; therefore man power involvement does not alter in case of conversion. Hence, it does not affect the total cost of the plant after conversion. Even in case of a slight increase in capacity no additional man power is required.

Membrane replacement cost

In case of membrane cell technology, the membrane itself needs to be replaced after every 3-4 years, which again costs approximately Rs.0.1 million/ sheets of membrane. The total cost of membrane replacement would depend on the capacity of the plant and number of electrolyzers used in a particular plant. On the basis of analyzing various Indian scenarios, it has been observed that, approximately 3% of the total project cost is considered as the maintenance cost, while in case of the mercury cell technology the industry required a different regimen of maintenance and replacements of parts on an annual basis. In a comparison of the maintenance costs between both technologies there is no indication of any significant variation between the two however; the cell membrane is certainly much more compact and uncontaminated.

Pollution control measures

In the case of mercury as well as membrane cell process, the initial investment on pollution control measures remains unchanged; thereby the conversion in technology did not envisage any additional investment.

The adoption of pollution control devices initially increase the investment cost, however it ultimately proves to be beneficial in terms of mitigating the pollution at source. This adoption of devices would ensure no extra cost in pollution abatement at later stage.

Additionally, shifting to membrane technology would also help in reducing extra cost, that is usually required in case of mercury cell technology as part of the preventive measures taken thereof.

Maintenance Cost

On the basis of analyzing various Indian scenarios, it has been observed that, approximately 3% of the total project cost is considered as the maintenance cost, while in the case of mercury cell technology the industry require a different regimen of maintenance and replacements of parts on an annual basis. The maintenance cost comparison between both technologies does not suggest any significant variation between the two but the cell membrane is certainly much more compact and hygienic.

C. SALE OF PRODUCTS

During the manufacturing of caustic soda in chlon-alkali plants, some by-products like chlorine and hydrogen are generated. According to the AMAI and various other studies, approximately 886 kg of chlorine and 280 Nm^3 of hydrogen are produced for each ton of caustic soda production. The market price of chlorine and caustic soda are reversely proportional. When the demand for caustic soda in Indian market increases, it automatically increases the chlorine production in excess to the market demand, which actually leads to the selling of excess chlorine at a comparatively lower price. However, in case of the increasing demand for chlorine, the situation is reversed thereby leading to selling of caustic soda at a lower price.

The hydrogen, generated from the Chlor-alkali plant is mainly used as captive fuel for preparing caustic flakes from lye. Sometimes, a part of this hydrogen is also combined with the chlorine for producing hydrochloric acid. Apart from this, sometime the plants, in their downstream bottling plant, store this hydrogen and sell it off to the market at an average price of Rs.12/Nm^3 approximately; however, the ratio of using the hydrogen in these different categories is subject to the internal requirement of the plant as well as the market demand for the products and the selling price of hydrogen also fluctuates depending on various factors.

In case of an average plant size of 300 TPD capacity, running at 75% capacity utilization, approximately 63000Nm^3 of Hydrogen gas will be generated per day.

Plant size	: 300 TPD
Capacity utilization	: 75%, i.e. 225 TPD
Hydrogen gas	: (280*225) Nm^3
	: 63000 Nm^3

In Indian market, the demand for caustic soda is very high in rayon and pulp industries, aluminium, textiles, soap and detergents, fertilizer, refineries etc. However, the plants in India are operating on the basis of the current market scenario.

In spite of the huge internal demand, these industries in India sometimes face major constraints due to external intervention. In the countries outside India, the bi products like, Chlorine, hydrochloric acid and hydrogen cannot be hauled long distances. Manufacturing units produce and use these products, which mean that, the economics of these plants is based on captive consumption. At the same time, the caustic soda needs to be disposed off, which sometime leads to export of this product to Indian market and therefore it is dumped here. This further leads to an imbalance in the domestic industry, which is already over-producing the caustic soda.

SITE REMEDIATION

The conversion from mercury to membrane cell technology requires site remediation in terms of complete cleansing of excess mercury and sludge generated from the mercury cell based plant. On the basis of the discussion with AMAI, it is observed that, for each ton of caustic soda produce, approximately 20kg of mercury waste, named 'sludge' is generated. This sludge is stored in a pit, properly lined, so as to avoid any leaching to the soil or ground water. The pit is then covered and trees are planted on top of the same.

In the case of membrane cell technology, the sludge generated from the process is completely mercury free, which can further be used in cement plants.

4.3 Return on Investment

The Chlor alkali plants from the very beginning of conversion were getting timely returns on the investment, except during the recession in the year 2008. In general, the return on investment for conversion can easily be obtained by selling the caustic soda in the market. In Indian scenario, the annual rate of return can be calculated separately for two separate scenarios, one is the conversion of the existing plant and the other one is conversion as well as expansion of the existing plant.

Scenario 1: Conversion without capacity expansion

In case of conversion without capacity expansion, a minimum investment of 1800 million rupees has been considered for an average sized plant of 300 TPD capacity (Refer: Sec. 4.2, A, wherein it is mentioned that the cost required for per ton conversion of the plant is approximately 6 million rupees). In order to calculate the rate of return, the following assumptions have been made:

1. Plant will run on 75% capacity, hence per day production is 225 T;
2. Plant runs 350 days a year;
3. Energy requirement for mercury & membrane cell is 3000 kWh and 2266 kWh respectively;
4. Unit electricity cost is Rs.5/kWh
5. Annual depreciation rate on investment is 15%

In the case of conversion of a similar capacity plant, depreciation on investment is considered as zero, because of the positive benefits from technology shifting; thereby considering it under gross savings. The interest outflow @ flat rate of 8% and electricity savings has been accounted for by calculating the net savings. Finally, it has been observed that, the payback period of this 300 TPD plant is seven years. The detailed calculation of the rate of return is attached to the report in ***Annexure I***

Scenario 2: Conversion with capacity expansion of upto 20%

In the case of conversion as well as 20% capacity expansion, an initial investment of approximately 2100 million rupees has been considered (refer: Sec. 4.2 A, where it is mentioned that, upto 50% of capacity expansion, an additional 5 million rupees/TPD of investment is required). The following assumptions have been made for this case:

1. Plant capacity after 20% capacity expansion is 360 TPD
2. Plant will run on 75% capacity, hence per day production is 270 tonnes;
3. Plant runs 350 days a year;
4. Salt and other chemicals' cost is Rs. 1600/T and Rs. 2000/T respectively
5. Electricity cost is taken as Rs. 11330/T

In this scenario, the payback period for a plant of 360 TPD capacity would be five years. The detailed calculation of the rate of return is attached in the report in ***Annexure I***.

4.4 The Indian Experience

In India, sometimes over import of caustic soda by cheapest rates also causes delay in recovering the initial investment; however, in order to protect the domestic industry, the Government of India has imposed an anti-dumping duty on the import of caustic soda.

A notification issued by the Department of Customs states that caustic soda originating in, or exported from, Thailand, Taiwan and Norway and imported into India, has been found to be below its normal value, causing material injury to the domestic industry. To protect the domestic industry from the effects caused by the dumped imports from these three countries, a definitive anti-dumping duty has been imposed on the imports of caustic soda, originating in, or exported from, these countries, adds the notification.

An anti-dumping duty at a rate of USD 379 per dry metric ton (DMT) has been imposed on caustic soda originating in, or exported from Thailand and Norway, while the rate would be USD 361 per DMT on caustic soda originating in, or exported from Taiwan.

The chlor alkali industries in India has since then stabilized and performed well. It has also demonstrated that environmental drivers can be economically beneficial in long term.

Annexure – I

Assumptions		
Plant Capacity	300	TPD
Capacity utilization	75%	
Working days per year	350	
Production per day	225	TPD
Energy Requirement		
For mercury option	3000	kwH per T
Price per kwH	5	Rs
Electricity costs per T	15000	Rs/T
For Membrane option	2266	kwH per T
Price per kwH	5	Rs
Electricity costs per T	11330	Rs/T
Savings per T	3670	Rs/T
Savings per day	825750	Rs
Average investment in change	1800	Million Rs
Average capacity increase	20%	
Depreciation rate	15%	

Scenario 1: No capacity increase

	Year	1	2	3	4	5	6	7	8	
	Depreciation value	1800.00	1530.00	1300.50	1105.43	939.61	798.67	678.87	577.04	
	Depreciation amount	270.00	229.50	195.08	165.81	140.94	119.80	101.83	86.56	
	Electricity savings	289.01	289.01	289.01	289.01	289.01	289.01	289.01	289.01	
	Gross savings	559.01	518.51	484.09	454.82	429.95	408.81	390.84	375.57	3621.60
Flat Rate 8%										
	Interest outflow	144	144	144	144	144	144	144	144	
	Gross savings	415.01	374.51	340.09	310.82	285.95	264.81	246.84	231.57	2469.60
54	Annual Maintenance cost outflow	54	54	54	54	54	54	54	54	
	Net savings	361.01	320.51	286.09	256.82	231.95	210.81	192.84	177.57	2037.60

Scenario 2: Capacity increased

Plant capacity increase	60	TPD
Total plant capacity	360	TPD
Capacity utilization	75%	
Working days per year	350	
Production per day	270	TPD

Sales price	25000	/T
Raw material		
Salt	1600	/T
Other chemicals	2000	/T
Additional electricity	11330	/T
Additional profit earned	10070	/T
Additional production	45	TPD
Additional production per year	15750	T
Additional profit earned	**158.60**	million Rs per year

Net savings	519.62	479.11	444.69	415.43	390.55	369.41	351.44	336.17	3306.42

- No carbon credit revenue estimated;
- Plant overhead & corporate tax have not been considered;

Annexure – II

Table: Specific Energy Consumed for Producing Caustic Lye in Mercury Cells				
Companies	Average Specific Energy Consumed (in per MT caustic lye produced on 100% basis)			Rank
	Power (kWh/MT)	Steam (MT/MT)	Total Energy (Gj/MT)	
Bihar Caustic & Chemicals Ltd	2889.67	0.00	10.40	6
BILT Chemicals	2863.00	0.15	10.44	7
DCW Ltd	2927.33	0.00	10.54	8
Kanoria Chemicals	3001.00	0.18	10.97	10
Shriram Fertilisers & Chemicals Ltd	2783.00	0.00	10.02	2
Century Rayon Ltd – mercury cell	2876.50	0.01	10.37	4
Grasim Industries Ltd - mercury cell	2773.33	0.00	9.98	1
Hukumchand Jute & Industries Ltd – mercury cell	2808.33	0.00	10.11	3
NRC Ltd – Chemical Division –mercury cell	2932.00	0.00	10.56	9
Punjab Alkalies & Chemicals Ltd – mercury cell	3142.11	0.00	11.31	11
Standard Industries Ltd – mercury cell	2879.26	0.00	10.37	5
Travancore Cochin Chemicals Ltd – mercury cell	3279.05	0.00	11.80	12
Average of all mercury cells	2929.55	0.03	10.57	
Average for mercury cell companies	2892.80	0.07	10.47	
Average of mercury cells of combined companies	2955.80	0.00	10.64	

Source: Green rating of Indian caustic-chlorine industry, CSE, 2002

Table: Specific Energy Consumed for Producing Caustic Lye in Membrane Cells				
Companies	Average Specific Energy Consumed (in per MT caustic lye produced on 100% basis)			Rank
	Power (kWh/MT)	Steam (MT/MT)	Total Energy (Gj/MT)	
Century Rayon Ltd (Membrane Cell)	2418.00	0.15	8.84	7
Chemfab Alkalis Ltd	2397.33	0.12	8.74	5
Grasim Industries Ltd (Membrane Cell)	2195.67	0.25	8.13	2
Gujarat Alkalies & Chemicals Ltd – Dahej	2262.50	0.65	8.73	4
Gujarat Alkalies & Chemicals Ltd – Vadodara	2435.00	0.60	9.31	14
Hukumchand Jute & Industries Ltd (Membrane Cell)	2714.00	0.20	9.95	17
Indian Petrochemicals Corporation Ltd	2266.00	0.98	9.04	11
Indian Rayon & Industries Limited	2137.21	0.31	7.97	1
NRC Ltd – Chemical Division (Membrane Cell)	2451.33	0.00	8.82	6
Punjab Alkalies & Chemicals Ltd (Membrane Cell)	2349.97	0.61	9.01	10
Search Chem Industries Ltd	2420.00	1.10	9.71	15
Shriram Alkalies & Chemicals Ltd	2364.33	0.62	9.07	12
SIEL Ltd	2310.95	0.67	8.92	8
Sree Rayalseema Alkalies & Allied Chemicals Ltd	2518.00	0.92	9.89	16
Standard Industries Ltd (Membrane Cell)	2437.16	0.49	9.22	13
Tamilnadu Petroproducts Ltd	2295.86	0.79	8.97	9
Travancore Cochin Chemicals Ltd (Membrane Cell)	2326.77	0.38	8.72	3
Average of all membrane cells	2370.60	0.52	9.00	
Average for membrane cell companies	2340.72	0.68	9.04	
Average of membrane cells of combined companies	2398.59	0.36	8.96	

Source: Green rating of Indian caustic-chlorine industry, CSE, 2002

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