EUROPEAN COMMISSION
DIRECTORATE-GENERAL III
INDUSTRY
Directorate C: Basic Industries
Chemicals, plastics, rubber

AN ECONOMIC AND ENVIRONMENTAL ANALYSIS OF THE CHLOR-ALKALI PRODUCTION PROCESS

MERCURY CELLS AND ALTERNATIVE TECHNOLOGIES

Final Report 30 June 1997

Prepared for the European Commission (DG III C-4, Chemicals, plastics, rubber)

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EXECUTIVE SUMMARY AND CONCLUSIONS

Introduction

1. The PARCOM Decision 90/3 of 14 June 1990 on reducing atmospheric emissions from existing chlor-alkali plants states in its point 3 that:

> "Contracting Parties to the Paris Convention for the Prevention of Marine Pollution from Land-Based Sources ..... *recommend that existing mercury cell chlor-alkali plants be phased out as soon as practicable. The objective is that they should be phased-out completely by 2010*."

This Decision resulted in part from the historical mercury emissions for the chlor-alkali industry. It has been unclear what kind of impact a phase-out on the indicated timescale as an objective could have on the structure of the chemical industry in the EU and on its global competitiveness, and on this basis DG III decided to undertake an economic and environmental analysis of the chlorine production process for mercury cells and alternative technologies.

Description of the EU Chlor-Alkali Industry

2. The EU chemical industry is the EU's second largest manufacturing industry and the world's most important producer of chemicals. Chlorine and caustic soda are co-produced in a fixed ratio (1:1.1) by chlor-alkali plants and both are important base chemicals in the chemical and related industries. The total EU chlor-alkali production value in 1996 has been estimated to have been about 3 billion ECU, and over 50% of the EU chemical industry turnover is generated by products which contain, or are derived from chlor-alkali production. The EU domestic chlor-alkali supply and demand are currently well balanced, with caustic soda net exports being 140 million ECU in 1996. In addition exports of chlorine derived products are significant, and in 1996 contributed at least 20 billion ECU in export earnings. Chlor-alkali production is completely inter-related with downstream businesses.

3. In 1995, the global chlorine production capacity was approximately 44 million tonnes, with the EU having 10.6 million tonnes of capacity. The total production capacity in the EU has declined over the past 10 years, whereas the USA capacity has increased to nearly 12 million tonnes with a higher utilisation rate than in the EU. The global demand for both chlorine and caustic soda has been forecast to increase by over 6 million tonnes tonnes by 2005. Increased demand in Asia for caustic soda and downstream chlorine products (for PVC manufacture) is projected to be met by some local investment, with exports from USA and Middle East being projected to grow. In contrast exports from the EU are projected to decline, due inter alia to a less favourable cost base for capacity expansion. New capacity is being located in the gulf

states of the USA to take advantage of the favourable cost base. The production capacity in the EU is not forecast to increase.

4. Production costs in the EU are reported on average to be of the order of $90 per tonne chlorine higher than the gulf states of the USA, in part due to electricity costs which are reported to be 35% lower in the gulf states of USA.

5. There are three distinct technologies used for chlor-alkali production in the EU and globally. These are mercury cell, diaphragm cell, and membrane cell processes. Based on present technology (typically the diaphragm cell process uses asbestos diaphragms at present), membrane cell technology is preferred for new installations, and has been in operation in the EU since the early 1980s. The present generation of membrane technology is reported to be approaching its limits in terms of performance, with only small incremental improvements possible.

Impact of the PARCOM Decision 90/3

6. The EU's mercury cell capacity is about 64% of its total production capacity and it has 50% of the global capacity (about 12 million tonnes) of mercury cells. In the USA, the mercury cell capacity is 13% of the total capacity. At the time the PARCOM Decision 90/3 was laid down industry appeared to be more hopeful of replacing mercury cells more rapidly than seems economically possible today. During the period 1982 to 1995, the average closure rate for mercury cells was 150,000 tonnes capacity per year, but an average closure rate of 550,000 tonnes capacity per year would be needed to eliminate all mercury cell capacity by 2010. Mercury cells were installed in the EU up to the mid 1970s. Economic plant lifetimes can be in the range of 40-60 years.

7. A typical conversion cost of mercury cells to membrane cells might be in the range of 560 to 610 ECU per tonne chlorine capacity, which would conventionally be depreciated over 10 years. Based on depreciation charges, but offset to some extent by reduced running costs for membrane cells, it appears that total costs for chlorine production after conversion could increase by of the order of 45 to 50 ECU per tonne for the 10 year depreciation period. This could on average be expected to further increase the reported difference between production costs in the EU and the gulf states of USA and other regions, and could be expected to stimulate the importation of caustic soda and chlorine derivatives from lower cost producers.

8. The present projected rate of economically driven conversion is not sufficient to phase out mercury cells by 2010. Projections also estimate that total chlorine production capacity could remain broadly static with of the order of 5 million tonnes of mercury cell capacity operating in the year 2010. A phase-out of mercury cells by 2010 has been projected to result in a significant shrinkage of about 20% in the EU's chlorine production capacity, due to closure without replacement of about 2.2 million tonnes of mercury cell capacity and conversion of about 3.6 million tonnes capacity.

9. If the projected reduction in chlorine capacity due to the PARCOM objective was to occur, a deterioration of the EU chemicals trade balance of the order of 2.3 billion ECU by 2010 could be estimated. The capital cost of non-economically driven conversions could be of the order of 1.5 billion ECU, and based on the assumption that the estimated average economic lifetime of the mercury cell capacity is

sufficiently long beyond 2010, this could approximate broadly to the economic cost. Based on the assumption that this capital could replace capital expenditure for other chemical industry projects, any economic activity in membrane cells construction and installation could be offset by a decrease in economic activity in other potentially more productive chemical engineering sectors. Capital expenditure of about 1.5 billion ECU on other chemical projects could be estimated to produce a turnover of about 2.2 billion ECU.

10. Significant effects on investment and turnover might be expected to have some impact on employment within the chemical industry, and some impact on second order (direct support) and third order (community) employment, but any estimates should be treated with caution. Based on the trends of the last 10 years, 4.5 billion ECU turnover in the EU chemical industry (from estimated trade balance effects and assumed impact on capital projects) could, based on the assumptions used, equate to about 10,000 employees directly in the chemical industry by the year 2010. The local intensity of employment for chlorine production will be a factor in determining the relative local impact of any capacity closure.

Mercury Emissions in Perspective

11. Mercury is a transboundary long range air pollutant. At present the estimated contribution of the EU chlor-alkali industry to the estimated total European mercury emissions could be about 4%. An economically driven emission scenario, that does not take account of conversion as laid down in the PARCOM Decision, could result in elimination by 2010 of 2.4% of present total European estimated mercury emissions. Eventually, for this scenario, all the EU mercury cells would be decommissioned in a timescale beyond 2010.

12. The chlor-alkali industry is unique as it has, at present, about 11,800 tonnes of pure mercury as an inventory within the EU mercury cells. Within the next few years, the EU chlor-alkali industry could become a net generator of mercury metal. due to the economic closure of some existing capacity. On decommissioning, mercury will be recovered from the cells, and once recovered, there is the possibility pure mercury may be exported to third countries regions for use in a wide range of applications. Eventually all of the stockpile of mercury contained in the EU mercury cells will need to be dealt with. Mercury is mined in the EU, with about 1350 tonnes of mercury produced in 1996, and a large proportion is at present exported outside the EU. A reassessment of the EU mercury policy as a whole, including mercury mining, secure mercury disposal, and appropriate approaches for the chlor-alkali stockpile appears necessary.

13. In the future caustic soda supplied from mercury cells should contain a maximum concentration of mercury of about 0.05 ppm. This is a similar trace level to the mercury content of a range of other materials, such as avocados, estimated natural background level in fish, limestone, wood, coal, and oil. At these levels it appears that material selection is not generally based on mercury content.

Environmental Performance For Mercury Cells

14. Major improvements have been reported for all sources of emission from operating mercury cells, but the main emission route is to air. From 1977 to 1995 the chlor-alkali industry in the EU reported decreased emissions of mercury to the environment from 220 tonnes to 18 tonnes per year, a decrease of 92%. At the Third North Sea Conference at The Hague in 1990, a general reduction target of 70% was established for mercury inputs. Over the period 1985 to 1995, the chlor-alkali industry in the EU reported a decrease in total annual mercury emissions to the environment of 69%. Based on the decrease in reported annual emissions, the greatly reduced purchases of mercury, and investments undertaken to improve environmental performance, the chlor-alkali industry in the EU is now a different industry compared with 20 years ago in terms of its environmental performance.

15. It has been estimated that a reduction of 80% in deposition of mercury, compared to 1990 levels, is considered necessary to prevent further accumulation of mercury in some European soils and lakes and allow concentrations to begin to diminish. An emission scenario for the EU chlor-alkali industry, that does not take account of phase-out as laid down in the PARCOM Decision could result in an estimated emission reduction of around 75% by 2010 from 1990 reported emissions, and reductions would be expected to continue due to economically driven closures.

16. Solid waste containing mercury, from operation of mercury cells, is disposed of in safely deposited wastes, according to the Harzardous Waste Directive, where emission to the environment is minimised or eliminated. Mercury disposed of as solid waste now makes up the largest part of the mercury removed from mercury cells, and an objective of seeking ways to minimise the generation of waste containing mercury follows from the review of the Community strategy for waste management.

Cost Effectiveness of Reducing Mercury Emissions

17. It has been estimated is that the EU chlor-alkali industry has invested 800 million ECU since the 1970s and revised procedures in order to improve the performance of mercury cell plants, and over this period closed or replaced 1.94 million tonnes of mercury cell chlorine capacity, leaving 6.6 million tonnes mercury cell chlorine capacity at present. Some further investment would be required in order to achieve a reduction in reported emissions, for an economically driven scenario. The cost effectiveness of phasing out mercury cells through conversion could be estimated from the present situation, or by taking into account economically driven conversions and future procedural improvements, or on an incremental basis from the additional cost to eliminate mercury emissions that would not be eliminated by economic conversions, and improvements due to investment and procedures. Based on the assumption that any possible net differences in the precise nature and quantity of solid waste containing mercury from operating mercury cells beyond 2010, when compared to decommissioning by 2010, appear unlikely to be significant in the context of relative cost effectiveness comparisons for emission scenarios, solid waste has not been taken into account for the various scenarios, which are summarised in the following table. The conversion cost effectiveness is based on capital cost.

Emission Reduction Scenarios	**Cost Effectiveness** ECU/kg mercury/yr[1]	**Emissions Eliminated** (tonnes)
Improvements to mercury cells		
1977 reported emissions 221 tonnes		
1977 to 1995 Investment (800 million ECU)	890	90
Operating procedure improvements		38
Economically driven conversion		75
1995 reported emissions 18 tonnes		
1995 to 2010 Investment (170 million ECU)	4,080	4.2
Operating procedure improvements		1.8
Economically driven conversion		4.5
2010 emissions scenario for economically driven scenario estimate 7.5 tonnes		
Phase-out through conversion of mercury cells		
2010 Forced conversions[2] (2.8 billion ECU)	24,000	11.7
Operating procedure improvements		1.8
Economically driven conversions		4.5
2010 Incremental effect of forced conversions (2.63 billion ECU)	35,000	7.5

Regulatory Instruments and Possibility of Environmental Agreements

18. Three Member States (Austria, Greece, and Italy), with mercury cell capacity are not committed to the PARCOM Decision. Also, the wording of PARCOM Decision 90/3 part 3 could result in some Member States that are Contracting Parties to the Paris Convention allowing the operation of mercury cells after 2010 on the basis that it is not practicable to phase them out by the date signalled as the objective.

19. Under the UN/ECE Convention on Long-Range Transboundary Air Pollution (LRTAP) a Protocol on Heavy Metals (HMs) is being developed, the aim of which is to reduce atmospheric emissions. There will be BAT and/or emission limit values for mercury emissions from chlor-alkali installations, which will mainly affect Eastern Europe, where emissions are thought to be significantly higher than in the EU.

20. The Communication from the Commission on Environmental Agreements sets out general considerations and guidelines for their use. The following points are especially relevant in this case:

- A key element is to base agreements on objectives already endorsed by the Community institutions or international conventions, which is the case for mercury emission reduction.

- Any environmental agreement in this sector would be part of a "policy-mix" together with regulatory or economic instruments. The IPPC Directive, PARCOM Decision 90/3, and UN/ECE Protocol on Heavy Metals provide a range of measures that will control emissions from chlor-alkali installations. IPPC BAT could define techniques

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[1] The cost effectiveness of converting mercury cells can be expressed as the cost effectiveness per kg of annual mercury emissions eliminated, based on depreciating investments over 10 years.

[2] for an estimated 5 million tonnes of mercury cell chlorine capacity

for decommissioning or mercury cells. At present the work programme schedules a BREF (BAT Reference Document) for chlor-alkali production for 1998.

- Euro Chlor represents all the companies that operate mercury cells in the EU, and there are a limited number of companies (about 30), and a limited number of mercury cell installations (about 60). There is considerable expertise available within Euro Chlor companies for the optimum operation of mercury cells; this expertise could be important for implementation of reduced emissions for plants in Eastern Europe.

- An environmental agreement at the Community level offers the possibility of monitoring both the total emissions of the EU chlor-alkali industry and the decommissioned mercury, which are not covered by OSPARCOM reporting, and to monitor trends as part of a staged approach. Other instruments, could set quantified objectives that cover emissions of individual installations.

21. The report proposes that discussions are held with industry, to explore if an environmental agreement at Community level with Euro Chlor, on behalf of its member companies, could be appropriate within the mix of instruments available.

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CONTENTS

1. INTRODUCTION

The PARCOM Decision 90/3 of 14 June 1990 on reducing atmospheric emissions from existing chlor-alkali plants states in its point 3 that:

> "Contracting Parties to the Paris Convention for the Prevention of Marine Pollution from Land-Based Sources ..... *recommend that existing mercury cell chlor-alkali plants be phased out as soon as practicable. The objective is that they should be phased-out completely by 2010*."

This measure for the chlor-alkali industry resulted in part from these factors:

- The historical performance of the chlor-alkali industry for emissions of mercury to the environment.

- A view at that moment that industry could convert from mercury cell technology at reasonable cost and with limited impact on the competiveness of the chlor-alkali (and chemical industry) in Europe.

The chlor-alkali segment of the chemical is a major and integrated part of the European chemical industry. It has been unclear what kind of impact the phase out of mercury cell technology by 2010 could have on the structure of the chemical industry in Europe and on its global competitiveness.

DG III decided to undertake an economic and environmental analysis of the chlorine production process for mercury cells and alternative technologies. The project had the support of Euro Chlor, which is the trade association representing the EU chlor-alkali industry.

2. EU CHEMICAL AND CHLOR-ALKALI INDUSTRIES OVERVIEW

The EU chemical industry is the EU's second largest manufacturing industry and the world's most important producer of chemicals. The EU chemical industry directly employed 1.65 million people in 1994, and had a turnover of ECU 358 bn in 1995. Another three million employees work in sectors using output of the chemical industry as direct inputs and thus depend on its competiveness.[1][2]

The chemical industry has had to continually restructure in the face of global competition; declining employment is one indication of this. The basic chemicals sectors have been especially affected by this. The average return on capital employed across the economic cycles is lower in Europe than in USA or East Asia. In a world of highly mobile capital, Europe must offer attractive rates of return on capital invested or see a dwindling of investment and a decline of activity therein. Europe will continue

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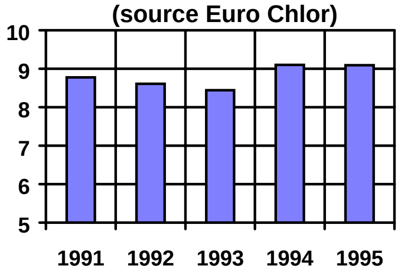
[1] Communication from the Commission, "An Industrial Competiveness Policy For The European Chemical Industry: An Example" COM(96) 187

[2] CEFIC Facts & Figures The European chemical industry in a worldwide perspective, November 1996

to provide the basis for the EU chemical industry's sales but exports are a vital source of earnings.


1995 Western European Chlorine Production (million tonnes) (source Euro Chlor)

The chlor-alkali industry forms a major part of the EU chemical industry. The total Western European[3] production value of chlorine and caustic in 1996 has been estimated to have been 3 billion ECU. Figures published by Euro Chlor indicate that 55% of the European chemical production depends on chlor-alkali products. Another estimate[5] is that in Western Europe at least 60% of the turnover is generated by products which contain, or are derived from chlorine and/or caustic soda (sodium hydroxide). Many chemicals, plastics and pharmaceuticals depend on chlorine during the manufacturing process, although chlorine is not contained in the end product. In 1995, 35% of all chlorine was used in the production of chlorinated polymers, such as PVC. Other major uses of chlorine are in the production of intermediates, non chlorinated polymers such as polyurethanes, polycarbonate, and epoxy resins, and for the production of inorganic products such as titanium dioxide. Decline in some markets for chlorine, such as for paper, CFCs, and solvents, have been balanced by increased demand for polymers such as PVC, resulting in broadly static chlorine production in Western Europe.[4,5] Caustic soda, the product coproduced with chlorine in chlor-alkali production is an important base chemical in the chemical and related industries, like oil, pulp and paper, and aluminium.

Western European domestic chlor-alkali supply and demand are currently well balanced, with caustic soda net exports being 140 million ECU in 1996. In addition exports of chlorine derived products are significant, and in 1996 contributed at least 20 billion ECU in export earnings.

3. STRUCTURE OF CHLOR-ALKALI INDUSTRY

3.1. Integration With Downstream Chemical Production

The fundamental building blocks of the chlor-alkali industry are chlorine and caustic soda. These are coproduced from salt solution by electrolysis, using mercury, membrane, or diaphragm cell technologies. The production of chlorine and caustic is

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[3] The structure of the industry means that some of the data sources refer to EU, but many of them refer to Western Europe which also includes Switzerland and Norway. However the scale of the chlorine production in non EU Western Europe (2.2% in 1995) means that no data adjustment is necessary, and for the purposes of this report the terms EU and WE can be assumed to represent the same industry. However data references EU or WE if this is applicable.

[4] Euro Chlor

[5] "Competitive Situation of the Western European Chlor-Alkali Industry in a Global Context", SRI Consulting, prepared for Euro Chlor, April 1997

completely inter-related with the downstream businesses, including the PVC industry and the intermediates used to manufacture PVC.

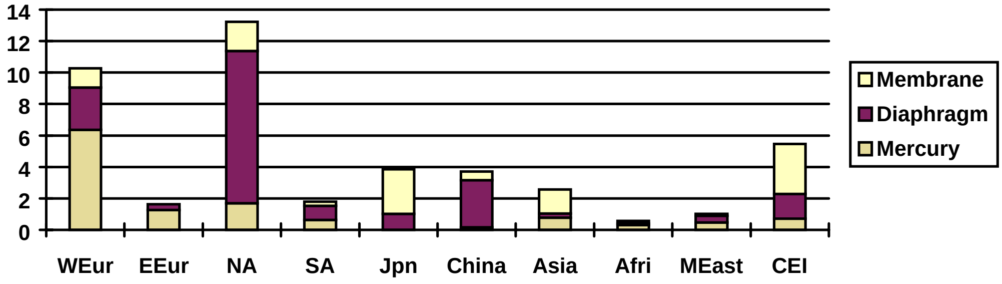
Chlorine is classified as a toxic and corrosive gas for transport (UN), and for EU supply, it is classified as toxic by inhalation, irritant to eyes, respiratory system, and skin, dangerous to the environment, and very toxic to aquatic organisms. Transportation of chlorine in EU is kept to a minimum. More than 85% of the chlorine produced in EU is used on the same or adjacent sites for other chemical processes, and converted to more readily transported chlorinated organic products and intermediates. These downstream products are more easily traded internationally, and any significant shortfall in chlorine production in EU, would lead to importation of downstream products and intermediates, replacing downstream production in the EU. International trade in for example EDC (used for PVC manufacture) effectively provides a means of trading chlorine. At present chemical exports utilise approximately 20% of the chlorine and caustic volumes produced in Europe.

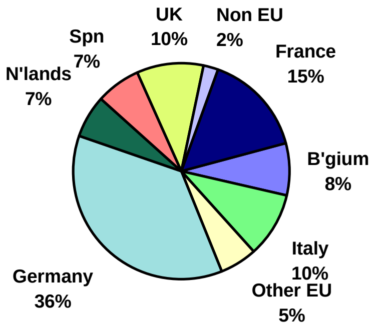
Caustic soda is used in various industry sectors, such as chemicals, pulp and paper, metallurgy, aluminium, soap, surfactants, and textiles, and caustic is extensively traded globally. Caustic soda consumption has a correlation with the industrial sector. Any shortfall in caustic production in EU could easily be replaced by product imported from other regions such as North America and the Middle East.

3.2. Chlorine and Caustic Production

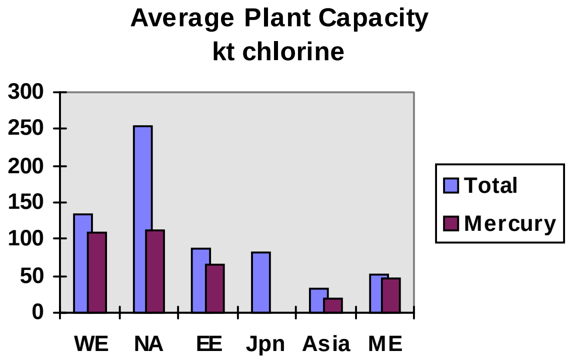
The three chlor-alkali production processes are mercury cell, the diaphragm cell, and the membrane cell processes, which are all electrolytic processes. All three processes produce 1.1 tonnes of caustic soda (sodium hydroxide, an alkali) and 0.028 tonnes of hydrogen for each tonne of chlorine produced. The hydrogen is either used as fuel for power generation locally, or sold commercially, or used as a feedstock for other chemical processes. The fixed link between chlorine and caustic soda, and hydrogen production means that the Electrochemical Unit (EChemU, 1 te chlorine, 1.1 te caustic & 0.028 te hydrogen) is sometimes used for assessing costs. Demand for chlorine and supply of caustic soda are linked, with other processes or natural sources providing alternative supplies of alkali. These other sources effectively provide a price ceiling for caustic soda.

Global Chlorine Production Capacity 1995
total 44 million tonnes





W Europe chlorine production 1995
9.1 million tonnes (Euro Chlor)



In 1995, the global chlorine production capacity was approximately 44 million tonnes, with EU having about 24% of this capacity (10.6 million tonnes of capacity).[6,7] More than 9 million tonnes of chlorine were produced in 1995 by the 79 chlorine production plants in 14 Western European countries. The plants in Western Europe employed about 42,000 people according to Euro Chlor data. Chlorine production plants typically do not operate at 100% of capacity so that production data for chlorine is lower than capacity data. One objective of rationalisation is to improve capacity utilisation. USA has the largest market and production capacity for chlorine with about 30% of the global market and capacity. However the USA has fewer chlorine production plants than Europe, with a larger average production capacity, providing advantages in economies of scale.

The six Member States Belgium, France, Germany, Italy, Spain, and UK each have over 8% of the EU mercury cell capacity, and together account for about 90% of the total EU mercury cell capacity. The average size of individual mercury cell plants in Western Europe (WE) and North America (NA) is similar, but membrane and diaphragm cell plants are, on average, larger in North America than in Western Europe. Mercury cell plants in other regions are, on average, smaller than in WE and NA.

The total production capacity in Western Europe has declined over the past 10 years from about 11.2 million tonnes chlorine capacity in 1987 to about 10 million tonnes in 1997. In contrast the USA capacity has increased from about 11 million tonnes in 1987 to nearly 12 million tonnes chlorine capacity in 1997,with a higher utilisation rate than in Western Europe (99% compared to 88%).

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6 Information Chemie n° 366 mars 1995, p107 Chlore: Situation Mondiale

7 Different data sources sometimes report slightly different capacities and production volumes for the same region, end use or production. Generally these differences are minor and have no influence on the interpretation of the data presented in this report.

3.3. Chlorine Market

The global chlorine demand was about 38 million tonnes in 1995, with the present supply for chlorine being tight. The global demand for chlorine has been forecast to increase to about 48 million tonnes by 2005[8], with Asia having the largest demand increase. Chlorine production capacity has been forecast to grow by at least 700,000 tonnes in USA during the next 5 years, as demand increases[9]. New capacity is being located in the gulf states of the USA to take advantage of the favourable cost base. The production capacity in Europe is not forecast to increase. Modest demand increases of about 1% per year can be met to some extent by an increased plant utilisation for the next few years. Global chlorine production capacity is forecast to be 50 million tonnes by 2005. When chlorine is in oversupply, according to a recent paper[10], competition is suggested to be in the downstream EDC market, which for low cost producers provides a ready sink for surplus chlorine.

3.3.1 Chlorine Flow in Europe in 1995

End Use	Chlorine ktpa %
Polymers, mainly PVC	3271 36%
Organic chemistry, dyestuffs, crop protection human health etc	1777 19%
Inorganic chemistry eg titanium dioxide	1345 15%
Intermediates for non-chlorinated polymers, PU, PC, epoxies	2171 24%
Elemental chlorine	258 3%
Solvents	271 3%
TOTAL	9093 tonnes

The chlorine use figures here (Euro Chlor) are based on the application of primary produced chlorine from chlor-alkali processes in Western Europe. In the ECOTEC study,[11] the chlorine streams in WE were studied in more detail and this resulted in the conclusion that 12.9 million tonnes of chlorine were processed. A substantial part (32%) was recycled in the form of hydrogen chloride (HCl), produced from chlorination processes, or recovery of chlorinated waste. Recycled HCl is used mainly in the production of 1,1-dichlorethane (EDC), which is used primarily for the manufacture of PVC. Salt is the starting product for the various chlorine chains, and also the disposal form for chlorine and was 23% of the chlorine processed in 1995. The economics of a wide range of chlorine related processes and products are linked and changes to the product chains may have a structural effect on parts of the chemical industry in Western Europe.

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[8] Chem Systems, The Chlorine/Caustic/EDC/VCM/PVC Chain April 1996

[9] Chemical Week, January 1/8 1997,p25; January 22, p29; February 26, p49-56.

[10]“Chlor-Alkali Industry Overview” C Fryer presented at the fourth TECNON Chlor-Alkali Conference June 1997

[11] Chlorine Flow in Europe 1995, A Study by ECOTEC for Euro Chlor

3.4. Caustic soda market

The USA is a significant exporter of caustic soda, due to the US demand being less than the demand for chlorine. Even so the USA is the largest market for caustic soda (28% of global demand) with EU being the second largest market (22%). Global demand has been projected to increase to 51 million tonnes by 2005, compared with 41 million tonne in 1995. Increased demand in Asia for caustic soda and downstream chlorine products (for PVC manufacture) is projected to be met by some local investment, with exports from USA and Middle East being projected to grow. In contrast exports from EU are projected to decline, due to a less favourable cost base for capacity expansion. The Chem Systems study forecasts that exports of caustic soda from USA will increase from 0.85 million tonnes in 1995 to 1.87 million tonnes by 2005. A recent paper[10] indicates that the caustic soda supply/demand balance drives the profitability of the chlor-alklai industry; when caustic soda is in over supply producers compete fiercely with each other for markets driving down their profitability.

3.5. Chlor-Alkali Industry Changes

In Scandinavia, chlor-alkali production plants have been closed down, because of a decrease in chlorine demand for pulp bleaching to a neglible level, whereas caustic soda demand has remained stable, according to Euro Chlor. These closure are reported to have included one small memebrane plant in Norway[12]. The decrease in chlorine demand is mainly caused by the substitution by other techniques of chlorine bleaching of pulp, whereas caustic soda is still used. A similar development in reduced regional demand, is occurring, although at a slower rate, with respect to chlorine bleaching in NA, including the closure of 4 membrane cell plants in USA and Canada[12], leading to some rationalisation of the industry in NA and in WE. Reduced demand for use in solvent manufacturing and products regulated by Montreal Protocol has also occurred.

In NA, chlorine is transported extensively, allowing some separation of chlorine production from downstream operations, whereas in WE chlorine transport is limited. In EU even though closures of uneconomic capacity have occurred over the past 10 years, chlorine production has remained broadly static since 1991, as demand in other sectors has offset decline in solvents, CFCs and paper and pulp. In the USA, chlorine use is growing, because of a growing demand for PVC in the USA and Asia, an important export destination for the USA EDC industry. It appears that the projected global growth in PVC is driving present and future investments in new chlorine capacity. Although caustic soda demand is growing, in the USA the surplus in supply/demand of this base chemical is growing but in WE the surplus is decreasing based on present trends. In the USA this will lead to increased exports to a wider range of destinations than the traditional ones. Based on the present economics of the various regions, investments in additional chlor-alkali capacity are more likely to occur in the gulf states of the USA and probably Asia.[13,14]

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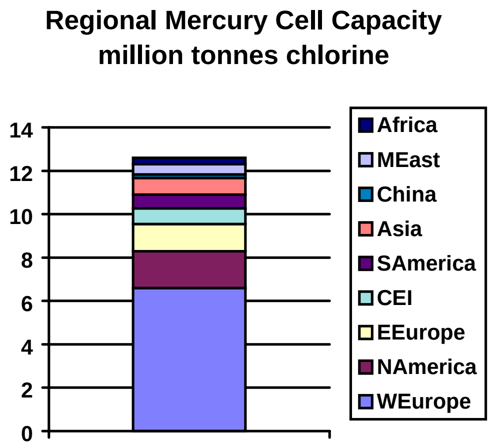
12 According to publicly available information collated by ICI Chemicals & Polymers

13 Chem Systems, The Chlorine/Caustic/EDC/VCM/PVC Chain April 1996

4. COMPETIVENESS OF THE CHLOR-ALKALI INDUSTRY

4.1. Cost Base Globally



In the various regions, the proportions of capacities of the three processes for chlor-alkali production is different.. WE's mercury cell capacity is about 64% of its total production capacity and it has 50% of the global capacity of mercury cells. In the USA, the mercury cell capacity is 13% of its total capacity. On a global basis, mercury cell capacity at about 12 million tonnes in 1995 is 28% of the total.[15]

Chlorine production is the most capital intensive part of the interlinked businesses which include downstream intermediates and products. The economics of chlorine production are broadly similar for each technology, but any replacement of old capacity at the end of its working life, or investment in new capacity generally uses membrane technology. Other factors such as economies of scale, electricity and raw materials costs tend to dominate.

The Chem Systems study indicates that the lowest cost producers are in Western Canada and the Middle East. The US Gulf States and Brazil are the next lowest, with Western Europe having costs which are on average of the order of $90 per EchemU higher than US Gulf States in 1995. Variable costs, and economies of scale are the most significant factors. The US Gulf States is a region that is attracting investment in chlorine production based in part on the electricity and raw material costs. The EU chlor-alkali industry has to compete for export markets with low cost producers, and consider the impact of low cost producers on the market within the EU. Comparison to the US Gulf States cost base appears to be appropriate.

4.1.1. Electricity Costs

Electricity costs play an important role in the chemical industry as a whole and are of vital importance for chlorine products. The Paris-based International Energy Agency produces data showing that average electricity prices to industry were 7.4 USc./KWh in OECD Europe and 4.7 USc./KWh in USA in 1994[16]. Furthermore, inside Europe

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14 D Hutchison, Anorganica Ltd, Current and Future Trends of Chlorine, Caustic Soda,and Chlorine Derivatives Production; GEST 97/230 Euro Chlor Fourth Technical Seminar February 1997

[15] Information Chemie n^{o} 366 mars 1995 and Euro Chlor data

[16] International Energy Agency Electricity Information 1995; OECD Paris 1996

energy prices to industry vary by as much as 100% between Member States, and in the USA electricity prices vary by a similar amount for North Eastern and US gulf states. Discounts are available for large electricity users, and in addition the EU chlor-alkali industry varies electricity demand, where practical, to match periods of lower electricity tariff, if available. As a result, the average price to chlor-alkali industry is generally lower than the industry average price, but the relative differences between countries and regions remain.

The SRIC study[9] for Euro Chlor found that the average cost of electricity to chlor-alkali manufacturers in Western Europe is 4.3 USc./KWh, whereas it is 2.8 USc./KWh in the US Gulf States. Taking into account the proportions of the three production processes used in WE at present, on average approximately 3000 KWh of electricity are required for the electroysis process to produce one EChemU (1 te chlorine, 1.1 te caustic soda, and hydrogen). On this basis, on average, a difference of 1.5 USc./KWh in electricity prices results in electricity costs differences of $45 per EChemU. This variation in electricity prices is equivalent to, on average, about 10% to 15% of the estimated present combined value of chlorine and caustic soda.[17,12]

The SRIC study[9] reports a broad range of electricity costs for individual production plants within Western Europe. The electricity costs varied between 2.3 and 5.5 USc./KWh for the plants surveyed. This wide variation of electricity costs within EU and across regions is one of the factors affecting competiveness within EU and externally.

The cost of electricity to the chemical industry will be affected by developing EU energy policies. Efforts to liberalise electricity markets will tend to lower energy cost inputs for the chemical industry. Chlor-alkali production uses electricity for electrolytic processes, but for membrane (and diaphragm) technology steam is also used to evaporate the caustic to a standard concentration. The required standard concentration is achieved directly using mercury cells.

The proposal for restructuring the Community framework for the taxation of energy products[18] considers the potential impact on the industrial sector, especially for energy intensive industries, and proposes exemptions, for example for the use of energy products in electrolytic processes (Article 13). It proposes approaches to allow Member States to refund some of the tax paid where energy costs for firms exceed 10% of production costs (Article 15). It proposes (Article 14) that Member States may apply total or partial exemptions or reductions in the level of taxation to heat generated during the production of electricity.

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[17] "Chlor-Alkali Industry Overview" C Fryer presented at the fourth TECNON Chlor-Alkali Conference, June 1997

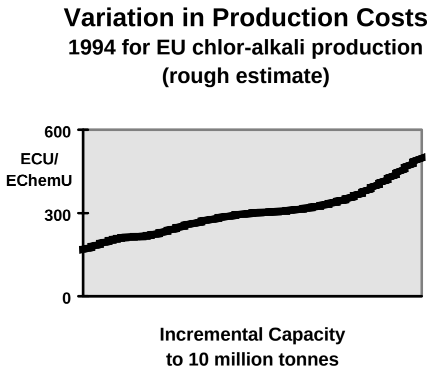
[18] Proposal for a Council Directive Restructuring the Community Framework for the Taxation of Energy Products (presented by the Commission) 97/0111(CNS)

"European Energy to 2020; A Scenario Approach"[19] considers various scenarios that lead to different overall energy costs. Two of the scenarios indicate falls in energy costs, of 3% or 14.9% based on 1995 costs, one indicates no change, and one indicates an energy cost increase of 3.2%. The potential impact of various approaches for fiscal measures for energy products has been modelled.[20] The study indicates electricity costs for industry, in general, are broadly similar or slightly higher by the year 2010 using the models applied.

It should be noted that the average USA electricity cost for industry in 1994 was 36% lower than in EU. The cost to the chlor-alkali industry in the gulf states of the USA is at present 35% lower than the average cost for the EU chlor-alkali industry according to the SRIC report.[9]

4.2. Cost Base In EU

Each chlorine production site within Europe is unique, in terms of chlorine production capacity (economies of scale), technology, and variable costs (salt and electricity). The chlorine may be used for one or more of a broad range of downstream chlorinated products or intermediates, and the available markets for caustic mean that there is a very broad spread of profitabilities for chlorine/caustic production units.The SRIC report indicates that salt costs varied between 1.5 and 5.5 USc./kg with an average of 3.6 Usc./kg in EU. This can be compared with the salt cost reported for the US Gulf States of 2.0 USc./kg.



Variation in Production Costs
1994 for EU chlor-alkali production
(rough estimate)

Some efforts have been made to compare the cost base of the production units across the EU. These were not based on directly collected information, but on an interpretation of available published data. This cost base comparison tends to indicate that other factors than the technology (mercury, membrane or diaphragm) tend to dominate, leading to a broad spread of costs and profitabilities, with minimal clustering based on technology.[21]

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[19] Energy in Europe, European Energy to 2020 A Scenario Approach Spring 1996, European Commission, Directorate General for Energy (DG XVII)

[20] Evaluation of Fiscal Measures for Energy Products in European Union, Results from the GEM-E3 and MIDAS Models, Report to European Commission DG XI, National Technical University of Athens , October 1996

[21] UK DTI Technology Foresight Study Chlor Alkali 1995

4.3. Assessments of the Prospects for WE Chlor-Alkali Industry

A qualitative view of some consultants,[22] familar with the global chlor-alkali industry, is that WE chlor-alkali industry is threatened by substantial rationalisation, based on its cost base and structure. New capacity growth is occurring outside EU, which may support the view that WE is not an attractive region, in general, for investment in chlor-alkali production. A qualitative view appears to be that unless the cost base changes significantly the same situation will continue. For economically driven scenarios that do not take account of the PARCOM Decision 90/3, there appears to be a qualitative view that there may be a "controlled rationalisation" over a period. Until the SRI Consultancy assessment prepared for Euro Chlor[23] there apparently has been no recent attempt to quantify the effect of the PARCOM Decision 90/3. At the time the PARCOM Decision 90/3 was laid down industry appeared to be more hopeful of replacing mercury cells more rapidly than seems economically possible today[24].

The background for such a study is that the chlor-alkali industry undergoes cycles in terms of supply/demand balance for both chlorine and caustic soda, which can be out of phase for the two products as their outlets are in different markets. Views of what may happen and what might be achievable change over time, but a study undertaken now has to be based on current views of what might happen. However the structural problems of the chlor-alkali industry and downstream industries appear to imply that there are fundamental issues to address irrespective of the position in the economic cycle.

This SRIC “Asssessment of the Competiveness of the WE Chlor-Alkali Industry” is in two parts; an independent survey of 14 companies, that operate 90% of the mercury cell capacity in WE, in terms of some of their costs and their present views of what could happen for their own mercury cell capacity in terms of closure or conversion for phase-out by 2010, and also for an economically driven scenario that does not take account of phase-out (closure or conversion) as laid down in the PARCOM Decision. Other available information has been taken into account for possible closure rates, process economics, and downstream process.

The second part of the assessment calculated, using a process economics model, the estimated production costs for WE on average for mercury cells and for converted plants taking into account the conversion costs and any differences in operating costs, and compared competiveness with the chlor-alkali industry in the gulf states of the USA, which is a region with expanding chlor-alkali production capacity and expanding exports. In addition it explored the potential economic impact on WE for

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[22] for example see papers presented at the fourth TECNON Chlor-Alkali Conference, London, June 1997

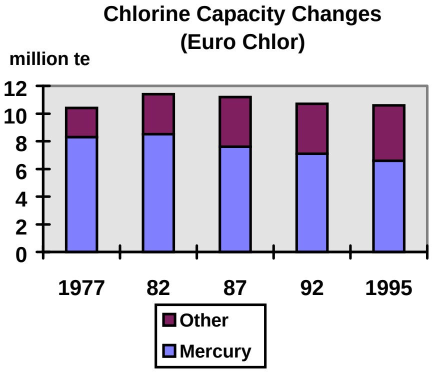
[23] SRIC “Competitive Situation of Western European Chlor-Alkali Industry in a Global Context” April 1997, prepared for Euro Chlor

[24] M G Beal, "Chlor-alkali: the Impact of Economic and Envionmental Pressures on Industry", in Modern Chlor-Alkali Technology; Volume 6, 1995, R W Curry (ed), SCI London

any changes in future chlor-alkali production capacity and costs. For the areas covered by the second part other sources of information are also available, and these have been taken into account in estimating conversion and production costs, and other economic effects.

4.4. Impact of a Phase-Out of EU Mercury Cells by 2010

Closure of mercury cell technology in Scandinavia occurred in part due to a drastic reduction in chlorine demand in that region, where local demand was largely for pulp and paper processing unlike the major chemical production industries in the rest of EU. During this capacity contraction in Scandinavia one small membrane cell in Norway was also decommissioned according to available information[25]. Industry indicates that generally, the replacement of some mercury cells with membrane cells occurs because the mercury cells have reached the end of their economic life and that this is expected to continue to occur in the future. In some instances the replacement of mercury cells may be judged to be economically viable because of particular local circumstances. However, it appears that each closure or replacement of mercury cells should be judged individually and not considered as a benchmark for the industry as a whole.



During the period 1982 to 1995, 1.94 million tonnes of mercury cell capacity were decommissioned, an average closure rate of 0.15 million tonnes capacity per year. From 1993 to 1997, the annual decommissioning rate was on average about 70,000 tonnes capacity. Based on the present mercury cell capacity of about 6.6 million tonnes an average closure rate of 0.55 million tonnes capacity per year would be needed to eliminate all mercury cell capacity by 2010. If the 1982-95 annual decommissioning rate was to occur until 2010, there could be about 4.8 million tonnes of mercury cell capacity 2010.

Present economically driven projections that do not take account of phase-out as laid down in the PARCOM Decision 90/3, estimate that total chlorine production capacity would remain broadly static,[26] with perhaps a slight decline of less than 5% in total capacity, as smaller less economically viable plants may be closed. For the mercury cell capacity surveyed by SRIC[9], which was 90% of the total mercury capacity, the capacity was forecast to remain broadly static (within 1%) with some mercury cell capacity being converted to membrane cells (0.9 million te of capacity), equivalent to the conversion of about 75,000 tonnes of mercury cell capacity per year until 2010 for the capacity surveyed.

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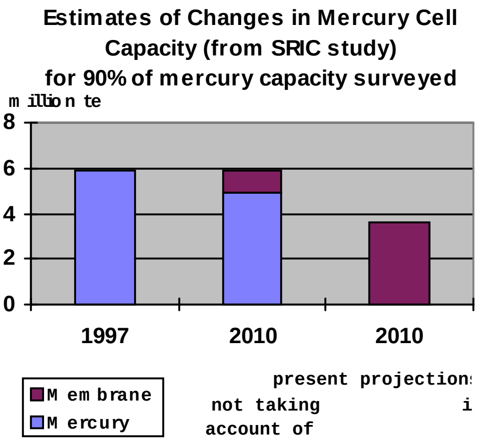
[25] According to available information collated by ICI chemicals & Polymers

[26] Chem Systems, The Chlorine/Caustic/EDC/VCM/PVC Chain April 1996

The apparently presently unfavourable cost base in WE means that significant investment in new or replacement capacity may be less attractive than investment in other regions. Furthermore integration with downstream operations means that any significant closures of chlor-alkali production plants without replacement will have a major impact on the viability of downstream operations. The future trend of electricity costs within the EU, and when compared to other regions, may have some influence on investment strategies.



Enforced phase-out of mercury cells by 2010 has been projected by the SRIC study[9] to result in a more significant shrinkage in chlorine production capacity estimated to be about 20% (2.2 million tonnes capacity). This is based on a survey of 90% of the mercury cell capacity in Western Europe (5.9 million te capacity, 14 companies). It could be expected that there might be a similar or even greater capacity reduction in the unsurveyed portion (0.7 million tonnes, 18 companies) as this tends to be the smaller plants. If a reduction of this magnitude did occur then it might be expected to lead to a restructuring of downstream operations. Each company operating mercury cells will naturally have its own strategy and this may result in some companies expanding their capacity in chlorine production, although it is not certain that this would occur in EU, whereas others would be expected to reduce capacity and perhaps focus investment in other sectors or geographic regions.

Scenario	Annual Decommissioning Rate	Mercury Cell Capacity by 2010 Estimate
1982 to 1995	150,000	
1997 to 2010	150,000	4.8 million tonnes
1993 to 1997	70,000	
1997 to 2010	70,000	5.8 million tonnes
Economically driven (SRIC) from survey of 90% of capacity	75,000	5.0 million tonnes (for 90% of present capacity, upto 5.7 million te extrapolated to 100% of present capacity)
To phase-out by 2010	550,000	0
Phase-out scenario (SRIC) for 90% of closures present conversions capacity	 183,000 300,000	0

Based on the possible scenarios considered for mercury cell decommissioning rates, it appears that up to of the order of 5 million tonnes of mercury cell capacity by 2010 may be appropriate for an economically driven scenario.

4.5. Projected Economic Impact due to Phase-Out of Mercury Cells by 2010

4.5.1 Trade Balance

If the reduction in chlorine capacity projected[9] occurs, due to phase-out by 2010, then it is possible to estimate the potential effects on the chemical industry in EU. These estimates will depend to some extent on the forecast demand for chlorine derivatives and caustic soda in the EU. The SRIC study[9] forecasts an increase in demand for chlorine (as chlorine or derivatives) of 350,000 tonnes by 2001. Another study[12] (Chem Systems) forecasts an increase in demand of up to 1 million tonnes of chlorine (as chlorine or derivatives) by 2005 in EU. Net exports of caustic soda from Western Europe in 1995 were about 900,000 tonnes (Chem Systems) and are forecast to decline to about 500,000 tonnes by 2005, due to increasing demand in EU, with little or no additional capacity being added.

The SRIC study projects a deterioration of Western European chemicals trade balance by at least 2.6 billion ECU by 2010 (equivalent to about 6 to 7% of the current Western European chemicals trade balance). In total it is estimated, that the shortfall is equivalent to 2.5 million metric tonnes of chlorine, and 2.9 million tonnes of caustic soda of by 2010. There would be a requirement to cover by imports the forecast increased demand for chlorine derivative products, and the forecast chlorine capacity reduction, due to phase-out by 2010. Based on these assumptions the impact on trade balance, attributable to the forecast capacity reduction of 2.2 million tonnes capacity, appears to be of the order of 2.3 billion ECU by 2010 (about 90% of the overall 2.6 billion ECU trade balance impact).

4.5.2 Capital Expenditure

The capital cost of replacing an estimated 5 million tonnes of mercury cell capacity, which could continue to be economically viable after 2010, could be of the order of 2.8 billion ECU, based on 560 ECU per tonne of capacity conversion cost. However the SRIC study suggests a shrinkage in production capacity could occur due phase-out by 2010, with of the order of 1.5 billion ECU required to replace the additional 2.7 million tonnes of mercury cell capacity that would be converted rather than closed. In principle, the net cost of advancing the conversion of mercury cells to 2010 from their economic lifetime, together with any differences in operating costs should be used to provide a more accurate economic cost. The capital cost could approximate to the economic cost if the average economic lifetime is sufficiently long beyond 2010, which may be the case based on typical mercury cell plant lifetimes, and if the operating costs are broadly similar. It appears that this capital would not generate any significant additional business for the chemical industry. In addition there appears to be a need to improve the competiveness of the chlor-alkali industry in EU, based on the cost competiveness compared to other regions such as the US Gulf States. This is expected to require significant capital investment, even without the further burden of capital investment for mercury cell phase out, to allow restructuring of chlorine production and downstream operations, and some restructuring has started[27].

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[27] see for example Chemical Week, March 26 1997

The integrated nature of the EU chemical industry, availability of capital for investment (which is also a function of profitability), and any effects of restructuring are difficult to take into account when estimating broad effects on the magnitude of turnover and employment. The main assumptions used are that the annual rate of investment by the EU chemical industry is broadly constant and that the impact of mercury cell replacement (per unit capacity) is broadly neutral in terms of turnover and employment. In addition any effects of restructuring are ignored.

The Western European chemical industry in total, with a turnover in 1995 of 380 billion ECU, has invested about 18 billion ECU in each of the years 1993, 1994, and 1995[28], although total capital expenditure is not fixed. The capital required to replace economically viable mercury cells could replace capital expenditure for other chemical industry projects, given that the industry as a whole tends to invest a certain amount of capital. Based on this assumption, any economic activity in membrane cells construction and installation could be offset by a decrease in economic activity in other potentially more productive chemical engineering sectors.

Based on the assumption that investment in mercury cell conversions could replace other capital expenditure then 1.5 billion ECU investment on other chemical projects could be expected to produce some additional turnover within the chemical industry. A Return on Capital of 15% and a Return on Sales of 10% equates to a turnover of 2.2 billion ECU, as a simple estimate. At the end of their economic life mercury cells would need to be replaced or closed, and capital expenditure would then be required, but for a significant proportion of the installed capacity the economic lifetime appears to be significantly beyond 2010, according to industry.

It appears that considering possible effects of capacity reductions (estimated at 2.3 billion ECU) and potential effects on other capital projects in the chemical industry (estimated at 2.2 billion ECU), and based on the assumptions used, there could be an overall impact on the chemical industry equivalent to a turnover of the order of 4.5 billion ECU by 2010.

4.5.3 Employment

The estimation of any effects on employment is open to question given the various methods that could be used to estimate such effects, and any estimate should be treated with caution. What is apparent is that significant effects on investment and turnover of the chemical industry might be expected to have some impact on employment within the chemical industry, and some impact on second order (direct support) and third order (community) employment. Second (direct support) and third (community) order employment effects have in some studies been related to primary employment by using a multiplier. The general trends of employment within the EU chemical industry could be used to provide a broad indication of the future relationship between turnover and employment for a sector of the basic chemicals industry. However the assumptions

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[28] Facts & Figures, The European chemical industry in a worldwide perspective, November 1996, CEFIC.

used to estimate the turnover under consideration will directly impact any estimation of primary employment.

Employment in the EU chemical industry on average is 4,660 employees per billion ECU of turnover in 1995.[29,30] Employment directly in chlor-alkali production was 42,000 in Western Europe in 1995 according to Euro Chlor data, a rate of about 14,000 employees per billion ECU of turnover. On average employment in the chemical industry is declining on average by about 1% per year, while output has increased by about 2.9% per year over the 10 years from 1985. Average employment rates within the basic chemicals sector appears to be about 90% of the average for the chemical industry as a whole, based on available data for 1993.[16]

Based on the trends of the last 10 years, one scenario is that the average employment rate in the Western European chemical industry, may decline by the year 2010 to 2,610 employees per billion ECU of turnover, from a 1% per year decrease in total employment and a 2.9% per year increase in total turnover. This may equate to a rate of about 2350 employees per billion ECU for basic chemicals. Based on these assumptions, 4.5 billion ECU turnover in the basic chemical industry could broadly equate to about 10,000 employees directly in the chemical industry by the year 2010. In addition there could be related second and third order employment.

4.5.4 Local Effects

Any restructuring of the chlor-alkali industry to improve competiveness might be expected to have some local effects. The timescale and magnitude of any local effects might be expected to be influenced by a decrease in chlorine production capacity. Economies of scale is one factor that will be important for any restructuring or closure of capacity, and on this basis smaller more isolated cellrooms may appear to be vulnerable. The local intensity of employment for chlorine production will be a factor in determining the relative local impact of any capacity closure.

5. CHLOR ALKALI PRODUCTION PROCESSES

5.1. The Three Production Technologies

There are three distinct chlor-alkali processes in use, the mercury cell, the diaphragm cell, and the membrane cell process. These chlor-alkali processes are based on the electrolysis of sodium chloride or potassium chloride forming the products chlorine, hydrogen, and sodium hydroxide or to a much lesser extent potassium hydroxide. Synonyms for sodium hydroxide and potassium hydroxide are respectively, caustic soda and caustic potash.

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[29] Communication from the Commission, “An Industrial Competiveness Policy For The European Chemical Industry: An Example” COM(96) 187

[30] CEFIC Facts & Figures The European chemical industry in a worldwide perspective, November 1996, and other information provided by CEFIC.

Mercury cells were installed in Europe up to the mid 1970s prior to the availability of efficient membrane cell technology. In the late 1970s and early 1980s diaphragm cells were the main technology choice in Europe until membrane cells were considered to have a sufficient track record of reliability.

All three technologies are applied in most regions of the world. However, in Japan, most of the mercury cells were substituted by mainly membrane cell production facilities. The reason was the Minamata tragedy, where serious organo mercury pollution from an industrial effluent, not related to chlor-alkali production, resulted in serious adverse effects on humans and the environment. A replacement program was set up, which took considerably longer than anticipated, when it became clear that diaphragm cells alone could not sustain the downstream industry due to the demand for high purity caustic. Time was needed to develop the membrane cell process, with viable membranes. Mercury cells plants are still in use in Japan for the production of chlorine in combination with potassium hydroxide[31].

5.1.1 Technical Differences

There are significant technical differences between the three technologies both in terms of the product quality and operation of the technology, which are summarised in the table[32].

- Mercury cell process

The mercury cell process has been in use in Europe since 1892 and it generates high quality sodium hydroxide with low salt content. It uses a thin flowing film of mercury, in a gas tight long wide trough (of the order of 15m by 2.5m for individual cells) as a cathode to remove sodium (or potassium) from the cell and transport it to a decomposer, where the mercury amalgam is reacted with water to produce hydrogen and sodium hydroxide.

- Diaphragm

The diaphragm cell process was developed in the 1880s in the USA, and a characteristic of the process is the production of low concentration caustic soda, about 12%, containing a high concentration of salt (about 15%). Concentration and salt removal is necessary for virtually all applications. The final caustic soda solution at 50% concentration contains up to about 1% salt and also chlorate, which makes it unsuitable for some applications. The individual diaphragm cells are of compact design (when compared to mercury cells), and contain a porous diaphragm, which is used to separate the two halves of the cell, allow a flow of brine, and to prevent chlorine and hydrogen from mixing. The present generation of diaphragm cells uses an asbestos diaphragm. Alternatives to asbestos are being investigated.

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[31] Topics in Alkali Demand and Supply, p18, D Hutchison; presented at The fourth TECNON Chlor-Alkali Conference, London 3 June 1997.

[32] see also Ullmann, Encyclopaedia of Industrial Chemistry, Volume A6, p406, Chlor-alkali process

- Membrane

In the 1970s the membrane cell process was developed in Western Europe and Japan. It was not until the late 1970s that suitable membranes, developed in Japan, were made available, following the development of durable and efficient fluoropolymer membranes. The process generates high quality products but also requires very high purity brine (salt solution) as the membrane performance is sensitive to very low concentrations of some impurities at ppb level compared to mercury or diaphragm which can accept impurities at ppm level.

	Mercury	**Diaphragm**	**Membrane**
Caustic quality	high	Contains 1% salt-not suitable for some applications	high
Caustic concentration	50%	12%- not suitable for some applications, requires concenttration to 50% for some applicationsq	33%-requires concentration to 50% for some applications
Chlorine quality	contains little oxygen contains some hydrogen	Oxygen content between mercury and membrane diaphragm pinholing or failure affects hydrogen content	contains less hydrogen contains more oxygen which can affect reactivity of the chlorine for some processes,
Brine feedstock	some purification required but depends on purity of salt or brine used	Some purification required, but some impurites eg magnesium levels must be controlled to maintain good diaphragm performance	very high purity brine is required as impurities affect membrane performance
Variable electric load performance	good variable electricity load performance, down to 30% of full load possible for some cell rooms, which is very important in some European countries	Constant electricity load and brine flows used to maintain diaphragm performance.	variable electricity load performance less than for mercury (40-60% depending on design load) affects product quality, and efficiency at lower loads.
service and maintenance	routine maintenance to prevent mercury emissions	Issue of sudden diaphragm failure or pinholing Diaphragm life typically 1 year for asbestos	membrane life typically 4 years, replaced either for individual cells on an ongoing basis or as part of a major maintenance programme

5.2. Caustic quality

Caustic from mercury cell or membrane cell caustic is considered high purity, but the salt concentration in membrane cell caustic soda is four times as high as in the mercury cell product. Compared to diaphragm grade caustic, which contains about 1% salt, mercury and membrane cell caustic have a wider application. Some chlor-alkali production facilities can combine the caustic production process from mercury and membrane cells in order to minimise energy costs. It is possible to feed 33% caustic from the membrane cells to the decomposer to produce 50% caustic without the need for evaporation.

5.3. Operating Parameters and Direct Costs

The three technologies have a different operating parameters and a different balance of operating costs, and some of the differences are indicated in the table[33]. A range of power consumption figures are available for each technology, and these appear to be due to the slightly different configurations and operating parameters that are used. Overall for membrane cells although additional costs may result from higher steam requirements and brine purification requirements, the operational cost is in most cases likely to be lower.

	Mercury	Diaphragm	Membrane
Current density KA/m^2 affects power consumption and unit output	8 to 13	0.9 to 2.6	3 to 5 3 to 4 (1994) 4 to 5 (new installations)
Electrolytic power consumption MWhr/te chlorine	3.36 at 10 KA/m^2	2.72 at 1.7 KA/m^2	2.75 at 3.3 KA/m^2 (1994) 2.5 at 5 KA/m^2 installers information for new installations
Power costs for electrolysis	of the order of 40% to 45% of total direct costs		of the order of 32% to 39% of total direct costs
Caustic soda evaporation (steam) Mwhr/te chlorine	0	0.61	0.2
Other raw materials costs excluding salt, power, and steam	of the order of 7% to 10% of total direct cost		of the order of 12% to 15% of total direct cost or 1.4 to 1.8 times absolute cost for mercury cells

According to membrane cell installers,[34,35] the present generation of membrane cells have reached a plateau in terms of performance, with only small incremental improvements remaining. The power consumption of cells is reaching the thermodynamic limit, with the possibility of 50 KWhr/te as an improvement target (about 2% of electrolyic power consumption). The improvements in cell design and geometries, and membrane resistance allow installations with higher current densities (typically 4.5 to 5 KA/m^2 of electrode area). Several years ago the current density of installations was typically less than 4 KA/m^2). Increased current density reduces capital costs of an installation because the production per unit cell capacity is higher. However there is a trade-off because higher current densities mean higher power

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[33] Based on SRIC April 1997 for Euro Chlor “Competitive Situation of Western European Chlor-Alkali Industry in a Global Context”, and Euro Chlor Publication, “Chlor-Alkali Mercury Cells: Economics and the Environment” October 1994, and discussions with companies that are members of Euro Chlor.

[34] Electrochemical Technology Business, ICI

[35] Krupp Uhde

consumption, and the unit cost of electricity can be a factor when determining the appropriate trade-off between capital cost and power consumption. At 5 KA/m^2 the power consumption per tonne of chlorine is reported by installers to be of the order of 2.5 MWhr, which is 25% lower than the reported power consumption of mercury cells at 3.36 MWhr per tonne chlorine. At lower current densities (3 KA/m^2) the power consumption would be lower at about 2.3 MWhr per tonne of chlorine for new membrane installations, but the unit output would be also be lower leading to higher capital cost. In 1994 the power consumption of membrane cells for electrolysis was reported as 2.75 MWhr per tonne chlorine (18% less than mercury cells).[36]

The reported power consumption for electrolysis for new membrane installations is about 9% lower when compared to several years ago. From the available information it appears that the power costs for electrolysis for membrane cells is of the order of 32% to 39% of the total direct cost on average in WE, suggesting that reduced electrolyic power consumption for new installations may result in a direct cost reduction of the order of 3% when compared to older membrane installations.

5.4. Variable Electric Load Performance, Impact on Base and Peak Electricity Demand

The use of variable electricity loads can vary significantly for individual chlor-alkali plants, and depends on several factors, including, cell technology, downstream demand for chlorine or caustic, and electricity tariff variations.

5.4.1 Electricity tariff

Where the electricity tariff is constant then stable operation imposes no cost penalty. Dedicated power stations or fixed contracts can help to achieve this. For example in the USA a large proportion of the membrane cell capacity is located in the gulf states, where the electricity tariff is constant. In some European countries the most cost effective way to run chlorine cells may be to vary the cell electrical demand to match the changing electricity tariff, which at some periods can be large variations on an hourly basis, for example during the daily peak demand period (16.00 to 19.00) in winter.[37] At constant load conditions at periods of high electricity tariff production may be uncompetitive in some circumstances. These high tariff periods may require that the cells are run at as low capacity as possible without unacceptable impact on performance. Some cell rooms have associated power stations which may supply a proportion of the required electricity to help minimise the impact of peak electricity tariffs. Variable electric load is reported to be used to some extent in most of the EU countries, although in Germany[38] constant load is reported to be utilised to a large extent.

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[36] Euro Chlor Publication, "Chlor-Alkali Mercury Cells: Economics and the Environment" October 1994

[37] "Electricity Prices An International View" P Boulding present at the fourth TECNON Chlor-alkali conference , June 1997

[38] Information provided by Bayer

5.4.2 Cell Technology

Mercury cells can be operated under a broad range of loads without a major impact on performance. Typically a 30% load may be considered the minimum acceptable. The mercury cells at some plants are operated in a highly flexible manner to ensure that chlorine production remains economic and competitive, as the electricity tariff varies. Membrane cells have somewhat less flexibility to operate at different loads, with 40% to 60% load being considered a minimum depending on the design load. The acceptable minimum load is determined by a decrease in caustic purity, formation of hypochlorite, and increased oxygen in the chlorine, At lower loads than acceptable the electrical efficiency decreases. Diaphragm cells require much more uniform operating conditions to maintain acceptable performance, with the diaphragm integrity and performance being sensitive to variations in operating conditions.

5.4.3 Impact of change to membrane cells

A complete switch to membrane cells will result in *a reduction in base load for EU*, (assuming production capacity remains broadly constant). This may be of the order of 500 to 600 MW, equivalent to about one power station. However the reduced variable load performance for membrane cells may result in less ability to reduce demand. The *increased peak demand load* could be of the order of 200 to 400 MW in EU (but from an overall lower base load). These estimates do not include steam generation for membrane grade caustic evaporation, which may utilise primary fuel sources directly, or be available from other chemical plant operations.

5.5. Chlor-Alkali Plant Lifetime

The installation of a plant (for any technology) is capital intensive, and requires dedicated buildings. The functional lifetime of a plant depends in part on the functional life of the building in which it is housed, given that individual cells are routinely maintained, refurbished, or renewed.

Plant lifetimes of 70 years are known but typically, according to Euro Chlor, the cell room lifetime tends to be in the range of 40-60 years in the absence of other factors, (economics, local chlorine demand, performance etc).

Although plant lifetimes can be of the order of 40-60 years, depreciation of the investment conventionally in EU appears to be over 10 years. Several reasons are indicated by industry for this approach; constant refurbishment of cells is required, as the cell components wear out and replacement is carried out routinely; predicting the economic viability of this type of plant much beyond 10-15 years is considered difficult given the dynamic nature of developments in the chemical industry, and prudent accounting practices are used; For converted plant (mercury to membrane), any associated downstream assets may already be quite old and the viability of the total complex is thought difficult to predict beyond 10-15 years.

For example according to publicly available information[39], 5 membrane cell plants have closed after operating for about 10 to 15 years. It appears that these were related to the supply of chlorine in locations where pulp and paper bleaching was the main outlet. Two of the plants were in Canada, two in USA and one in Norway. The publicly available information indicates that one of the US plants (about 90,000 tonnes capacity) opened in 1985, was closed in 1994, and reassembled in India. Apparently the small membrane plant (16,000 tonnes) in Norway was operated by Tofte and closed in 1992 after operating from 1981.

6. CONVERSION TO MEMBRANE TECHNOLOGY

6.1. Technical Issues

Membrane cells are very different to mercury cells. Converting mercury cells to membrane cells incrementally over a period of time within a mercury cell room appears to be not generally considered to be practical or cost effective by industry. The main reasons reported for this are:

- A separate recirculated brine system could be required because for membrane cells trace quantities of mercury can have a significant impact on the performance of the membrane. In principle it may be possible to consider using an ion-exchange systems to remove the mercury, but any mercury would tend to accumulate in the membrane affecting performance and lifetime. The membrane lifetime and performance are critical issues given their high cost.

- The cell layouts are totally different for membrane and mercury cells, and the power densities and heat loads are also different. This suggests separate power supply system (rectifiers) would be needed.

- The mercury cell room layout is designed to enable mercury to be contained. Operating membrane cells within the same cell room would require some mercury containment activities and some of the working practices even in those areas where the membrane cells are located, again indicating that incremental conversion is not generally considered practical.

Therefore conversion from mercury cells to membrane cells is normally carried out for a complete cell room. This can be achieved in different ways:

- Retaining the building shell and replacing totally the mercury cells with membrane cells. This option depends on the quality of the building structure and the decontamination required prior to installation of membrane cells. A complicating factor is the local chlorine demand, given the integrated nature of many complexes using chlorine, which may preclude, for some installations, a significant decrease in chlorine supply implicit in this type of conversion.

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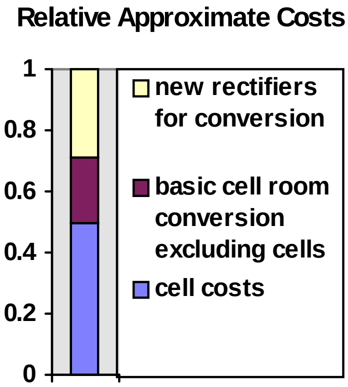
[39] according to information provided by ICI Chemicals & Polymers

- Building a completely new cell room either in the same location (which may be a chemical complex). The existing mercury cell room would then be decommissioned, and the downstream demand for chlorine would be provided by the replacement cellroom. This would allow essentially uninterupted chlorine supply which may be required for the downstream operations to remain viable, with the reconfiguration of the chlorine supply systems occuring over a short period of time. The reuse of the rectifiers, a major cost item for any cellroom, will depend on the type of membrane cell configuration and its power requirements, the rectifier refurbishment options if any, and the age of the rectifier. However any savings from the reuse of rectifiers could potentially be offset to some extent, depending on the circumstances, due to lost production (including downstream processes) from disruption during changeover.

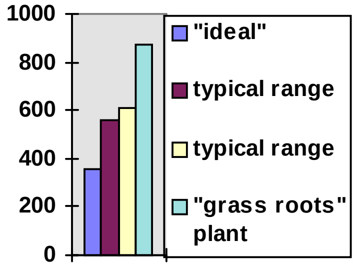
- Building a replacement cell room in an entirely new location to take advantage, for example, of any economic factors, but this may require a restructuring of downstream production processes given the integrated nature of many chemical complexes producing and using chlorine. Relocation of downstream operations and the issue of chlorine transportation becomes important when considering any restructuring of the industry.

6.2. Cost of Conversion



The cost of converting a mercury cellroom to a membrane cell room varies according to the determined requirements for any particular conversion. A range of costs may be quoted, and again this is influenced by what is included in the total cost. The cell costs could be of the order of half of the conversion costs if new rectifiers are required, but the conversion cost would be lower if the rectifiers can be reused[41], subject to any penalty from disruption of production.

Approximate Conversion Costs
ECU/te chlorine capacity



A range of approximate conversion costs are available. An “ideal” mercury cell conversion (reusing everything including the rectifiers, but replacing just the cells) may be about 360 ECU per tonne of chlorine capacity for plants with capacities less than about 100,000 tonnes chlorine according to one estimate[40,41,42,43]. There are published details[44], including costs, for a conversion that occurred in 1990. The conversion reused the existing building structure and rectifier and could be considered as closer to an “ideal” conversion. The published costs are equivalent to 408 ECU per tonne chlorine capacity[45] and for comparison to present cost estimates, any effect of inflation might be offset to some extent by any cost reductions in membrane cells since 1990. For this conversion the site layout and chlorine demand allowed for a planned conversion that minimised production disruption. This was possible because chlorine requirement had decreased 20,000 tonnes prior to 1990, resulting in the availability of some spare mercury cell capacity and an available rectifier. One reported trade-off involved using the older, less efficient rectifier, with perhaps less useful working life, as this allowed for a future capacity increase.

A typical conversion cost might be in the range of 560 to 610 ECU per tonne chlorine for capacities of about 150,000 tonnes, and a “grass roots” plant might be of the order of 870 ECU per tonne chlorine capacity for plants with capacities less than 100,000 tonnes chlorine. However there is a broad spread of costs quoted for replacement plant depending on what is actually required and the interpretation of what is considered to be the “plant boundary”. The SRIC study uses a conversion cost US$700 (610 ECU[46]) equivalent to US$111 million (96.6 million ECU) for the average Western European mercury cell plant capacity of 157,000 tonnes of chlorine.

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[40] Krupp Uhde (membrane cell manufacturer and installer).

[41] Electrochemical Technology Business ICI (membrane cell manufacturer and installer).

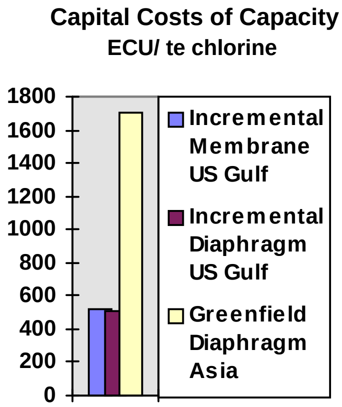
[42] SRIC “Competitive Situation of the Western European Chlor-Alkali Industry in a Global Context” April 1997, prepared for Euro Chlor;

[43] The Chlorine/Caustic/EDC/VCM/PVC Chain April 1996, Chem Systems

[44] “Practical Experiences on the Conversion of Mercury Cells to Membrane Technology” B Lott p243-251 in Modern Chlor-Alkali Technology Vol 6 Ed R W Curry SCI 1995

[45] 40,000 tonnes chlorine capacity, cost 11.58 million UK pounds, using current exchange rate of 0.71 ECU per UK pound

[46] SRIC uses 1 US$=0.87 ECU (also used 1 ECU=1.95 DM 1ECU=0.71UKpound)



These costs are broadly in line with the cost quoted (by Chem Systems) for an incremental expansion of an existing membrane or diaphragm plant in the US Gulf, where there is the ability to expand at much lower investment costs than for greenfield projects.

This replacement investment can be compared with that required for a natural gas combined cycle power station. The use of membrane cells should result in a electricity saving, which could be of the order of 25% (ignoring steam requirements and other changes in costs) for an investment of about 88 to 97 million ECU, for an average capacity cell room. The 30 to 38 million ECU required for a (share of a) natural gas power station required to provide the electricity for the average European capacity mercury cell production unit could result in an increase in fuel efficiency of about 30% for electricity generation compared to a coal fired power station.[47]

6.3. Conversion Cost for the Chlor-Alkali Industry in Western Europe

Different scenarios are possible to estimate the conversion cost for the chlor-alkali industry in Western Europe. An economically driven scenario[42] that 15% of the mercury cells (0.9 million tonnes capacity) might be converted by 2010 for the 90% of mercury cell capacity surveyed. The same study indicates that phase-out by 2010 could result in a reduction in chlorine production capacity of 2.2 million tonnes (out of 5.9 million tonnes surveyed) and installation of 3.6 million tonnes of membrane capacity. From these figures the additional membrane capacity installed due to the PARCOM Decision is 2.7 million tonnes. Using a conversion cost of 560 ECU per tonne of chlorine, results in an estimated cost to the industry of 1.5 billion ECU. This cost of conversion excludes any other costs associated with the projected closure of 2.2 million tonnes of production capacity such as associated rationalisation of downstream production. In principle, the net cost of advancing the conversion of mercury cells to 2010 from their economic lifetime, together with any differences in operating costs should be used to provide a more accurate economic cost. The capital cost could approximate to the economic cost if the average economic lifetime is sufficiently long beyond 2010, which appears to be the case for a significant proportion of mercury cells in the EU, based on typical mercury cell economic lifetimes, and if the operating costs are broadly similar.

The cost to replace the estimated 5 million tonnes of mercury cells not converted due to economic reasons, without shrinkage of chlorine production capacity, could be estimated at 2.8 billion ECU by 2010, which is similar to the total turnover of the chlor-alkali industry (estimated at about 3 billion ECU). Replacing the 6.6 million

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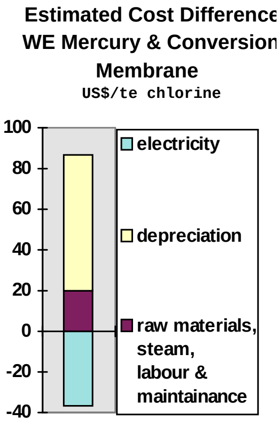
[47] Based on published information for investment in a combined cycle natural gas power station in UK

tonnes of mercury cell capacity currently in Western Europe, based on conversion costs of 560 ECU per tonne capacity is estimated to cost 3.7 billion ECU.

6.4. Economics of Conversion

The Western European chlor-alkali industry is on average less competitive than the North American industry, and in particular when compared to the chlor-alkali industry in the US Gulf States. The downstream EDC/VCM/PVC chain is also less competitive. Any demand growth in PVC has been proposed to drive the entire business,[43] with PVC demand reported to growing globally. The PVC industry in Europe had low or zero profitability in 1996,[48] which appears to be the result of structural issues for the industry in EU (eg economies of scale, compared to other regions). The fact that chlor-alkali production is the most capital intensive part of the entire business chain means that chlorine producers are reluctant to expand chlor-alkali capacity without assured outlets for chlorine specifically in the PVC chain.[49] The issue of conversion of mercury cells appears to be broadly similar for a significant part of the chlorine producing industry. Assured commercially viable outlets for the chlorine are necessary in order to underpin any investment. However the Western European Chlorine/Caustic/EDC/VCM/PVC chain, even without the additional investment required for mercury cell conversion, may have to address its cost base through restructuring (difficult for chlorine production due to the present industry structure in Western Europe), to achieve improved economies of scale and reduced variable costs, in order to remain sufficiently competitive. This restructuring is already occurring for PVC production in Western Europe[42], but it is reported that further work needs to be done[50].



The additional investment required due to phase-out by 2010 to replace economically viable mercury cells, assuming that the economic lifetime is sufficiently long beyond 2010, is expected to lead to an increase in total costs for the average European plant. Depreciation of the investment, over ten years, could add 64 to 70 US$ (based on a reported typical conversion cost in the range 560 to 610 ECU per tonne chlorine capacity) in allocated costs per tonne of chlorine production (assuming 100% capacity utilisation) for a period of 10 years. At lower capacity utilisation the allocated cost per tonne would be proportionately higher and at 92% capacity utilisation would be about 70 to 76 US$ per tonne chlorine

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[48] reported company results for 1996 for a major European PVC manufacturer; and SRIC "Competitive Situation of the Western European Chlor-Alkali Industry in a Global Context" April 1997, prepared for Euro Chlor; and Chemical Week, March 26, 1997, p16

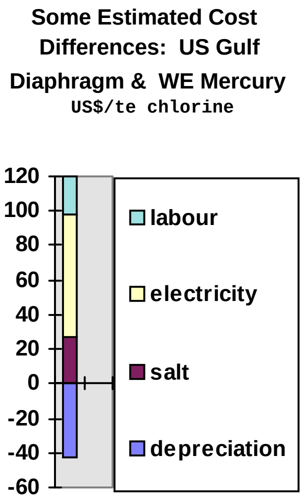
[49] The Chlorine/Caustic/EDC/VCM/PVC Chain April 1996, Chem Systems

[50] "The Changing Face of PVC Global Integration" M Stanley, presented at the fourth TECNON Chlor-Alkali Conference, June 1997

production. This allocated cost increase could be offset, to some extent by an overall decrease in direct costs. From an assessment of the available published data,[42,51] and some discussions with Euro Chlor member companies, it appears that the decrease in average direct costs could be of the order of 15 to 20 US$ per tonne (13 to 17 ECU), based on a 25% reduction in electricity consumption for membrane electrolysis at 2.5 MWh per tonne chlorine (a saving of about 37 US$ on average based on the SRIC reported[42] cost of electricity for WE chlor-alkali industry of 4.3USc./KWh), an increase in raw materials costs, an increase in steam usage, and a perhaps a decrease in labour and maintenance costs.

Based on these differences it appears that total costs for chlorine production after conversion could increase by of the order of 50 to 60 US$ per tonne (45-50 ECU), for 92% capacity utilisation, but the cost increase would be slightly lower for higher capacity utilisation. The SRIC study[42] estimates a cost increase of the order of 70 US$ per tonne , based on their process economics model. Based on information from membrane cell installers a further 50 KWh electricity per tonne chlorine production may be a possible future improvement target, which is equivalent to about 2 US$ per tonne chlorine (at 4.3 USc./KWh). There is also reported to be a tradeoff between capital cost and power consumption (see Chapter 5: section: Operating Parameters and Direct Costs).

The apparent increase in cost burden from conversion could on average be expected to further increase the reported difference between production costs in WE and the gulf states of USA.



The chart indicates some of the sources of cost differences, according to the SRIC study[42], based on an average 157,000 tonne chlorine production plant in WE using mercury technology, compared to a 678,000 tonne diaphragm cell plant in the gulf states of USA, where economies of scale result in cost benefits, such as labour costs. The much lower depreciation for mercury cells compared to relatively new diaphragm cells offsets some of the cost differences. The direct cost of production for diaphragm and membrane in the gulf states of USA is, according to Chem Systems[43], broadly similar (about 7 US$ per tonne of chlorine difference), and the difference in cash cost of production between gulf states USA and WE is estimated[43] to be of the order of 90 US$ per tonne in 1995.

It is not anticipated that deregulation of the electricity supply market in EU will eliminate the difference from US Gulf States prices across EU as a whole. However even if this did occur, a net deterioration in the relative cost base of the EU chlorine production industry could still be projected from conversion, in the absence of other

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[51] Euro Chlor publication “Chlor-Alkali Mercury Cells: Economics and the Environment” October 1994

factors. The Middle East, when compared to the gulf states of USA, is reported[43] to have similar or lower cash costs of production, due to low power costs[52].

The market price of caustic soda is of the order of US$50 per tonne lower in USA than in EU[42,52]. The costs of shipment (freight, duties, and handling) for caustic from United States, estimated at US$66/te of caustic (equivalent to US$60 per te *chlorine production*) are proposed as not preventing the imports from being competitive if EU producers allocated additional costs from conversion to caustic soda.[42] The downstream PVC business in Europe is projected, based on present performance, to move into loss if the additional costs are passed on in the chlorine price. Therefore one possible outcome of using price to offset increased costs is to stimulate the importation of caustic soda, and chlorine derivatives used in the PVC chain (EDC, VCM, and PVC) into Western Europe from lower cost producers. A recent paper[50] anticipates that a number of PVC producers faced with the costs of converting their own mercury cell chlorine capacity will instead seek to buy in at least some ‘chlorine’ as EDC from either the USA or the Arabian Gulf.

6.5. Downstream Integration and Conversion

Although chlorine is transported to some extent within Europe (15% of the chlorine produced in Western Europe) and to a greater extent in USA, there is no significant chlorine transportation between regions, due to the hazardous nature of the chlorine. Therefore the chlorine/EDC/VCM/PVC chain is vulnerable to increased chlorine cost within EU because:

- The narrow margins of the PVC industry, in EU, making reinvestment in chlorine production for use in the PVC chain in EU uncertain, in the context of global investment in chlorine capacity driven by PVC global demand.

- The international trade in EDC and PVC provides accessible options for alternative sources of feedstock or PVC polymer

Other industries use chlorine in very efficient processes for making products that do not contain chlorine. The chlorine is recycled as HCl (hydrochloric acid), and the economics of the present integrated chemical processes make it cost effective to use the HCl in the EDC/VCM/PVC chain or for other uses. A catalytic process (oxychlorination) is used for conversion of the HCl to EDC. An alternative is to use electrolytic cells (similar to those used for chlorine production using membrane cells) to convert the HCl back to chlorine and hydrogen, to reuse the chlorine, with some chlorine make-up required to account for process inefficiencies. The viability of an electrochemical process for recycling HCl to chlorine may vary depending on local factors including the price of electricity and outlets for HCl. In Europe the use of HCl in the EDC/VCM/PVC chain or for other uses is a preferred option at present. The high capital cost of electrochemical cells and the present level of performance have been suggested as factors which limit the competiveness of electrochemically

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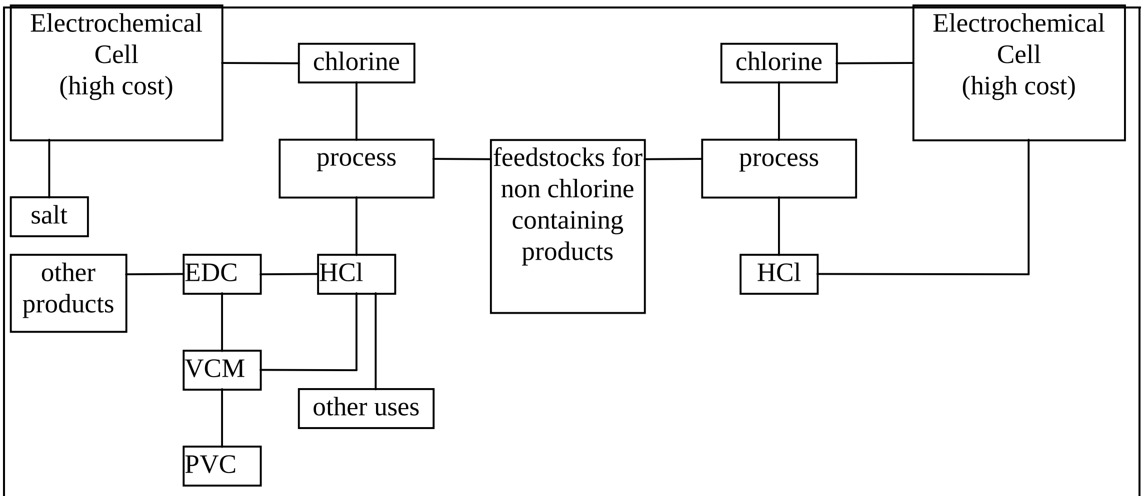
[52] “Chlor-Alkali Industry Overview” C Fryer, presented at the fourth TECNON Chlor-Alkali Conference, June 1997

recycling HCl to chlorine. There are some electrochemical cells installed in Western Europe for this process, with technology being available from European and USA suppliers[53]. It is reported that electrochemical recycling of HCl to chlorine is used extensively by Du Pont in the USA.



Integrated or Recycle Production Using Chlorine (simplified)

The industries which use chlorine in processes, but with no chlorine in the final products have investigated alternative routes that are chlorine free in order to further improve the economics of their processes. However for several industries the use of chlorine provides the most efficient processes with the minimum of side products, due to the reactive nature of chlorine, and increased use of chlorine by these sectors is forecast by 2001[42] or 2005.[54]

Polycarbonate and propylene oxide production are sectors where chlorine free routes are beginning to be use for some new production plants, although capacity for routes using chlorine are also reported as expanding[42,54]. However chlorine free processes if they are further developed to be more cost effective processes would in general be for new plants and may not be suitable for existing plants. This implies that existing plants using chlorine processes could continue to be operated, in the absence of other factors, for many years to come until they reach the end of their economic life. Therefore it can be expected that there should remain a demand chlorine for the production of products that do not contain chlorine, utilising outlets for HCl. At present, according to Euro Chlor, about 24% of chlorine production is used initially for production of non-chlorinated polymers, and increased chlorine use in this sector has been forecast[54] by 2005 for epoxies, polycarbonate, polyurethanes, and propylene oxide.

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[53] Du Pont and Krupp Uhde for example

[54] “Non-Vinyl Uses of Chlorine 1995-2005”, J Marcantonio &D Sherry presented at the fourth TECNON Chlor-Alkali Conference, June 1997

The SRIC study[42] indicates that phase-out by 2010 could result in the conversion of an additional 2.7 million tonnes of membrane cell capacity being installed by 2010 due to some conversions, and the loss, through closure, of at least 2.2 million tonnes of capacity. The specific integration of chlorine production with downstream processes is expected to be a factor which may influence the investment decisions of some companies, given that different downstream uses for chlorine appear to have different sensitivities to chlorine price.

6.6. Potential for Improving The Economics of Conversion

The present generation of membrane technology is reported to be approaching a plateau in terms of performance with only small incremental improvements reportedly possible[40,41]. The capital cost of membrane cells, and the apparently unattractive economic case for replacing viable mercury cells suggest it is worth considering what technology improvements might be potentially possible in the future that could improve the economic case for replacing mercury cells more rapidly.

Membrane cells produce caustic at 33% concentration, which can then evaporated to 50%, a standard concentration for supply. Membrane manufacturers have investigated membranes that could operate producing 50% caustic soda directly, but there are reported to be drawbacks, including operation at higher voltage (and power consumption offsetting to some extent any savings in steam for evaporation) and a more difficult start up and shutdown as the 50% caustic in the cell is more aggressive and perhaps a harsher environment for the membrane[41].

A new technology approach is reportedly, according to membrane cell installers[40,41], under assessment at the research stage, which may have the potential on a 10 to 15 year timescale to offer some benefits in certain circumstances when considering new chlor-alkali production capacity. This is the use of air-cathodes in a modified membrane cell, which would operate in a similar way to fuel cells, to react hydrogen at the cathode and reduce the operating voltage (and power consumption) of the electrolytic cell. However the extremely harsh environment of 33% caustic soda means that it is reported to be an extremely challenging target with no guarantees of success, particularly as the levels of investment for new chlor-alkali production capacity mean that reliability and robustness for any new technology is paramount.

However the concept of air cathodes does not necessarily offer benefits for some integrated chemical plants[55], which use the hydrogen generated by conventional electrolytic routes (mercury, membrane, and diaphragm) as a feedstock in other chemical processes, possibly resulting in a higher value for the hydrogen than if it was used as fuel in a combined heat and power plant.

It may be worthwhile for the chlor-alkali industry (producers and equipment suppliers), to assess in more detail the possibilities for technology improvements in the future and to consider if there is a possibility of collaboration in RTD for the chlorine production process. There is considerable expertise in EU for membrane cell

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[55] Information provided by Bayer and Solvay

technology as membrane cell installers from EU have installed a major share of the membrane cell capacity globally (excluding Japan). SUSTECH, an initiative extending beyond the chemical industry, aimed at promoting collaborative RTD in technologies for sustainable process industries in Europe, may provide a basis for such RTD if it was considered appropriate. The term “sustainable” is used in this context to mean process industries which are resource and energy efficient and which generate the minimum of waste and damage to the environment.[56]

6.7. Relative Scale of Required Investment for Conversion

In order to better understand the economics of capacity replacement a comparison with electricity generation could be made. There appear to be some similarities, but also some differences, when comparing the issues for the conversion of mercury cells and the replacement of coal fired power stations, which is occurring, particularly in deregulated electricity markets with good access to natural gas (UK).

- Historically in Europe, coal combustion power generation and mercury cells in the chlor-alkali were major sources of mercury emissions, but greatly reduced emissions are now achievable for both processes. In 1987 and 1988 the dominating sources of mercury emissions to air were chlor-alkali factories in East Germany and coal combustion units without flue gas cleaning systems in East Germany and Czechoslovakia, together accounting for nearly 40% of the total anthropogenic mercury emissions in Europe[57].

- Current technology coal fired power stations emit some mercury to atmosphere even with the most upto date environmental measures. Emissions from natural gas fired power stations are much lower, given the mercury content of processed natural gas.

- Natural gas combined cycle is clearly superior to coal fired in terms of efficiency, carbon dioxide emissions, and other emissions (including SO_2 and NO_x).

- The investment to install a natural gas fired combined cycle power station (700MW) is of a similar order to that required to replace a mercury cell room with a membrane cell room (600,000 tonnes chlorine). A natural gas combined cycle plant costs around half that of the equivalent conventional coal-fired plant.[58]

The investment required can be related to the turnover generated from investment in a unit of capacity, and the overall cost to the industry of replacing the total capacity. The units of capacity selected for this comparison are 1000 tonnes of chlorine capacity per year, and 1 MW of power generating capacity. The capacities selected appear to be not unreasonable based on typical plant capacities (several hundred 1000 tonnes of

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[56] Communication from the Commission, “An Industrial Competiveness Policy for the European Chemical Industry: An Example”COM(96) 187

[57] G Petersen, A Iverfeldt, & J Munthe, Atmospheric Science vol 29, No 1, pp 47-67, 1995

[58] European Energy to 2020, A Scenario Approach, Directorate General for Energy, DG XVII, Spring 1996, p100

chlorine or several hundred MW). The total industry figures are hypothetical for coal conversion as this is not anticipated to occur in practice, but it provides a useful comparison.

Relative Investments ***for defined capacity***	**1000 te chlorine capacity** mercury cell conversion	**1 MW capacity** combined cycle natural gas
Investment	0.56 million ECU	0.49 million ECU
Turnover/unit capacity	0.35 million ECU	0.55 million ECU
Investment/turnover ratio	160%	89%
for total industry	**Mercury cell conversion**	**Coal power plant conversion**
Investment 1995 (all cells converted) 2010	3.7 billion ECU 2.8 billion ECU	42 billion ECU 19 billion ECU (Forum scenario)
Turnover 1995 assuming chlor-alkali 2010 does not shrink & todays prices	3 billion ECU 3 billion ECU	146 billion ECU 173 billion ECU (Forum scenario)
Investment/turnover ratio 1995 & current prices 2010	123% 93%	29% 11%
Investment/turnover ratio assuming conversion over 5 years from 2005, no shrinkage of chlor-alkali	18.6% per year for 5 years	2.2% per year for 5 years

The comparison[59] indicates that the relative scale of investment to replace mercury cells with membrane cells appears greater per unit capacity, based on the estimated turnover generated from the investment. The “dash for gas” in the UK appears to be in part related to the cost of natural gas combustion capacity (feedstock costs, availability and deregulation are other factors). The investment required to replace all mercury cells now or by 2010 appears to be similar to the turnover of the chlor-alkali industry in EU (turnover generated for chlorine and caustic soda), as a result of the high unit capacity cost and the high proportion of mercury cell capacity in EU (64%). For this comparison, the price of chlorine and caustic soda have been assumed to remain at present levels. A study by Chem Systems[43] contains a projection of prices upto 2005, and suggests that average EChemU price of chlorine and caustic could be within about 5% of 1995 values in USA. It also suggests that caustic soda could be within about 5% of 1995 values in the EU, but it indicates that in the EU there are no transparent market prices for chlorine (as much is used on integrated complexes).

Investment to replace mercury cell capacity of 5 million tonnes, that might be economically viable beyond 2010 (current mercury cell capacity is 6.6 million tonnes), with no decrease in chlorine production capacity would be expected to be phased over a number of years, due to limitations of capital availability and skilled engineering resources. Conversion over a 5 year period from 2005 in order to replace all mercury cells by 2010, indicates an estimated rate of investment of about 18% per year, based on turnover. The current rate of investment by the chemical industry as a whole in

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[59] The estimates in the table are based on information contained elsewhere in this report. Also the European Energy to 2020, A Scenario Approach, Directorate General for Energy, DG XVII, Spring 1996, using the Forum scenario, with current electricity prices from International Energy Agency Electricity Information 1995; OECD Paris 1996. Electricity costs are assumed to remain at 1995 levels for this comparison. Recent capital cost information has been used for natural gas combined cycle plant, which has reduced substantially in the past few years.

Western Europe is about 5% per year based on turnover.[60] Replacing all the current mercury cell capacity over a period of 10 years by 2010 appears to require an investment rate of 12%. The SRIC study[42] indicates that the PARCOM Decision could result in a reduction in chlorine capacity, with 2.2 million tonnes of mercury cell capacity being closed without replacement. The investment estimated under this scenario is 1.5 billion ECU. Investment over a 5 year period from 2005, would appear to indicate an investment rate of about 12% per year (allowing for a decrease in turnover to 2.4 billion ECU as capacity is closed).

7. ENVIRONMENTAL PERFORMANCE FOR MERCURY CELLS

7.1. Mercury Use and Emissions

There is at present approximately 11,800 tonnes of mercury in mercury cells used for chlorine production in the EU. This is based on an average of 1.8 tonnes of mercury per 1000 tonnes of chlorine capacity. One estimate is that the chlor-alkali industry in Western Europe purchased approximately 60 tonnes of mercury in 1996[61]. This is significantly less than purchases in the late 1970s and early 1980s, which were of the order of 500 to 1000 tonnes annually. Reported emissions (Euro Chlor) of mercury (18 tonnes in 1995) to the environment from the chlor-alkali industry in WE are equivalent to 1.2% of the mercury produced in Europe in 1995, which was 1500 tonnes in 1995[62]. Much of the mercury production is exported outside EU for probable use in products, chlor-alkali, or other applications.

The chlor-alkali industry is unique in that a large inventory of mercury is contained and recycled within a chemical process and this inventory is localised on a relatively small number of industrial sites. Closing mercury cell plants requires carefully planning and procedures to keep mercury emissions to an absolute minimum, to recover the mercury for reuse (if considered appropriate), and to pay attention to safe disposal for any mercury wastes. The chlor-alkali industry already has considerable experience of the closure of old or uneconomic mercury cells plants. From 1982 to 1995, Euro Chlor data indicates that 1.94 million tonnes of mercury cell chlorine capacity have been decommissioned, leaving 6.57 million tonnes capacity in 1995.

During the operation of mercury cell plants large quantities of mercury are recycled or recovered for reuse, and a relatively small proportion is disposed of as solid waste (76

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[60] Facts & Figures, The European chemical industry in a worldwide perspective, CEFIC November 1996.

[61] Information Source: Minas De Almaden Y Arrayanes, S.A.

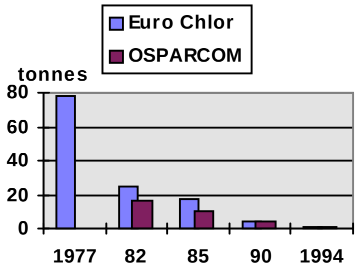
[62] Mercury Stock Management in the Netherlands, P A Maxson & G H Vonkeman, Institute for European Environmental Policy, Background Document prepared for the workshop “Mercury: ban it or bridle it?” 21 November 1996, The Hague; commissioned by The Netherlands Ministry of Environment

tonne, in 1995 from reported Euro Chlor[63] data equivalent to about 0.6% of the mercury cell inventory; 43.2 tonne reported for cell rooms covered by OSPARCOM), but this is regulated to ensure disposal in ways which should not result in releases to the environment (Hazardous Waste Directive). Some mercury is released to the environment, and at present (Euro Chlor data indicates 18 tonnes in 1995) this is about 0.15% per year of the mercury in use in mercury cells in the chlor-alkali industry. In the future, emissions should decrease due to the application of BAT, and by 2003, from an emissions scenario based on Euro Chlor projections, could be of the order of 0.1% (less than 12 tonnes annually) of the mercury in use in mercury cells.

7.1.1 Emission Compartments

Emissions of mercury from the operation of the mercury cell process are to compartments air, water, and products. Major improvements have been reported for all sources of emission from operating mercury cells, but now and in the future the main emission route should be to air based on data reported by Euro Chlor and a draft industry BAT proposed by Euro Chlor for mercury cells[64].

7.1.1.1 Reported Losses of Mercury to Water



In 1995, of the reported 18 tonnes of mercury emissions for Western Europe, discharges to waste water streams accounted for 1.3 tonnes, and OSPARCOM reported discharges to water were 0.78 tonnes in 1994. Data from Euro Chlor indicates that discharges to water have been reduced by over 95% since 1977. OSPARCOM reports a reduction of 95% between 1982 and 1994.

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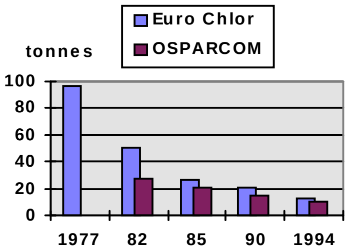
[63] OSPARCOM reports only cover those plants that are relevant to the catchment area covered by OSPARCOM, whereas Euro Chlor reports cover Western Europe and includes all the plants covered by OSPARCOM

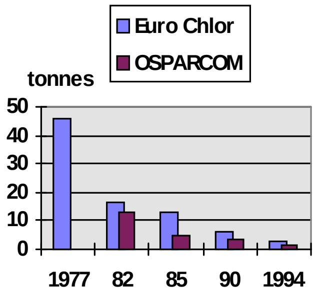
[64] Euro Chlor Document: Env. Prof 10. “Chlorine Production. BAT for the amalgam electrolysis process. Mercury emissions to air, water, and products”-5th draft January 1997.

7.1.1.2 Reported Losses of Mercury to Air



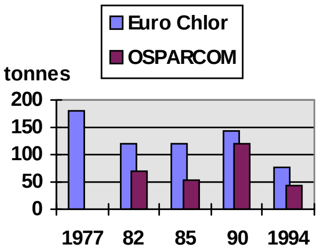
Losses to air arise from two main sources:-Process exhaust streams and cell room ventilation. These are measured separately by Euro Chlor member companies, but for reporting purposes they are both emissions to air. Emissions to air reported by Euro Chlor have been reduced by 85% since 1977, with OSPARCOM reporting a 65% reduction between 1982 and 1994.

7.1.1.3 Reported Losses of Mercury to Products



Products are chlorine, caustic soda, hydrogen, and sodium hypochlorite. The losses to chlorine (<0.001 g per tonne or <10 kg in total) and hydrogen (<0.01g per tonne of chlorine), proposed for the BAT being developed by Euro Chlor are very low. Sodium hypochlorite is made from caustic and chlorine. Caustic soda is virtually the only product stream where any mercury in products should be found in the future. Reported losses of mercury to product have been reduced by over 90% since 1977 (Euro Chlor) and by over 90% between 1982 and 1994 (OSPARCOM). In 1995, mercury in caustic soda was reported to be of the order of 0.2ppm (in 50% caustic soda), which is equivalent to about 0.4g of mercury per tonne of mercury cell chlorine capacity.

7.1.2 Mercury in Solid Waste

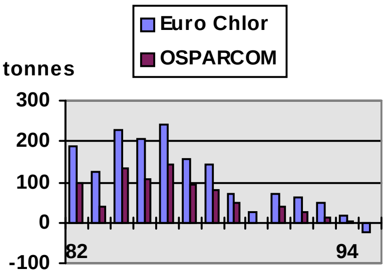


Mercury in safely deposited wastes (Hazardous Waste Directive) is not considered as an emission to the environment. This category is for mercury that is not recycled or recovered. In recent years the reported solid waste has been between 10-17g per tonne of chlorine capacity. In 1982 it was reported as 120 tonnes (Euro Chlor) and 69 tonnes (OSPARCOM). In 1994 it was reported as 76.9 tonnes (Euro Chlor) and 43.2 tonne (OSPARCOM).

Mercury disposed of as solid waste now appears to make up the largest part of the mercury removed from mercury cells. The volume of solid waste containing mercury will depend on the concentration of mercury in the solid waste. Lower concentrations of mercury will lead to higher volumes of solid waste. An objective of seeking ways to reduce the generation of waste containing mercury follows from the hierarchy of principles of waste management policy as set out in the communication on the review of the Community strategy for waste management[65]. The mercury solid waste, from the operation of mercury cells, could be in a number of forms, including the sulphide, other concentrated waste, or waste with low levels of mercury contamination. Some Member States have regulations which require mercury not to be recovered from solid waste, but to be disposed of, for example, by encapsulation and this may have an influence on the total amount of solid waste generated. Euro Chlor report that they are producing guidance relating to solid waste, and indicate that the quantity of solid waste containing mercury from operating mercury cells could perhaps decrease in the future, subject to any requirements relating to the recovery of mercury from solid waste. Solid waste that is encapsulated and stored according to the requirements of some Member States or the Hazardous Waste Directive might be expected to have very low or zero emission rates to the environment.

7.1.3 Unaccounted For Mercury

The reports submitted to OSPARCOM[66] have a category for "unaccounted for mercury". This is effectively a difference to balance, based on the measured emissions, mercury solid waste, and the inventory of mercury in the cells. In 1982 the "unaccounted for mercury" reported to OSPARCOM was 99.5 tonnes or 42.5 g per tonne of mercury cell chlorine capacity. In the same year the reported emissions were 56.7 tonnes and the solid waste was 69.1 tonnes. In 1994 the "unaccounted for mercury" was reported to OSPARCOM as 4.2 tonnes, with reported emissions at 9.6 tonnes and solid waste 43.2 tonnes. The "unaccounted for mercury" reported by Euro Chlor was 186.4 tonnes in 1982, and 17.5 tonnes in 1994.



An accurate balance depends on the ability to measure the mercury inventory in the cells to a high degree of accuracy. This is because the volume of mercury in the cells is large relative to the emissions and any inaccuracy in the inventory will lead to a difference to balance. Present measurement of inventory in cells is reported to be accurate to 0.5%, which is equivalent to 59 tonnes of mercury based on the total cell inventory[67]. A year to year variation in the measured inventory will lead to "unaccounted for mercury". However it appears that this does not account for all the "unaccounted for mercury", which requires additional explanations.

An explanation proposed for some "unaccounted for mercury" is that during operation of mercury cell rooms mercury collects in all the plant pipe work until some form of equilibrium is reached, possibly over a period of years. Another explanation is that

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[65] Communication from the Commission on the reveiw of the Community Strategy for Waste Management COM(96) 399 final

[66] OSPARCOM Working Group on Point Sources(Point) Draft Report on Mercury Losses from the Chlor-Alkali Industry (1982-1995) POINT 96/17/1-E

[67] Mercury Analysis by Radioindicator, accuracy reported by companies offering this service

mercury wastes may also accumulate in various parts of the plant and be recovered during decommissioning. Some attempts have been made during cell room decommissioning of old plant to establish what proportion of “unaccounted for mercury” this represents. One mercury cell plant decommissioned in The Netherlands has been subject to an investigation for mercury recovery[68]. The recovered mercury metal from the cells and equipment was found to be about 108% of the nominal cell inventory. During the decommissioning an additional 24% of the nominal cell inventory was recovered as mercury waste. Recovery of “unaccounted for mercury” has also occurred for a recently decommissioned mercury cellroom in Germany[69], but the mercury recovery is not yet fully complete. At present Euro Chlor indicates that further mass balance investigations are required to obtain a better understanding of the proportions of “unaccounted for mercury” that might be recovered during decommissioning.

Another possible explanation for some “unaccounted for mercury” is that accuracy of loss measurements was not as high in the early 1980s and late 1970s, resulting in inaccuracies in the losses, or mercury disposed as solid waste. The issue of reliability of reported loss data was noted by the POINT sources working group, a subgroup of OSPARCOM.

Euro Chlor reported a mercury recovery (a positive difference to balance of 23 tonnes) in 1995, as a result of mercury recovery from stored waste. Norway adjusted its “unaccounted for mercury” for OSPARCOM reports, based on a mass balance study of a plant closed in 1987. This was estimated at 24 tonnes from 1947 to 1987 which is about 600kg per year. However it also reported a mercury recovery of 1584 kg in 1993.

The “unaccounted for mercury” may be expected either to be recovered in the future during plant closures and/or represent some additional historical emissions. Euro Chlor has indicated that it is working to improve its understanding of this issue.

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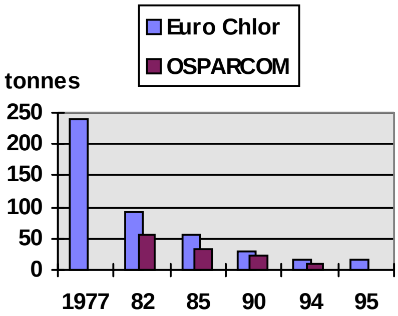
[68] Information provided by Dr S Troost, Akzo Nobel Chemicals

[69] Information provided by Hoechst

7.1.4 Total Mercury Emission Reductions

From 1977 to 1995 the chlor-alkali industry in WE (Euro Chlor) reported decreased emissions of mercury to the environment from 220 tonnes to 18 tonnes per year, a decrease of 92%. For the mercury cells covered by OSPARCOM, the emission reduction, based on reported data, was 83% from 1982 by 1994 (56.7 tonnes reduced to 9.6 tonnes per year).[70] The reported quantity of mercury as solid waste has also decreased but mercury in safely deposited wastes is not considered as an emission to the environment. However seeking ways to further reduce the quantity of waste containing mercury, from operating mercury cells, follows from the review of the Community strategy for waste management.



At the Third North Sea Conference at The Hague in 1990, a general reduction target of 70% was established for mercury inputs. Over the period 1985 to 1995, the chlor-alkali industry in WE (Euro Chlor) reported a decrease in total annual mercury emissions to the environment of 69% (58 tonnes in 1985 reduced to 18 tonnes in 1995). The reported reduction in annual emissions to air over the same period was about 48%, with larger relative reported reductions to water (93%) and products (80%). For the mercury cells covered by OSPARCOM, the reported total emission reduction over the period 1985 to 1994 was 71% (32.5 tonnes in 1985 reduced to 9.6 tonnes in 1995), with reported reductions to air (52%), water (93%), and products (74%) similar to those for Western Europe as a whole.

Based on the decrease in reported annual emissions, the greatly reduced purchases of mercury, and investments undertaken to improve environmental performance, the chlor-alkali industry in EU is now a different industry compared with 20 years ago in terms of environmental performance. The implementation of IPPC and BAT would be expected to lead to further improvements in the future, for mercury cells as well as for the other technologies used to manufacture chlorine. The reported data for three Member States[71] indicates that annual emissions of mercury from the chlor-alkali industry have decreased absolutely and also as a proportion of anthropogenic emissions in those countries.

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[70] Emissions from the former East Germany chlor-alkali industry are not included for emissions in 1970s and 1980s for the Euro Chlor data. This would represent additional emissions during this period.

[71]: sources: Belgium- BMM Noordzee (Ministry of Environment-Belgium); UK-from DOE Report “UK Emissions of Air Pollutants 1970-1993; Netherlands-Euro Chlor (from Akzo Nobel Chemicals bv)

Reported Anthropogenic Emissions of Mercury (tonnes)

	1985	1993	1995
Belgium			
Total	>15.7		>8.0
Chlor-alkali	3.9		1.6
proportion	<25%		<16%
reduction from 1985			60%
Netherlands			
Total	13.9		6.3
Chlor-alkali	1.07		0.37
proportion	<8%		<6%
reduction from 1985			65%
United Kingdom			
Total	35.4	25.3	
Chlor-alkali	9.7	3.1	
proportion	<28%	<13%	
reduction from 1985		68%	

7.1.5 Accuracy of Mercury Emission Measurements

Euro Chlor indicate that over the last 15 years measurement techniques for the monitoring of mercury emissions have improved significantly. Euro Chlor indicates that the overall errors for sampling and analysis vary depending on the circumstances and the emission stream being monitored. A range of specialist analytical instruments for mercury emission measurement are available from several suppliers, and these include automatic online and off-line mercury measurement equipment.

Sampling and analysis of emissions to liquid effluent streams (using routine analysis or automatic analysers) and caustic soda is reported to be straightforward, and accuracies of the order of 2%-10% are reported to be achievable. Mercury removal from hydrogen is reported to generally involve the use of processes where the mercury content achieved can be correlated with the process parameters, which means that a routine offline technique for measuring mercury in hydrogen should confirm the expected mercury content from process control parameters. The draft Euro Chlor BAT[64] indicates that in the future liquid effluent and products could account for of the order of 10% of total emissions to the environment, which implies that liquid effluent and product could contribute less than 1% to the accuracy for total emissions. The emissions to air are reported to occur from process exhaust gases and cell room ventilation. The draft Euro Chlor BAT indicates that process exhaust gases should be routinely analysed and flow rates measured at frequencies that reflect the range of plant operating conditions. The emissions to atmosphere from cellroom ventilation can be measured using sampling techniques for the mercury concentration and measurement of air flow. Emissions due to cell room ventilation are reported to vary with maintenance periods, temperature (climate), and other factors, and sampling regimes should reflect these variations. Static or portable sampling devices can be used.

Euro Chlor have reported[72] that it is less difficult to determine mercury losses in closed or semi-closed cell rooms than in open cell rooms as air flow measurements are

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[72] Euro Chlor Fourth Technical Seminar; BAT for the Mercury Process for Chlor-Alkali Production February 1997.

required to determine mercury emissions. For open cell rooms (full open air or a simple roof), the measurement of mercury can be carried out at various locations, air flows estimated from measurement of wind speeds and modelling techniques, if appropriate. Semi-closed cell rooms lie between the two limits. The majority of cell rooms in WE are closed or semi-closed, according to Euro Chlor. Following sampling and analysis techniques set out in the draft Euro Chlor BAT, it has been suggested that emissions to atmosphere could be of the order of 10-30% accuracy depending on the type of cell room and technology used.

The quantity of mercury in safely deposited wastes is measured by analysis, but Euro Chlor indicates that there are difficulties in obtaining a representative sample, as the solid waste may not be homegeneous. Euro Chlor experience indicates errors may be in the range of 30%.

7.1.6 Relative Mercury Emissions

Mercury emissions are considered to be a regional and global issue, as mercury is a transboundary long range air pollutant. The mercury emissions from the EU chlor-alkali industry can be compared to the total estimated anthropogenic emissions from the EU, from Europe (W+E), and globally. A recent paper[73] provides an estimate for Europe at present (a minimum of 435 te mercury), which is based on an estimated 40% reduction in emissions since 1989. On this basis, the estimated emissions in 1989 would be of the order of 725 tonnes, with the paper reporting a range of estimates from 627 to 802 tonnes. The same paper indicates that the estimated EU emissions in 1989 were 197 tonnes, but the paper does not provide an estimate of EU emissions at present. It has been suggested that emissions in Eastern Europe have decreased by a greater percentage than emissions in EU from relatively higher emissions in 1989. On this basis one estimate is that the emissions in EU at present are of the order of 150 tonnes (approximately 25 % reduction since 1989). An estimate for anthropogenic point sources globally is of the order of 4000 tonnes[74]. Another paper indicates that 4000 tonnes may be an upper estimate for total global anthropogenic emissions.[75]

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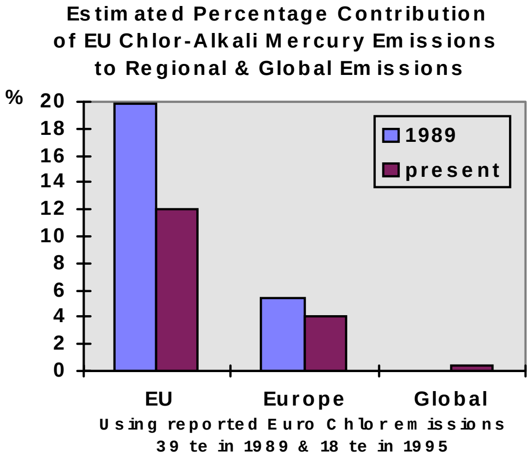
[73] Mercury in products-a source of transboundary pollutant transport, J Munthe & K Kindbom, Swedish Environmental Research Institute (IVL) Report to the National Chemicals Inspectorate (KemI), March 1997

[74] Mercury Atmospheric Processes: A Synthesis Report; prepared by: expert panel on mercury atmospheric processes convened March 16-18, 1994 Florida USA

[75] Mercury, Case Study, Draft Interim Report to the Secretariat of the Commission for Environmental Cooperation, North America, March 1997



Based on these estimates it appears that the reported emissions from the chlor-alkali industry in EU have decreased as a percentage of total anthropogenic emissions from 1989 to the present, for both EU and Europe. The Euro Chlor reported emissions indicate that at present chlor-alkali may contribute about 12% of EU anthropogenic emissions, about 4% of European anthropogenic emissions, and less than 0.5% of the estimated global anthropogenic emissions.

7.2. Mercury Emission Trends

There is a large natural flux and reservoir of mercury in the environment. This has been the case for millions of years given the low but measurable levels of mercury found in, for example coal, oil, natural gas, and limestone.

Recent estimates indicate that of the approximately 200,000 tonnes of mercury emitted to the atmosphere since 1890, about 95% resides in terrestial soils, about 3% in the ocean surface waters, and 2% in the atmosphere. Mercury accumulating in soils is released only slowly to terrestial waters, whereas the atmosphere, open ocean waters, and biota are estimated to decrease in mercury burden much more rapidly (10-20 years). Globally, anthropogenic emissions are estimated to be about 4000 tonnes and about 50 to 75% of the current total annual input to the global atmosphere.

In general, mercury emissions to air (from anthropogenic sources) are in two main forms, bound to particles, or elemental. Elemental mercury can be transported globally, with particulate mercury being transported up to about 1000 kilometres. It has been estimated that 50 to 60% of anthropogenic mercury emissions are transported by long range atmospheric processes.[76,77] There is still debate about the precise mechanisms for mercury transport and deposition. Particulate mercury can be wet or dry deposited and for the elemental form of mercury it has been proposed that ozone (associated with VOCs and nitrogen oxides) can promote deposition. Soot is also thought to be implicated in the deposition of mercury from the air.[78]

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[76] Mercury Atmospheric Processes: A Synthesis Report; prepared by: Expert panel on mercury atmospheric processes convened March 16-18, 1994

[77] Case Study Mercury; Draft Interim Report to the Secretariat of the Commission for Environmental Cooperation, North America, March 1997

[78] J Munthe et al, Water, Air and Soil Pollution 80, 227-233, 1995; 80, 363-371, 1995;Atmospheric Environment vol 29, No12 pp 1441-1457, 1995

Most of the mercury emissions in Europe are considered to be from anthropogenic sources. In 1987 and 1988 the emissions in East Germany, thought to be due to lignite coal burning without flue gas desulphurisation equipment, and high levels of losses of mercury from chlor-alkali factories, accounted for more than 40% of the European total[79]. Actions that have already been taken in many industries, including the chlor-alkali industry, are having a positive effect in reducing localised concentrations of mercury. Historical evidence suggests that regional scale mercury deposition may have been decreasing in recent decades in industrialised areas of Europe[80,81] and North America[82].

According to a 1996 paper, recent data suggests that atmospheric mercury concentrations may be slowly increasing on hemispherical or global scale[83]. Power generation by fossil fuel combustion has previously been identified as the largest contributor to anthropogenic atmospheric emissions of mercury emission globally, regionally and very often on a national scale[84]. The trend in regional emission reductions in Europe, may be affected, according to a recent paper[85], for example, due to a rapid economic development in large areas of the Eastern Europe, followed by an increased energy useage. If this is not accompanied by efficient cleaning equipment, a rise in airborne mercury may occur in Scandinavia. Based solely on coal use, Russia and China (75% of country’s total energy requirements are fuelled by coal) are likely to produce significant mercury emissions[77].

It has been estimated that a reduction of 80% in deposition of mercury, compared to 1990 levels, is considered necessary to prevent accumulation of mercury in agricultural land for the Netherlands.[86] Papers published in 1991 indicated that a mercury deposition in southern Sweden should be reduced by around an 80% if a level not exceeding the critical load is to be achieved, which is a level where input to soil is less than output from soil and where the concentration of mercury in the upper stratum of the soil thus begins to diminish.[87,88] For Scandinavian lakes, even when an overall

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[79] G Petersen, A Iverfeldt,and J Munthe GKSS 95/E/16

[80] J Munthe et al, Water, Air and Soil Pollution 85,743-748,1995

[81] Mercury in products-a source of transboundary pollutant transport, J Munthe & K Kindbom, Swedish Environmental Research Institute (IVL), report to the National Chemicals Inspectorate (KemI), March 1997

[82] “Is Atmospheric Mercury Deposition Decreasing in Mid-Continental North America”, D R Engstrom paper presented at 3rd International Conference on Mercury as a Global Pollutant

[83] G Petersen, J Munthe, and R Bloxam GKSS 96/E/83

[84] Mercury in the UK, UK Department of the Environment, report by ERM, March 1996

[85] J Munthe et al, Water, Air and Soil Pollution 80, 227-233, 1995

[86] National Institute of Public Health and Environmental Protection, Netherlands; Integrated Criteria Document Mercury January 1995, Report no. 601014008, p151-2

[87] K Johansson et al, Water, Air, and Soil Pollution 56:267-281, 1991

reduction of deposition of 80% is achieved it would take many decades (perhaps 100 to 200 years) for the mercury levels to fall naturally. Remedial actions are being investigated, but these are not seen as a solution to the problem but perhaps a means of accelerating recovery.

Depending on the type of waste and the disposal method, mercury as solid waste may be prone to evaporation and subsequent emission to the atmosphere. Mercury waste that is safely disposed of, and which may be encapsulated, might be expected to have a very low or zero emission factor. However, emission factors for landfill for disposal of products containing mercury (for example batteries) have been considered and arbitarily chosen emission factors assigned.[81] The same paper reports that a medium sized landfill in Sweden emits about 1 kg mercury/year through volatilisation.

7.3. Projected EU Chlor-Alkali Mercury Emissions

Emissions of mercury to air is now and will remain the main route in the future for emissions from the chlor-alkali industry in EU. Mercury is also converted to solid waste during the operation or decommissioning of mercury cells and conversion to solid waste makes up the largest part of the mercury removed from mercury cells. The nature of mercury as a long range transboundary pollutant suggests that trends in the chlor-alkali industry in EU should also be considered for any potential impacts on regional or global mercury emissions. It is assumed for this scenario that mercury as solid waste is in safely deposited wastes and not considered as an emission to the environment.

7.3.1 Projected Mercury Emissions in an EU Context

The future emissions of the chlor-alkali industry could be compared against a mercury deposition reduction of around 80% from 1990 levels, which is considered necessary to prevent further accumulation in soils according to some studies. The Netherlands report[86] compares estimated emissions in 2010 with 1990 estimated total mercury emissions. An emission scenario, based on Euro Chlor projections for an economically driven scenario, could result in an estimated emission reduction of around 75% by 2010 from 1990 reported emissions (31 tonnes reported emissions in 1990, decreasing to a scenario estimate of 7.5 tonnes by 2010).

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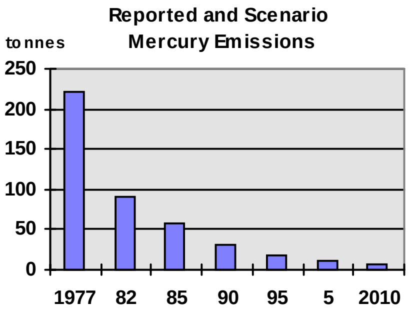
[88] Mercury in the Environment Problems and Remedial Measures in Sweden, Swedish EPA1991



Beyond 2010, for this scenario, mercury emissions from operating mercury cell rooms would be expected to continue to decrease as mercury cellrooms continue to be closed due to economic reasons. Within a short period, for this scenario, emissions might be expected to have decreased by around 80% from 1990 reported levels, and would be expected to continue to decrease as further mercury cells rooms were closed due to economic reasons. Eventually, all EU mercury cells would be decommissioned, but the timing of this would be uncertain for this scenario, as it would be influenced by a range of factors, some of which are discussed elsewhere in this report.

At present the estimated contribution of the chlor-alkali industry to estimated EU mercury emissions is about 12%. An emission scenario, based on Euro Chlor projections for an economically driven scenario, could result in the elimination of 7% of present total EU estimated mercury emissions by 2010. The estimated reduction in Western European chlor-alkali emissions could be of the order of 58% by 2010 from 1995 levels (18 tonnes reported in 1995, decreasing to an estimated 7.5 tonnes by 2010). From the high emissions reported in 1977, the Western European chlor-alkali industry might, for this scenario, reduce emissions by over 96% by 2010.

7.3.2 Projected Mercury Emissions in a European Context

Anthropogenic emissions of mercury can be considered regionally, as a result of transboundary transport of mercury. At present the estimated contribution of the Western Europe chlor-alkali industry to the estimated total European mercury emissions is about 4%. This is the proportion of present European anthropogenic emissions that the Western European chlor-alkali industry can address for any closure or emission reduction scenario. Closure by 2010, due to the PARCOM Decision, may eliminate 4% of present estimated European emissions.

An emission scenario, based on Euro Chlor projections that does not take account of conversion as laid down in the PARCOM Decision, could result in elimination of 2.4% of present total European estimated mercury emissions by 2010. Beyond 2010 for this scenario, economic closure of mercury cells could begin to eliminate the other 1.6% of present European mercury emissions, from operating mercury cells, that can be addressed by the WE chlor-alkali industry. Eventually, for this scenario, all WE mercury cells would be decommissioned.

In 1995, the mercury cell capacity in Eastern Europe was reported[89] as 1.26 million tonnes, with an additional 0.72 million tonnes in CEI. Mercury emissions from chlorine production in some other regions, such as Eastern Europe, are at present

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[89] Information Chemie n°366, p107, mars 1995

significantly higher than in EU, and there is at present less pressure to reduce them. The UNECE Protocol on Heavy Metals will have BAT and/or emission limit values for the emissions of mercury from chlor-alkali mercury cell rooms. The implementation, over a period of years, of these control measures in Eastern Europe, for those countries that ratify the Protocol, will require investment and technical expertise to reduce and accurately monitor emissions. The Euro Chlor companies have considerable experience in the reduction of mercury emissions. Phase-out by 2010 could lead to a loss of expertise in Euro Chlor for the optimum operation of mercury cells, and it should be considered if this expertise is important for implementation of reduced mercury emissions for plant in Eastern Europe that may continue to operate after 2010.

The phase-out of mercury cell capacity in the EU by 2010 has been projected[90] to result in at least a 20% reduction in chlorine production capacity overall in EU (2.2 million tonnes reduction). Chlorine and caustic soda production in EU would decrease, but based on present forecasts demand would continue to grow in EU and globally. It appears that the forecast reduction in EU chlorine and caustic soda production could be expected to be balanced by production increases in other regions to compensate, given the current projections of growth in chlorine and caustic soda demand globally. In addition the EU would be forecast to become an importer of caustic soda and downstream chlorinated products, and offer reduced competition for export markets. It is possible that this situation would allow marginally competitive capacity (perhaps mercury cells) in other regions, such as Eastern Europe, to remain economically viable for a longer period.

A recent paper[91] suggests that some East European producers of downstream chlorinated products are carefully evaluating events and prospects in West Europe for one downstream sector, and examining the sustainability of demand compared to their existing perhaps more fragile demand (for chlorine).

7.3.3 Projected Mercury Emissions in a Global Context

At present the estimated contribution of the Western Europe chlor-alkali industry to the estimated total global mercury emissions is of the order of 0.45%. This is the proportion of present estimated global anthropogenic emissions that the Western European chlor-alkali industry can address for any closure or emission reduction scenario. Closure by 2010, due to the PARCOM Decision, may eliminate 0.45% of present estimated global emissions. An emission scenario, based on Euro Chlor projections for an economically driven scenario, could result in elimination of 0.26% of the present total estimated global anthropogenic mercury emissions by 2010. Beyond 2010, for this scenario, economic closure of mercury cells could begin to eliminate the other estimated 0.19% of present global anthropogenic mercury

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[90] “Competitive Situation of the Western European Chlor-Alkali Industry in a Global Context”, SRI Consulting, prepared for Euro Chlor, April 1997

[91] Non-Vinyl Uses of Chlorine 1995-2005 J Marcantonio/D Sherry TECNON Consulting; presented at The Fourth TECNON Chlor-Alkali Conference London, 3 June 1997

emissions, from operating mercury cells, that can be addressed by the WE chlor-alkali industry.

However the decommissioning of mercury cells potentially could release pure mercury from the chlor-alkali stockpile contained in EU mercury cells. It appears to be important to consider what impact if any this could have on the global emissions.

7.3.4 Decommissioning of Mercury Cells

The decommissioning of all Western European mercury cells may in principle, under present measures, lead to over 10,000 tonnes of mercury becoming available on the international mercury market. It may be appropriate to consider what could be the impact on emissions to the environment for this mercury, if released onto the international market. This could be compared to emissions if the mercury was retained within EU chlor-alkali mercury cells.

7.3.4.1 International Mercury Market

The chlor-alkali industry is unique as it has, at present, about 11,800 tonnes of high purity mercury as an inventory within the mercury cells[92]. On decommissioning mercury will be recovered from the cells, along with other mercury and mercury waste that has collected in different parts of chlor-alkali plants ("unaccounted for mercury"). Once recovered, there is the possibility that pure mercury may be exported to other regions for use in a wide range of applications. In general, these applications appear to be less controlled.

Mercury Consumption	**1993**
CIS	1379
USA	558
Europe	448
Iran	414
China	345
India	345
Other	345
Total (tonnes)	**3834**

The Commission Regulation[93] concerning the export and import of certain dangerous chemicals, relating to the international prior informed consent procedure (PIC) established by the United Nations Environmental Programme (UNEP) and by the Food and Agricultural Organisation (FAO), includes mercury compounds, but not pure mercury, on the list of chemicals subject to the international PIC procedure.

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[92] based on an average 1.8 tonnes mercury in cells for each 1000 tonnes of chlorine production capacity

[93] Commission Regulation (EC) No 1492/96 amending Annex II and Annex III to Council Regulation (EEC) No 2455/92 concerning the export and import of certain dangerous chemicals.

Exports of mercury from Spain to:	**1990**	**91**	**92**	**93**	**94**	**1995**
Europe	402	379	223	69	39	286
Africa	1	10	0	0	0	7
USA	0	28	12	0	0	14
C & S. America	34	96	95	57	47	31
Asia	39	231	565	1042	1712	602
Total (tonnes)	**476**	**744**	**895**	**1168**	**1798**	**940**

The issue of international mercury trade is discussed in some detail in a recently published report.[94] This report indicates that most mercury mines are state owned, with some governments subsidising mercury mining. Within EU, mercury is mined in Spain, with about 1500 tonnes of mercury produced in 1995, and an estimated 1350 tonnes in 1996. A large proportion is at present exported outside EU, according to the data in the report.

The availability of secondary mercury[95]and mercury which may become available from government stockpiles (eg CIS and USA) is expected to hold market prices down. With all these forces pushing mercury onto the market, and with few forces acting to keep mercury off the market, it appears that supply of mercury will continue to exceed demand, encouraging additional uses and low prices. World demand for mercury is expected to remain more or less stable for the next several years.

Primary Mercury Production	**1989**	**90**	**91**	**92**	**93**	**94**	**1995**
China	950		760	580	520	554	570
Algeria	776		431	476	459	414	292
Spain	967			36	643	393	1497
Kyrghizstan	1650			300	250	380	170
Finland	160		74	85	98	90	90
USA(byproduct)	428	114	58	64	50	50	50
other	533			379	250	185	171
total (tonnes)	**5464**	**4100**	**2540**	**1920**	**2270**	**2066**	**2840**

The report also comments that it is equally obvious that these same forces will push mercury into uses (especially those that are difficult to monitor) and regions (increasingly outside the OECD countries) where environmental controls are weakest. Special attention was paid to existing mercury stocks during the Netherlands national workshop on mercury flows[96]. For the policy of decreasing the use of mercury, the potential trading of mercury from large stocks is a threat for the emissions of mercury to the environment. The Defence Logistics Agency (DLA) in USA has an inventory of 4408 tonnes of mercury (compared to total Federal holdings of just over 5200 tonnes). Congress suspended sales of mercury from DLA in July 1994, and expressed concern about the sales' possible contribution to domestic pollution, as well as its possible use after export to third countries in applications banned in the US. It is not yet clear if sales from DLA will resume.

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[94] Mercury Stock Management in the Netherlands, P A Maxson & G H Vonkeman, Institute for European Environmental Policy, Background Document prepared for the workshop “Mercury: ban it or bridle it?” 21 November 1996, The Hague; commissioned by The Netherlands Ministry of Environment.

[95] In the Mercury Stock Management report, primary mercury is defined as that produced by mining of mercury ores or from eg gold-bearing ores; secondary mercuryids defined as that recovered from fossil fuels (especially North Sea natural gas), or from refining of zinc or phophate ores etc; reprocessed mercury is defined as that recovered from a commercial application and does not by this definition add to the mercury in the biosphere. Both primary and secondary mercury are assumed to add to the mercury in the biosphere.

[96] “Mercury: ban it or bridle it?” 21 November 1996, The Hague; commissioned by The Netherlands Ministry of Environment

The mercury inventory of the chlor-alkali industry may be considered as a stockpile. This follows from a rough estimate of the cumulative future emissions of operating mercury cells which are recommended to be phased out by 2010 due to the PARCOM Decision 90/3. Based on present emission levels reported by Euro Chlor and phase out over a period of years up to 2010, perhaps about 1.4% of the current estimated 11,800 tonne mercury inventory might be emitted to the environment by operating mercury cells by the year 2010. From this and allowing for some conversion of mercury to solid waste, it is possible to estimate that about 10,600 tonnes of mercury may still be available for reuse from the chlor-alkali by 2010[97] due to phase-out of mercury cells by 2010. This excludes any “unaccounted for mercury” that may be recovered, in addition to the cell inventory, during decommissioning. There is the possibility that pure mercury could be exported for use in other regions where environmental controls are weakest. An estimate of mercury use for gold mining globally is 350 to 450 tonnes in 1996, while it appears, according to the report, that some Asian countries are using mercury much as Western economies did in the first half of the 20th century.

7.3.4.2 Disposal of Mercury from the Chlor-Alkali Industry

The price for selling mercury from chlor-alkali industry on the world market was of the order of 1-1.5 ECU per kg in 1994 according to the “Mercury Stock Management in the Netherlands” report. At these prices, the value of the chlor-alkali stockpile is of the order of 10.6 to 15.9 million ECU. The cost of final disposal of mercury for the chlor-alkali industry was estimated at about 10 ECU per kg in 1994 This is equivalent to a cost of 106 million ECU (if disposal costs remain at similar levels) for disposal of the chlor-alkali stockpile, if this remains possible within the Member States, which may be available by 2010 due to the PARCOM Decision 90/3. Mercury sales by the chlor-alkali industry, if this was to occur, would avoid mercury disposal costs. There will be other mercury containing wastes, generated during decommissioning of mercury cells and these will need to be disposed of or reprocessed.

If the mercury stockpile was not traded on the international market, it might be treated in one of three ways:

- Stored as mercury metal, but to what purpose unless as a part of an overall mercury strategy by EU.

- Converted to waste and stored or disposed of within the Member State. In theory the waste could be exported within EU for reprocessing to recover mercury, but this appears to be an inappropriate use of resources.

- Transported within EU as mercury metal for subsequent conversion to waste (eg mercuric sulphide) for disposal, which could require a EU mercury management policy.

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[97] based on estimates of current cell inventory, emissions, and mercury disposed of as solid waste, and ignoring unaccounted for mercury and any other mercury recovery during decommissioning.

Since 1982 approximately 2 million tonnes of mercury cell chlorine capacity have been decommissioned according to Euro Chlor data. This is equivalent to approximately 3,600 tonnes of mercury. Historically mercury recovered from the closure of mercury cells appears to have been reused by the chlor-alkali industry, or returned to the international mercury market. In the future the reduced requirements of the chlor-alkali industry (one estimate is that chlor-alkali industry purchased 60 tonnes of mercury in 1996[98]) and the closure of some further mercury cell capacity, at the end of its economic life, indicates that the chlor-alkali industry may very shortly, within the next few years, become a net generator of mercury metal. The timing for the industry to become a net generator of mercury should depend to a large extent on any current mercury stock within the industry, and the precise phasing of economic closure of existing capacity.

This potential issue prompts the question of should there be a reassessment of EU mercury flows as a whole, including mercury mining and the possible impact of the chlor-alkali stockpile.

7.3.4.3 Mercury Emissions During Decommissioning

When cell rooms are closed and decommissioned it is apparent that there will be some loss of mercury to the environment. Loss of mercury to atmosphere during decommissioning and demolition appears to be the most difficult to prevent and could to some extent be influenced by cell room design, and geographic location (temperature).

From discussions with companies that have experience in this area, it appears that once the cells are shut down the cell room temperature decreases, and the evaporation rate of any exposed mercury is reduced. Normally cell room ventilation, for closed cell rooms, is used in part to reduce temperature due to the heat load generated by operating mercury cells. During decommissioning cell room ventilation may be greatly reduced, depending on the mercury concentration in the air, leading to a reduced emission of mercury. Similar procedures to those used to minimise or eliminate emissions during cell room operation can also be used during decommissioning. On this basis it appears that in general emissions during decommissioning could be lower than during operation. Decommissioning will occur over a period of years and might on this basis not contribute greatly to mercury emissions. Demolition and site remediation might be more difficult to estimate in terms of mercury emissions.

Euro Chlor has indicated that it already has guidance available for decommissioning based on companies’ experience, which is increasing over time.

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[98] Information source: Minas De Almaden Y Arrayanes, S. A., Spain.

7.4. Mercury in Products Trends

7.4.1 Caustic

Caustic, directly after formation by the mercury cell process contains some mercury. A treatment process is used to remove virtually all the mercury and apparently this results in a very small quantity of mercury remaining in the caustic. Historically the reported content of mercury in caustic was higher. Industry reports that it has made improvements to the treatment process, and also to the control and monitoring of the treatment process. The 1995 value of 0.4g per tonne of chlorine capacity for all products reported by Euro Chlor equates to a maximum of about 0.2 ppm in 50% caustic. In the future it should be possible to set mercury in all products at a maximum of 0.1 g mercury per tonne chlorine capacity, according to the BAT proposed by Euro Chlor[99]. If this was all contained in the caustic it would result in a maximum of about 0.05 ppm in 50% caustic (a standard concentration for supply). This proposed future maximum mercury content of caustic can be compared to the mercury content of other materials. The comparison indicates similar trace levels of mercury in a range of materials such as avocados, estimated natural background level in fish, limestone, wood, coal, and oil. At these levels it appears that material selection is not generally based on mercury content.

Material	Mercury Content	Mercury Content ppm equivalent	Reference
Caustic 1995	0.4 g/tonne chlorine production	0.2	Euro Chlor reported data
Caustic Euro Chlor BAT	0.1 g/tonne chlorine production	0.05	Proposed Euro Chlor BAT
Wood	200 mg/tonne	0.2	UK DOE Mercury in UK 1996, ERM
Coal	0.28 mg/kg	0.28	UK DOE Mercury in UK 1996, ERM
Limestone	6 to 49 ng/g	0.006 to 0.049	UK DOE Mercury in UK 1996, ERM
Oil	0.7 g/tonne	0.7	UK DOE Mercury in UK 1996, ERM
Fish (natural background)	0.05 to 0.2 mg/kg	0.05 to 0.2	K Johansson, Water, Air and Soil Pollution 56; 267-281, 1991
Avocados	21 µg/kg	0.021	Netherlands Integrated Criteria Document Mercury, 1995

The mercury in all products reported by Euro Chlor in 1995 was 2.6 tonnes, based on 0.4 g per tonne of chlorine. The maximum concentration in products of 0.1g per tonne chlorine capacity allows an estimate of the maximum amount of mercury in product in the future. An economically driven scenario provides an estimate that by 2010 there may be 5 million tonnes of mercury cell chlorine capacity. This allows an estimate of a maximum 0.5 tonnes of mercury in products (essentially in caustic). This is equivalent to 0.3% of the present estimated annual anthropogenic mercury emissions in EU, and 0.1% of the present estimated annual anthropogenic mercury emissions in Europe as a whole.

7.4.1.1 Integrated Caustic Production

There are some small perturbations to the simple estimate of total mercury in caustic. These arise because some companies with both mercury and membrane cells may

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[99] Euro Chlor Document: Env. Prot 10. Chlorine Production. “BAT for the amalgam electrolysis process. Mercury emissions to air, water, and products”-5th draft January 1997.

combine, to some extent, the caustic generation systems. Normally caustic is produced in the mercury cell process by feeding water to the mercury sodium amalgam (in mercury denuders) to produce 50% caustic directly. For a combined membrane cell mercury cell complex it is possible to feed 33% caustic from the membrane cells to the mercury denuders to produce 50% caustic without the need for evaporation. This allows an energy saving for the existing chlor-alkali production capacity, but results in caustic, originally produced by membrane cells, containing a very small quantity of mercury, like the mercury cell caustic.

7.4.2 Other Products

The future concentration of mercury in hydrogen is proposed, by Euro Chlor, is equivalent to less than 0.01g per tonne of chlorine capacity, assuming all hydrogen is used as product. The present mercury cell capacity (6.6 million tonnes of capacity) indicates, for this proposal, a maximum of 66 kg of mercury in hydrogen in the future, which would reduce further as capacity is decommissioned.

The mercury concentration in chlorine is extremely small, at less than 0.001 g per tonne (0.001 ppm), according to Euro Chlor. However Euro Chlor indicates that this level is not thought to be due to the operation of the mercury cell process, but may arise from the presence of mercury in the sulphuric acid used for drying chlorine. The total Western European chlorine production of 9 million tonnes of chlorine in 1995, indicates a maximum of less than 9 kg of mercury in chlorine.

Sodium hypochlorite, which is made from caustic and chlorine, in the future will have a typical mercury content of 15 mg mercury per tonne of sodium hypochlorite (13% solution) according to Euro Chlor. This is equivalent to 0.015 ppm.

7.5. Emissions from Energy Generation Utilised for Chlor-Alkali Production

7.5.1 Primary Energy Sources

Chlor-alkali production is energy intensive. Membrane cell have lower power consumption for electrolysis than mercury cells, but higher steam requirements for caustic evaporation. The power consumptions for electrolysis are similar for membrane and diaphragm, but diaphragm has the highest steam requirements of the three technologies for caustic soda evaporation. Therefore for the same primary energy sources for electricity and steam generation membrane cells would result in lower energy related emissions per tonne of chlorine generated. However each chlorine production plant may use electricity and steam sources with a different balance of primary energy sources (fossil fuel mix, hydroelectric, or nuclear) leading to the possibility of a range of energy related emissions per tonne of chlorine generated, even for the same technology.

Each country within Europe has a different balance of electricity generating capacity, and chlorine production plants may have electricity supply contracts with specific electricity generating companies. In addition some chlorine production plants (for example on chemical complexes) have dedicated, or associated power stations. Depending on the existing utilised generating capacity, associated investment in, for example, a dedicated Combined Cycle Gas Turbine plant could lead to lower carbon dioxide and other energy related emissions for the existing mercury cells than converting to membrane cells and retaining the existing electricity power generation capacity, if for example the primary energy source was coal.

7.5.2 Carbon Dioxide Emissions From Electrolysis Power Consumption

The carbon dioxide emissions for membrane and mercury cells can be compared either for a range of primary energy sources that could be used for power generation, of by region for average estimated CO2 emissions based on the regional fuel mix[100]. The effect of associated investment in gas plant (to replace coal for example) or the impact of a reduction capacity in EU, due to phase-out of mercury cells and compensating expansion of production in other regions could be compared. Based on these comparisons it appears that membrane cells may not always offer the lowest CO2 emissions depending on the primary fuel sources. However this comparison might be considered to be somewhat simplistic given the complicated nature of strategic decisions for electricity generation globally and supply/demand effects.

Primary Fuel Source	**CO2 emissions kg/KWh**	**Mercury cell** (3.36 Mwhr/te chlorine) **te CO2/te chlorine**	**Membrane Cell** (2.5 Mwh/te chlorine) **te CO2/te chlorine**
Coal	1.11	3.7	2.8
Oil	0.77	2.6	1.9
Gas	0.55	1.8	1.4
hydroelectric or nuclear	0	0	0
EU average 1995	0.47	1.6	1.2
USA average	0.65	2.2	1.6
Middle East	0.63	2.1	1.6
Non OECD Europe	0.79	2.7	2.0
Asia (excl. China)	0.66	2.2	1.7

7.5.3 Emissions of Mercury from Electrolysis Power Consumption

Fossil fuels such as coal or oil contain small amounts of mercury. Chlor-alkali production, independent of cell technology, may result in some small mercury emission associated with electricity generation if fossil fuels (coal or oil) are utilised as primary energy sources. The associated emissions would depend on the mercury content of coal and the cleaning technology utilised[101].

8. COST EFFECTIVENESS OF CONVERSION

8.1. Cost Effectiveness of Improvements

The cost effectiveness of converting mercury cells to membrane cells can be expressed as the cost effectiveness per kg of annual mercury emissions eliminated. Historically, since 1977 the chlor-alkali industry in Western Europe has reported a reduction in

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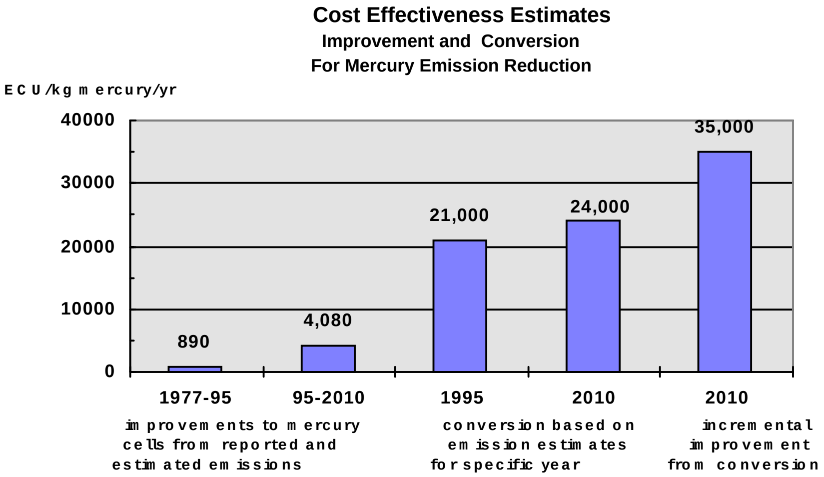
[100] CO2 emissions estimates taken from AFEAS/DOE TEWI report

[101] Department of the Environment, Mercury in the UK, prepared by ERM, March 1996

mercury emissions of 203 tonnes per year, from 221 tonnes in 1977, to 18 tonnes in 1995. In order to achieve this reduction the industry reports it has improved operating



procedures, invested in emission reduction technologies, and closed some mercury cell plant capacity.

One rough estimate is that the EU chlor-alkali industry may have invested 800 million ECU since the 1970s to improve the performance of mercury cell rooms, and over the same period closed or replaced 1.94 million tonnes of mercury cell capacity[102]. Typically some of the capacity closed would be older and might be expected to have had higher emissions of mercury than capacity which remained in operation. Assuming emissions from the plants decommissioned were a factor of 2 higher than emissions from capacity which remained in operation, then reductions in reported mercury emissions from retained capacity would be of the order of 128 tonnes. Typically 70% of these emission reductions (90 tonnes) could be considered to be a result of the investments, with 30% of the emission reductions achieved through improvements in operating procedures.[103] On this basis the estimated cost effectiveness of the investment would have been 890 ECU/kg mercury/yr reported emission reduction.[104]

Euro Chlor has indicated that some further investment would be required in order to achieve a reduction in reported emissions from approximately 18 tonnes in 1995 to an

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[102] 6.57 million tonnes mercury cell capacity in 1995, 8.3 million tonnes in 1977, peaking at 8.51 million tonnes in 1982 (Euro Chlor data), which suggests about 1.94 million tonnes decommisssioned

[103] Investment estimated from broad information from several companies with plants in different countries, including Germany, and assumes that plants in different Member States have different levels of historical investment. The emission improvement resulting from investments is an estimate from several companies.

[104] For all the scenarios used, the investment is annualised over 10 years

emission scenario, based on Euro Chlor projections (that do not take account of phase-out as laid down in the PARCOM Decision) of the order of 7.5 tonnes in 2010. According to an economically driven scenario, some mercury cell capacity would be replaced due to economic reasons, leaving an estimated 5 million tonnes of mercury cell capacity. The remaining capacity would be improved in terms of emissions. A rough estimate is that future investment could be a further 170 million ECU[105] in improvements, if it was assumed that 5 million tonnes of mercury cell capacity remained in operation by 2010. Assuming the future improvements result from investment and procedure in the same ratio as in the up to 1995 (70% of improvements resulting from investment), and taking into account the closure of some mercury cell plants, indicates that the estimated cost to eliminate annual emissions attributable to investment (4.2 tonnes) could be of the order of 4080 ECU/kg mercury/yr.[106] Reductions due to improvements in procedures could be of the order of 1.8 tonnes per year for this scenario.

8.1.1 Solid Waste

Beyond 2010, for an economically driven scenario, there would be generation of some solid waste containing mercury from operating mercury cells, although an objective of seeking ways to reduce the generation of solid waste containing mercury follows from the hierarchy of principles of waste management policy as set out in the communication on the review of the Community strategy for waste management.[107] It is expected that the chlor-alkali industry will become a net generator of mercury within the next few years, at which time the total quantity of mercury that needs to be dealt with should not increase further. Some mercury will be in the form of emissions, but for an economically driven scenario beyond 2010 it appears that of the order of 99% of the total mercury within the EU industry would need to be dealt with by recovery or disposal. If this mercury is dealt with by disposal, then it is likely to be in a secure form as solid waste, where mercury emissions to the environment are very low or zero. The volume of solid waste containing mercury generated for mercury cells that continue to operate may be influenced by the requirement in some Member States that mercury is not recovered from solid waste but disposed of, for example by encapsulation.

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[105] A rough estimate, taking into account the differences in investment to date for emission reductions for plants in different Member States and assumes that EU plants, which remained in operation in 2010, would on average have to invest similar amounts cumulatively per unit capacity to bring them up to equivalent standards to achieve the required emissions. Therefore the estimate is derived from the historical investment estimate (per unit capacity) and estimated future investment based on data from one company’s plants (including plants in Germany), which is then extrapolated to EU industry as whole. The estimates were then discussed with several other companies. Takes into account that some capacity will be converted for economic reasons

[106] Scenario assumes that 6 tonnes of mercury emission reduction are from improvements (investment and procedures), the other reduction (4.5 tonnes) from replacement of some capacity due to economic reasons, leaving 5 million tonnes of mercury cell chlorine capacity by 2010.

[107] Communication from the Commission on the review of the Community Strategy for Waste Management COM(96) 399 final

Based on the assumption that any possible net differences in the precise nature and quantity of solid waste containing mercury, from operating mercury cells beyond 2010 when compared to decommissioning by 2010 appear unlikely to be significant in the context of relative cost effectiveness comparisons for emission scenarios, solid waste has not been taken into account for the various scenarios for comparison of improvements with conversion of mercury cells.

8.2. Cost Effectiveness of Conversions

Replacing mercury cells, based on 1995 reported emissions and mercury cell capacity (6.6 million tonnes mercury cell capacity) has been estimated at a capital cost of 3.7 billion ECU, equivalent to a capital cost of about 21,000 ECU/kg mercury/yr to eliminate the reported 18 tonnes of mercury emissions in 1995. However this is not a true economic cost given that some plants will close due to economic reasons, and the net cost of advancing the conversion should in principle be used.

The cost effectiveness of conversion by 2010 could take into account economic conversions that may occur for an economically driven scenario. For this scenario, if it was assumed that 1.6 million tonnes of mercury cell capacity may have been eliminated by 2010 leaving 5 million tonnes of mercury cell capacity, which would account for about 4.5 tonnes of the reported emissions in 1995. In addition an estimated 1.8 tonnes of emission reductions may occur under this scenario due to improvements in procedures. Conversion as laid down in the PARCOM Decision could then account for 11.7 tonnes of emission reductions, assuming no further investment by the industry to improve the performance of existing mercury cell plants. The cost of conversion of 5 million tonnes of mercury cell capacity may be estimated at a cost of 2.8 billion ECU, equivalent to about 24,000 ECU/kg mercury/yr for the 11.7 tonnes of emissions eliminated. In principle, the net cost of advancing the conversion of mercury cells to 2010 from their economic lifetime should be used, together with any differences in operating costs, to provide a more accurate economic cost, but the capital cost may approximate to the economic cost if the average economic lifetime is sufficiently long beyond 2010, and if operating costs are broadly similar.

The incremental cost effectiveness of conversion could be estimated based on the additional cost to eliminate mercury emissions that would not be eliminated by economic closure of some plants, and improvements due to investment and procedures. On this basis the incremental cost effectiveness of conversion could be estimated as 35,000 ECU/kg mercury/yr[108]. These cost effectiveness scenarios do not include the phase-out by 2010 which involves closure of mercury cell capacity (rather than conversion), and is based on capital cost.

The cost effectiveness for conversion does not include any potential impact on global emissions that might occur if the chlor-alkali mercury stockpile is released onto the

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[108] Based on subtracting the estimated improvement cost (170 million ECU) from the conversion cost (2.8 to 3.05 billion ECU) for eliminating emissions of 7.5 tonnes of mercury that could be the level of emissions in 2010 from a scenario based on Euro Chlor projected emissions that does not take account of Conversion as laid down in the PARCOM Decision.

international mercury market.[109] By 2010, the estimated stockpile of 10,600 tonnes, if it is released onto the international mercury market, need only contribute to slightly greater annual emissions than those that might have been achieved from retaining the mercury in chlor-alkali cells in EU to result in a *negative* cost effectiveness when considering global mercury emissions.

8.3. Comparison of Improvement and Conversion Cost Effectiveness

The various cost effectiveness scenarios are summarised in the following table. The conversion cost effectiveness is based on capital cost.

Emission Reduction Scenarios	**Cost Effectiveness** ECU/kg mercury/yr[110]	**Emissions Eliminated** (tonnes)
Improvements to mercury cells		
1977 reported emissions 221 tonnes		
1977 to 1995 Investment (800 million ECU)	890	90
Operating procedure improvements		38
Economically driven conversion		75
1995 reported emissions 18 tonnes		
1995 to 2010 Investment (170 million ECU)	4,080	4.2
Operating procedure improvements		1.8
Economically driven conversion		4.5
2010 emissions scenario for economically driven scenario estimate 7.5 tonnes		
Phase-out through conversion of mercury cells		
2010 Forced conversions[111] (2.8 billion ECU)	24,000	11.7
Operating procedure improvements		1.8
Economically driven conversions		4.5
2010 Incremental effect of forced conversions (2.63 billion ECU)	35,000	7.5

8.4. Relative Cost Effectiveness of Improvements and Conversion

Cost effectiveness per kg of mercury emissions reduction could also be considered in terms of the impact on overall emissions for EU, Europe, and globally. Mercury emissions are considered a regional and a global issue, given that mercury emissions may be transported across regions or globally and considering cost effectiveness in global terms appears to be valid. In EU, at present, the estimated emissions of mercury

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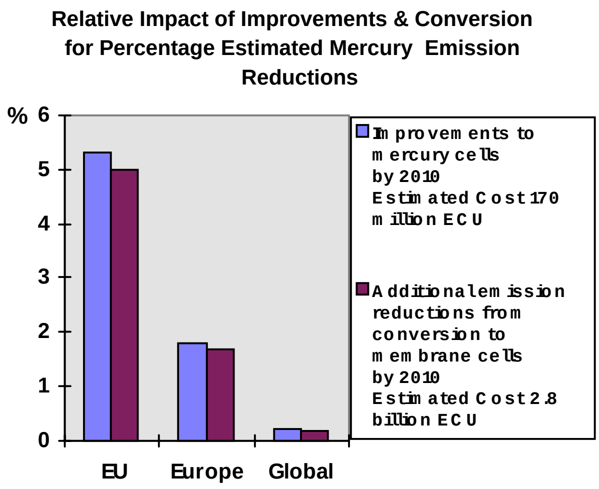
[109] Mercury Stock Management in the Netherlands, P A Maxson & G H Vonkeman, Institute for European Environmental Policy, Background Document prepared for the workshop "Mercury: ban it or bridle it?" 21 November 1996, The Hague; commissioned by The Netherlands Ministry of Environment. see also section on Decommissioning in Chapeter concerning BAT.

[110] The cost effectiveness of converting mercury cells can be expressed as the the cost effectiveness per kg of annual mercury emissions eliminated, based on depreciating investments over 10 years.

[111] for an estimated 5 million tonnes of mercury cell chlorine capacity

might be of the order of 150 tonnes based on a recent paper[112]. This paper gives an estimate of a minimum of 435 tonnes for mercury emissions for Europe as a whole. The global anthropogenic mercury emissions have been estimated at about 4000 tonnes.[113]



At the global level, improvements to mercury cells may eliminate about 0.2% of global mercury emissions at present, at an estimated cost of 170 million ECU. The additional reduction for global emissions from conversion may be about 0.19% at an estimated capital cost of 2.8 billion ECU. The estimated emission reduction for conversion does not include any potential impact on global emissions that might occur if the chlor-alkali mercury stockpile is released onto the international mercury market. At currently reported prices on the international mercury market, the cost to purchase 7.5 tonnes of mercury (equivalent to the additional annual emissions that may be eliminated by conversion by 2010) is of the order of 40,000 ECU.

At the European level, improvements may eliminate 1.8% of the estimated present European emissions at an estimated cost of 170 million ECU. The additional reduction from conversion may be 1.7% at an estimated capital cost of 2.8 billion ECU.

At the EU level, improvements may eliminate 5.3% of estimated present anthropogenic emissions at an estimated cost of 170 million ECU. The additional reduction from conversion may be 5% at an estimated capital cost of 2.8 billion ECU.

9. REGULATORY INSTRUMENTS AND PROPOSALS

9.1. European Union

9.1.1 Emissions to the Aquatic Environment

Mercury was one of the first substances subject to EU provisions to prevent or reduce pollution, in particular by its classification as a list I substance under Council Directive 76/464/EEC on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community. Under this framework directive, standards to

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[112] Mercury in products- a source of transboundary pollutant transport, Report to National Chemicals Inspectorate (KemI) J Munthe & K Kindbom, Swedish Environmental Research Institute (IVL) March 1997.

[113] Mercury Atmospheric Processes: A Synthesis Report; prepared by: expert panel on mercury atmospheric processes convened March 16-18, 1994 Florida USA

control discharges from chlor-alkali installations have been set by Council Directive 82/176/EEC on limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry. The standards for chlor-alkali installations set out emission limits for two different types of mercury cell process. The limit for the recycled brine process was set at 0.5 g of mercury present in effluent per tonne of chlorine production capacity, and the limit for the lost brine process was set at 5.0 g per tonne (by 1986) for all mercury containing water discharged from the site of the industrial plant.

The reported emissions to water for the chlor-alkali industry in Western Europe in 1995 were, on average, 0.2 g per tonne of chlorine capacity according to Euro Chlor. This includes both processes (recycled and lost brine). International and Member State measures have helped to provide the framework for these reported emission levels. Euro Chlor is at present drafting[114] its own BAT (Best Available Techniques) for mercury cells, for implementation in the future, and a guide for emissions to water, as a component for achieving a proposed total emissions limit of 1.9 g per tonne of chlorine capacity expressed as an annual average, is indicated as 0.1 g per tonne of chlorine capacity.

9.1.2 Integrated Pollution Prevention and Control Directive

The Council Directive concerning integrated pollution prevention and control[115] (IPPC) is a framework directive, as it defines a procedural framework, which is the integrated permitting process to address emissions to the environment as a whole. New and existing installations are distinguished under IPPC, with implementation for new plants in 1999, and for existing plants not later than 8 years after the Directive is brought into effect. The IPPC framework requires no mandatory prescription of technologies. BAT Reference Documents (BREFs) will be prepared for all sectors of industry covered by the Directive. Member State authorities should take account of BREFs, for local permitting, but may also take into account local and plant specific factors. At present the work programme as fixed after the IPPC BAT Information Exchange Forum-IEF[116], schedules a BREF for chlor-alkali production for 1998. The BREF for chlor-alkali could be one of four “composite BREFs” to cover the inorganic chemical industry, as discussed at the workshop on BAT for the chemical industry in Europe held on 14-16 May 1997, Paris.

A key element in the IPPC Directive is the concept of ‘Best Available Techniques’ (BAT) defined in Article 2 (11) as follows:

‘best available techniques’ shall mean the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission

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[114] Euro Chlor Document, Env.Prof. 10. Chlorine Production. BAT for the amalgam electrolysis process. Mercury emissions to air, water and products 5th draft January 1995

[115] Council Directive 96/61/EC concerning integrated pollution prevention and control

[116] Brussels, 2 April 1997

limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.

•'techniques' shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;

•'available' techniques shall mean those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator;

•'best' shall mean most effective in achieving a high general level of protection of the environment as a whole.

In determining the best available techniques special consideration should be given to the items listed in Annex IV of the Directive.

9.1.2.1 Factors Associated with Mercury Cell Operation in the EU

There are various factors associated with the operation of mercury cells in the EU which may be relevant for the process of developing a BREF for the chlor-alkali process.

•The existence of the PARCOM Decison 90/3, part 3 of which recommends to phase out mercury cells by 2010.

•The availability of membrane technology as the preferred technology for new or replacement installations, offering no direct emissions of mercury and lower electricity consumption.

•Euro Chlor have stated that no new mercury cells will be constructed.

•Three Member States (Austria, Greece, and Italy) are not committed to the PARCOM Decision. All three countries have mercury cell capacity at present. Mercury cells are the main production technology in Italy (of the order of 80% of total capacity[117]), and mercury cells in Italy are about 12% of the Western European mercury cell capacity. Greece (35,000 tonne of mercury cell capacity, 0.5% of WE mercury cell capacity) and Austria[118] (60,000 tonnes, 0.9% of WE capacity) both have a small mercury cell plant, which was 100% of the production capacity in each country in 1995.

•Not all mercury cell installations in Member States that are members of PARCOM are included in the PARCOM reporting process for the chlor-alkali industry, for

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[117] Information Chemie n°366 mars 1995 p109

[118] The closure of a second plant in Austria was recently announced, reported in Chemical Week Februay 12 1997

discharges into the North Sea basin. In 1994 the mercury cell capacity included in the report was 4.37 million tonnes. The members of PARCOM have a further 1.4 million tonnes approximately, not covered by the OSPARCOM reporting process. This capacity is in France, Germany, and Spain, with a small plant in Finland (60,000 tonnes capacity).

- PARCOM Decision 90/3 part 3 of which recommends that existing mercury cell chlor-alkali plants be phased out as soon as practicable, with the objective that they should be phased out completely by 2010. The wording of part 3 could result in some Member States that are Contracting Parties to Paris Convention allowing the operation of mercury cells after 2010 on the basis that it is not practicable to phase them out by the date signalled as the objective.

- The decommissioning of mercury cells may in principle, under present measures, lead to over 10,000 tonnes of mercury becoming available on the international mercury market. The impact on emissions to the environment for this mercury, if released onto the international market should be considered. Decommissioning of existing mercury cell installations could fall within the scope of BAT in the context of IPPC.

- The BREFs should be taken into account when implementing IPPC, which is required for existing plants not later than 8 years after the Directive is brought into effect. The SRIC study, which reports on economic issues of conversion by 2010, appears to be directly relevant to economic viability in this timeframe. Conversion of mercury cells appears to be considered by industry as uneconomic for of the order of 33% (2.2 million tonnes) of the present mercury cell capacity, and the total chlorine production capacity has been projected[119] to shrink by about this amount (2.2 million tonnes).

- According to Euro Chlor, the application of the same BAT, which it is developing for mercury cells, could under a range of local plant circumstances, such as climate, geographical location, local environmental circumstances, age of plant, or process variants result in a different numerical outcome as to the emission levels. Euro Chlor reports that significantly lower emissions may be achieved under the most favourable circumstances.

- The issue of reliability of reported emission data for chlor-alkali installations[120] was noted by the POINT sources working group, a subgroup of OSPARCOM. The Euro Chlor document for the proposed industry BAT discusses monitoring and sampling methods. Continuing to improve confidence in the reliability and accuracy of the mercury emission and solid waste data appears to be important and it seems appropriate to review the methods and accuracy for measurement of mercury emissions, and mercury as solid waste.

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[119] SRIC,”Competitive Situation of Western European Chlor-Alkali Industry in a Global Context”, prepared for Euro Chlor, April 1997

[120] OSPARCOM Working Group on Point Sources (Point) Draft Report on Mercury Losses from the Chlor-Alkali Industry (1982-1995) POINT 96/17/1-E

9.2. PARCOM

In 1990, the Third Ministerial North Sea Conference (The Hague) established a 70% general reduction target for mercury. In addition, for the chlor-alkali industry, a standard was given for atmospheric emissions and the objective was set to phase out mercury cells completely. In the same year, these were adopted by the PARCOM Decision 90/3 on reducing atmospheric emissions from existing chlor-alkali plants, which states that:

"Contracting Parties to the Paris Convention for the Prevention of Marine Pollution from Land-Based Sources Agree

.1 that existing mercury based chlor-alkali plants shall be required to meet by 31 December 1996 a standard of 2g Hg/t Cl2 capacity for emissions to the atmosphere, unless there is a firm commitment that the plant will be converted to mercury free technology by the year 2000;

.2 that mercury in hydrogen which is released to the atmosphere, or is burnt, is to be included in this standard;

.3 and recommend that existing mercury cell chlor-alkali plants be phased out as soon as practicable. The objective is that they should be phased out completely by 2010."

The emissions to air for the chlor-alkali industry in Western Europe in 1995 were reported, on average to be 2.1 g per tonne chlorine capacity. Euro Chlor is at present drafting its own BAT (Best Available Techniques) for mercury cells, for implementation in the future, and a guide for emissions to air, as a component for achieving a proposed total emissions limit of 1.9 g per tonne of chlorine capacity expressed as an annual average, is indicated as 1.7 g per tonne of chlorine capacity.

The 1992 OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic will, when fully ratified, supersede the Paris Convention and the Oslo Convention, and will formalise the legally binding nature of PARCOM Decisions.

9.3. UN/ECE

The UN/ECE has over 50 members including USA and Canada, and is a pan-European forum for intergovermental environmental cooperation. It has set up legally binding multilateral conventions dealing with cross-border environmental issues. The Convention on Long-Range Transboundary Air Pollution (LRTAP) started the development of a Protocol on Heavy Metals (HMs), to reduce atmospheric emissions of cadmium lead and mercury. Control measures for emissions from stationary sources and specific emission standards for selected major stationary sources will be contained in annexes to the Protocol. These will provide BAT and/or emission limit values for mercury emissions from chlor-alkali installations. Depending on progress, the Protocol could come into force in the timeframe 2000-2005.

9.4. EU Environmental Agreements

The Communication from the Commission on Environmental Agreements[121] sets out general considerations and guidelines for their use. To date a rather limited number of non-binding agreements, taking the form of unilateral commitments promoted or recognised by the Commission, have been concluded at European level. Binding agreements, however, have not been concluded with the European Community as party to the agreement. Binding policy instruments explicitly named by the Treaty of Rome are Regulations, Directives, and Decisions.

For the time being, the Commission has to resort to non-binding agreements as the available instrument to encourage a pro-active approach from industry and it is necessary to base non-binding agreements on objectives already endorsed by the Community institutions or international conventions, which is the case for mercury emission reduction. The issues associated with mercury emissions from the chlor-alkali industry can be considered against the objectives of the Communication.

It is considered most likely that cost-effective use of Environmental Agreements will be made as part of a policy-mix together with, for instance, regulatory or economic instruments. The IPPC Directive, PARCOM Decision 90/3, and UN/ECE Protocol on Heavy Metals provide a range of measures that will control emissions from chlor-alkali installations. IPPC BAT could also define techniques for decommissioning of mercury cells.

It is important that any agreement can cover sufficiently the sector in question, and for relatively large numbers of companies with a range of sizes, a strong business association could help in the burden-sharing between participating companies. Euro Chlor represents all the companies that operate mercury cells in EU, there are a limited number of companies (about 30), and a limited number of mercury cell installations (about 60) in EU. There is in place a reporting mechanism for mercury emissions of companies to be submitted and collated by Euro Chlor, and Euro Chlor is developing an industry BAT, to which individual companies should be committed. This structure provides encouragement that “free-riders“ might be avoided and that effective negotiation could take place. In a wider European context, which is important for mercury emissions, Euro Chlor represents all Western European companies operating mercury cell plants and some Eastern European companies. There is considerable expertise available within Euro Chlor companies for the optimum operation of mercury cells; this expertise could be important for implementation of reduced mercury emissions for plants in Eastern Europe.

It must also be considered if the commitments of industry can be used as an effective environmental measure. There are a range of existing and developing instruments that control emissions of mercury from chlor-alkali installations, but the decommissioning of mercury cells and the stockpile of mercury contained in all the EU mercury cells

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[121] COM(96) 561 final, Communication from the Commissions to the Council and the European Parliament on Environmental Agreements

will need to be dealt with. The timing of any appropriate measures is important given that the chlor-alkali industry is expected to become a net generator of mercury within the next few years, and an Environmental Agreement could encompass this issue.

The objectives of an Environmental Agreement have to be quantified, intermediate objectives should be set as part of a staged approach, and results have to be monitored. An Environmental Agreement at the Community level offers the possibility of monitoring the total emissions of the EU chlor-alkali industry, which is not covered by OSPARCOM reporting, and to monitor trends as part of a staged approach. Other instruments, could set quantified objectives that cover emissions of individual installations.

In light of these aspects, it seems interesting to hold discussions with industry, to explore if an Environmental Agreement at Community level with Euro Chlor, on behalf of its member companies, could be appropriate within the mix of instruments available.