United States Environmental Protection Agency | Office Of Air Quality Planning And Standards Research Triangle Park, NC 27711 | EPA December 2000 EPA-452/R-01-002

Air

EPA

Economic Impact Analysis for the Proposed Mercury Cell Chlor-Alkali Production NESHAP

Office of Air Quality Planning and Standards

Clean Air

OAQPS

This report has been reviewed by the Emission Standards Division of the Office of Air Quality Planning and Standards of the United States Environmental Protection Agency and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, or from the National Technical Information Services 5285 Port Royal Road, Springfield, VA 22161.

Acronyms

EIA	Economic Impact Analysis
EPA	United States Environmental Protection Agency
HAPs	Hazardous Air Pollutants
ISEG	Innovative Strategies and Economics Group
NESHAP	National Emission Standards for Hazardous Air Pollutants
OAQPS	Office of Air Quality, Planning, and Standards
RFA	Regulatory Flexibility Act
SBREFA	Small Business Regulatory Enforcement Fairness Act

SECTION 1

INTRODUCTION

Chlorine is used in the production of a wide range of products including organic and inorganic chemicals, as well as in direct application for uses such as drinking water treatment. Producers can choose from a variety of processes for the production of chlorine. One process, the mercury cell process, results in the release of hazardous air pollutants (HAPs) in the form of mercury emissions. Under Section 112 of the Clean Air Act (CAA), the U.S. Environmental Protection Agency (EPA) is required to promulgate national emission standards for hazardous air pollutants (NESHAP) for mercury cell chlor-alkali facilities in early part of the year 2001, and develop a maximum achievable control technology (MACT) standard to reduce HAPs from the facilities. To support this rulemaking, EPA's Innovative Strategies and Economics Group (ISEG) has conducted an economic impact analysis (EIA) to assess the potential costs of the rule. This report documents the methods and results of this EIA.

1.1 Agency Requirements for an EIA

Congress and the Executive Office have imposed statutory and administrative requirements for conducting economic analyses to accompany regulatory actions. Section 317 of the CAA specifically requires estimation of the cost and economic impacts for specific regulations and standards proposed under the authority of the Act.[1] The Office of Air Quality Planning and Standards' (OAQPS') *Economic Analysis Resource Document* provides detailed instructions and expectations for economic analyses that support rulemaking (EPA, 1999). In

[1]In addition, Executive Order (EO) 12866 requires a more comprehensive analysis of benefits and costs for proposed *significant* regulatory actions. Office of Management and Budget (OMB) guidance under EO 12866 stipulates that a full benefit-cost analysis is required only when the regulatory action has an annual effect on the economy of $100 million or more. Other statutory and administrative requirements include examination of the composition and distribution of benefits and costs. For example, the Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement and Fairness Act of 1996 (SBREFA), requires EPA to consider the economic impacts of regulatory actions on small entities.

the case of the mercury cell chlor-alkali MACT standard, these requirements are fulfilled by examining

- facility-level impacts,
- market-level impacts,
- industry-level impacts, and
- societal-level impacts.

1.2 Overview of the Chlor-Alkali Industry

The U.S. Census Bureau refers to the "chlorine" industry as the "alkalies and chlorine" industry (SIC 2812; NAICS 325181), or the "chlor-alkali" industry. Even though it is a significant economic commodity itself, chlorine is linked with other products because of unique characteristics in the production process. As described in more detail below, chlorine is typically produced by a chemical process that jointly creates both chlorine and sodium hydroxide (caustic soda), an alkali, in fixed proportions. As a result, chlorine and sodium hydroxide are joint commodities and must be considered together in an economic analysis. Chlorine is among the ten largest chemical commodities by volume in the United States (see Table 1-1) (Shakhahiri, 2000).

The three most popular methods for producing chlorine are the membrane cell, the diaphragm cell, and the mercury cell. These methods account for over 95 percent of chlorine production. The regulations examined in this analysis pertain directly to the mercury cell chlor-alkali facilities, which account for 16 percent of chlorine production.

Much of the chlorine produced is used internally by facilities to produce other products (referred to as captive production), while only 27 percent of chlorine is sold directly on the merchant market in the 1997 base year. Based on traditional measures of industry concentration, the chlorine industry appears to be highly concentrated, although the merchant market is less concentrated than the overall production numbers suggest. The economic analysis presented below was carried out under two different assumptions about market concentration—a perfectly competitive merchant market for chlorine and a concentrated merchant market for chlorine.

Table 1-1. Top Ten U.S. Chemicals by Mass: 1997

Rank	Chemical	Mass (10^9 lbs)
1	Sulfuric acid	95.6
2	Nitrogen	82.8
3	Oxygen	64.8
4	Ethylene	51.1
5	Lime	42.5
6	Ammonia	38.4
7	Phosphoric acid	33.6
8	Propylene	27.5
9	Ethylene dichloride	26.3
10	Chlorine	26.0

Source: Shakhahiri, B.Z. 2000. Chemical of the Week: Sulfuric Acid. <http://www.scifun.chem.wisc.edu/CHEMWEEK/sulf&top/Sulf&top.html>. Obtained June 15, 2000.

1.3 Summary of EIA Results

The proposed mercury cell chlor-alkali rule will impose small regulatory control costs on production and therefore generate small economic impacts in the chlorine market. The impacts of these cost increases will be borne largely by producers, especially the directly affected facilities in both the merchant and captive markets. The key results of the EIA for chlorine and sodium hydroxide are as follows:

- *Engineering Costs*: Total annual costs measure the costs incurred by the industry annually. The annual engineering control costs are estimated to be $1.460 million before accounting for behavior changes by consumers and producers.
- *Price and Quantity Impacts*: These impacts are small.
  - The average prices in the merchant market for chlorine and sodium hydroxide are projected to remain essentially unchanged (prices increase by less than 0.001 percent) in either the competitive market model or the concentrated market model.

  - The quantities of chlorine and sodium hydroxide produced for the merchant market are projected to fall by less than 50 tons per year in either the competitive market model or the concentrated market model.

- *Small Businesses*: The economic model does not predict any significant changes in revenue or profits for small business as a result of the regulation. The ratio of compliance costs-to-sales (CSR) is less than 1 percent for both large and small businesses.

- *Social Costs*: The economic model estimates the total social cost of the rule at $1.460 million in the competitive model and $1.462 million in the concentrated market model. Directly affected producers bear nearly all of these costs as profits decline by $1.459 million in the competitive market model and $1.460 in the concentrated market model. Consumers (domestic and foreign) are projected to lose less than $10,000 annually in both models.

1.4 Organization of this Report

The remainder of this report supports and details the methodology and the results of the EIA of the chlorine NESHAP.

- Section 2 presents a profile of the chlor-alkali industry.
- Section 3 describes the regulatory controls and presents engineering cost estimates for the regulation.
- Section 4 describes the EIA methodology and reports market-, industry-, and societal-level impacts.
- Section 5 contains the small business screening analysis.

In addition to these sections, several appendices provide detail on the economic modeling approach and sensitivity analysis of some of the key parameters.

SECTION 2

INDUSTRY PROFILE

The NESHAP will potentially affect 43 (chlorine production) facilities known to be in operation in 1997. Thirty-nine of the facilities use the chlor-alkali processes, jointly producing sodium hydroxide. Three chlor-alkali processes exist: diaphragm cell, membrane cell, and mercury cell. The remaining facilities use one of four other processes that exist to produce chlorine: Downs sodium process, magnesium production process, hydrogen chloride (HCl) decomposition, and nitric acid salt process. This profile begins by characterizing the supply side of the chlor-alkali products industry, including the stages of the production process, the types of chlorine products, and the costs of production. Section 2.2 addresses the consumers, uses, and substitutes for chlorine and sodium hydroxide products. The organization of the chlorine products industry is discussed in Section 2.3, including a description of U.S. manufacturing plants and the parent companies that own these plants. Finally, Section 2.4 presents historical statistics on U.S. production and consumption of chlorine and sodium hydroxide as well as data on the foreign trade of chlorine and sodium hydroxide.

2.1 Production Overview

This section describes the process by which chlorine and alkali co-products are produced and presents information on the configuration of production plants and the cost of production.

2.1.1 Chlor-Alkali Process[1]

More than 95 percent of the domestic chlorine produced results from the chlor-alkali process that involves the electrolysis of brine (*Chemical Week,* 1996). Figure 2-1 presents a simple diagram of this process. Chlorine and sodium hydroxide are co-products of

---

[1]The material in this section draws heavily from Kroschwitz (1991) and Gerhartz (1992). Any exceptions to this or specific references within these two sources are noted accordingly.

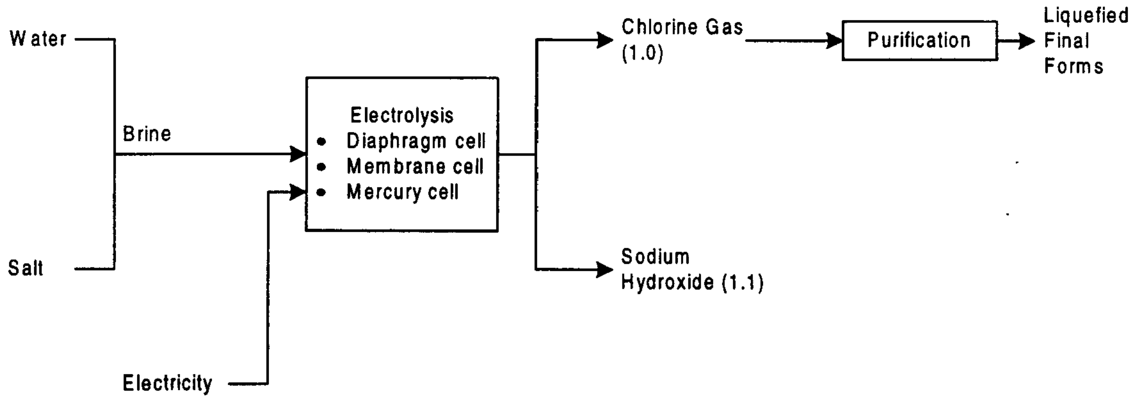


Figure 2-1. Chlor-Alkali Process

electrolysis of sodium chloride brine. Electricity acts as a catalyst in this reaction, which takes place in electrolytic cells. The amount of electricity required depends on electrolytic cell parameters such as current density, voltage, anode and cathode material, and the cell design.

Conversion of sodium chloride brine to chlorine and sodium hydroxide can take place in one of three types of electrolytic cells: the diaphragm cell, the membrane cell, or the mercury cell. An important distinguishing feature of these cells is the manner by which the products are prevented from mixing with each other, thus ensuring generation of products having the proper purity (Kroschwitz, 1991).

The chlorine produced by the electrolysis of brine is then purified and liquified for commercial use. Important factors affecting the liquefaction process are the composition of the chlorine gas, the desired purity of the liquified chlorine, and the desired yield. Each of the main process steps is now described in more detail.

2.1.1.1 Chlorine Synthesis

As indicated previously, electrolysis is the primary method of chlorine production; however, other chlorine manufacturing processes exist. These operations generally capture chlorine as a co-product of the production of another chemical or as a result of a chemical reaction. Similarities exist across the cells used for electrolysis; however, there are important distinctions between the diaphragm cell, the membrane cell, and the mercury cell processes.

The primary distinguishing characteristic is the manner by which the electrolysis products are prevented from mixing.

Diaphragm Cell Process. During the diaphragm production process, saturated brinc enters the electrolytic cell and flows into an anode chamber (see Figure 2-2). As the brine flows past the anodes, the electrons are stripped off the chloride ions to form chlorine gas. The solution passes through the diaphragm into the cathode chamber where sodium hydroxide and hydrogen are produced. Chlorine gas is collected at the top of the cell, cooled, compressed, and liquified. The sodium hydroxide solution may undergo further purification steps, but it is generally suitable for over 80 percent of the caustic market. Hydrogen gas is collected at the top of the cell similar to chlorine, cooled and filtered, used on-site or sold off-site, or released to the atmosphere.

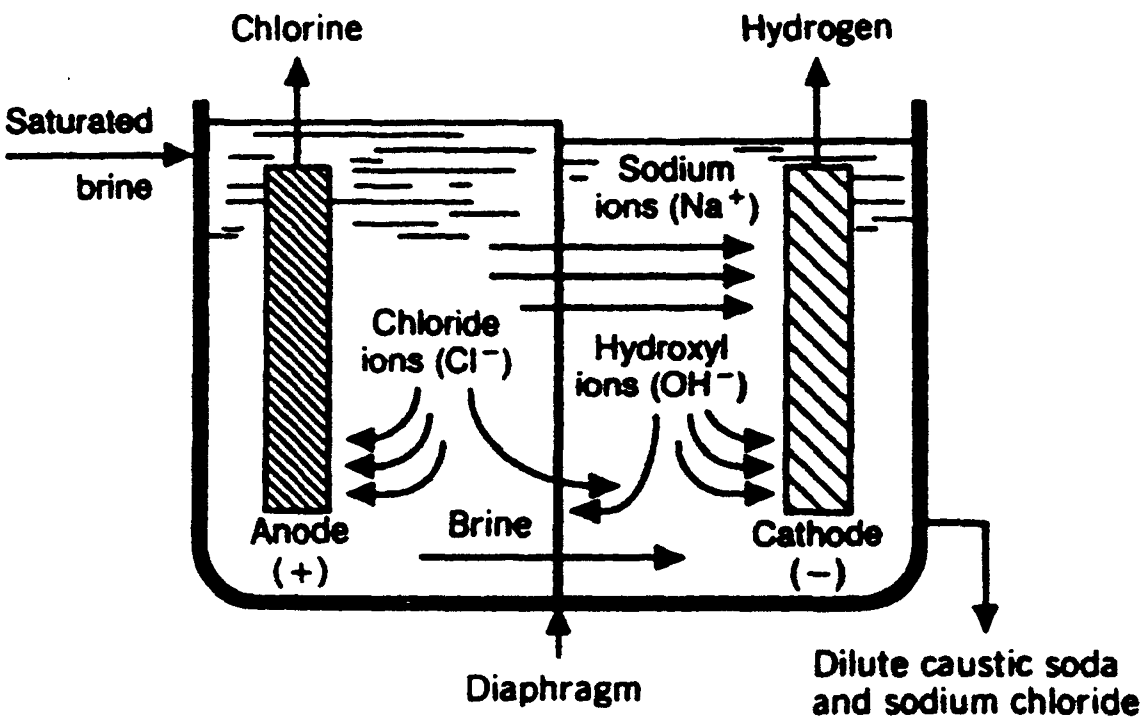


Figure 2-2. Schematic of the Diaphragm Cell Process

Source: Kroschwitz, Jacqueline. 1991. *Kirk-Othmer Encyclopedia of Chemical Technology*, 4th Ed. New York: John Wiley & Sons.

Membrane Cell Process. The membrane cell also contains an anode and cathode assembly, but they are separated by a semipermeable Nafion (ion-exchange) membrane (see Figure 2-3). Brine flows into the annode chamber, but unlike the diaphragm process, chloride ions cannot migrate through this membrane into the cathode chamber. An electric voltage is applied between the anode and cathode that generates chlorine gas in the anode and releases sodium ions and water into the cathode. The chlorine gas flows out of the anode chamber and is ducted to a chlorine purification section. In contrast, the catholyte solution is processed in an evaporation system where a sodium hydroxide solution is obtained, filtered, and sold. The sodium hydroxide derived from the membrane process is higher quality than that derived from the diaphragm process.

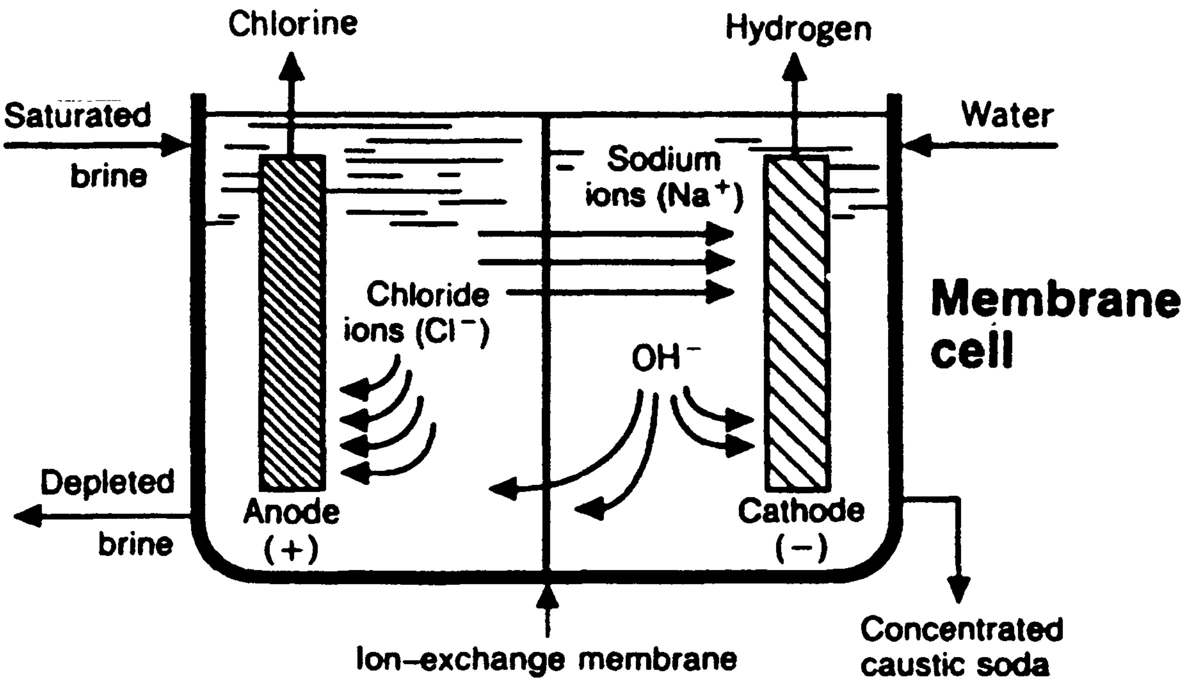


Figure 2-3. Schematic of the Membrane Cell Process

Source: EC/R Incorporated. September 12, 1996. *Background Information Document: Chlorine Production Summary Report.* Prepared for the U.S. Environmental Protection Agency. Durham, NC: EC/R Inc.

Mercury Cell Process. In the mercury cell process, chlor-alkali production involves two distinct cells. The electrolytic cell produces chlorine gas (see Figure 2-4), and a separate amalgam decomposer (not pictured) produces hydrogen gas and caustic solution.[2] A saturated salt brine is fed to the electrolytic cell, and the brine flows on top of a continuously fed mercury stream (which acts as the cathode in this process). An electric current is applied, causing a reaction that produces chlorine gas at the anodes suspended in the top of the cell and a mercury-sodium amalgam at the cathode. The chlorine is collected at the top of the cell while the amalgam proceeds to the decomposer. In the decomposer, the mercury amalgam comes in contact with deionized water where it reacts and regenerates into elemental mercury and produces caustic solution and hydrogen. Caustic solution and hydrogen are transferred to other processes for purification, and the mercury is recycled back into the cell. Like the diaphragm process, the mercury cell produces high quality sodium hydroxide directly from the caustic solution.

Of the three electrolytic processes, the diaphragm and membrane processes are the most similar. Both share the advantage of lower electricity consumption. New plant construction has favored membrane cell construction because of low capital investment and operating costs relative to diaphragm and mercury processes. Membrane cells' share of domestic capacity increased from 3 percent in 1986 to 16 percent in 1999 (Chlorine Institute, 2000). Although still economical, the diaphragm process share of domestic capacity has declined slightly from 76 percent in 1986 to 71 percent in 1999. The diaphragm process produces a lower-quality sodium hydroxide, which may be a contributing factor to this decline. The mercury cell process produces high-quality sodium hydroxide with simple brine purification, but the use of mercury includes the cost disadvantages associated with environmental controls (Kroschwitz, 1991). Similar to the diaphragm process, the mercury process' share of domestic capacity has declined from 17 percent in 1986 to 12 percent in 1999. In addition, no new mercury cells have been built since 1970.

---

[2]The decomposer is a short-circuited electrical cell in which graphite acts as the cathode and the amalgam as the anode.

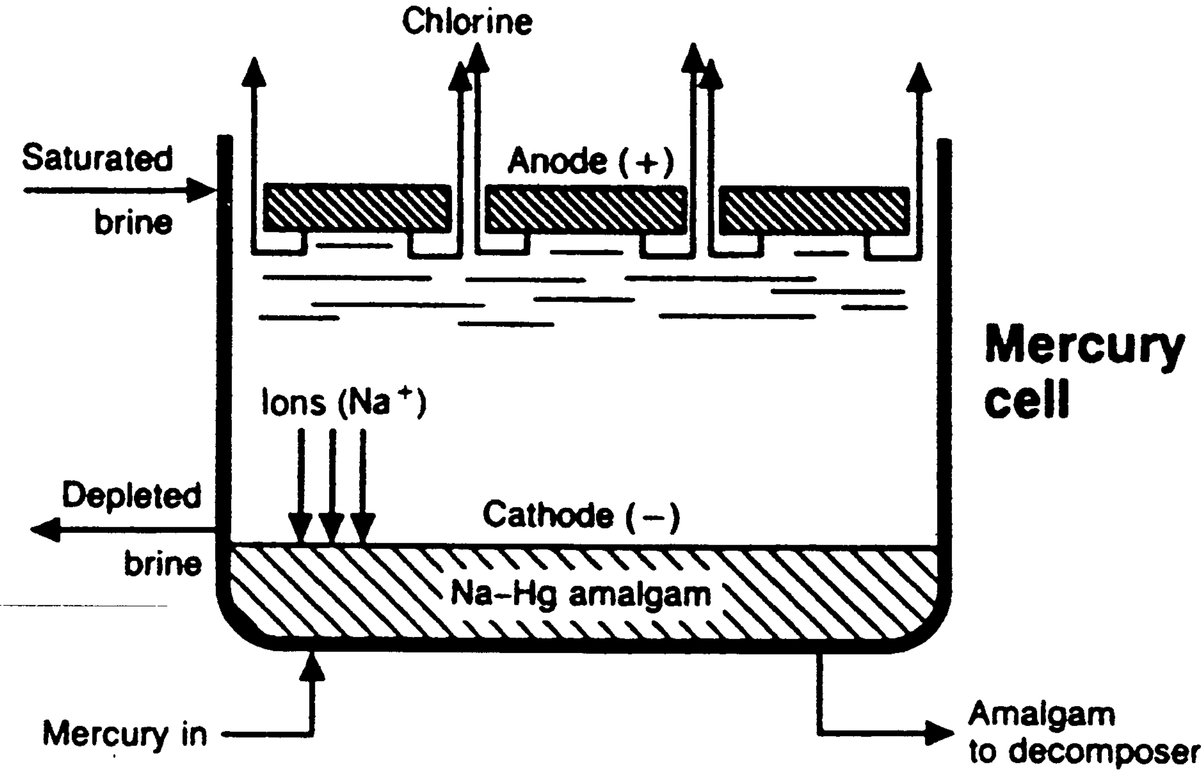


Figure 2-4. Schematic of the Mercury Cell Process

Source: EC/R Incorporated. September 12, 1996. *Background Information Document: Chlorine Production Summary Report.* Prepared for the U.S. Environmental Protection Agency. Durham, NC: EC/R Inc.

2.1.1.2 Other Chorine Synthesis Processes

While the vast majority of chlorine is produced by one of the three electrolytic methods, other commercial processes for chlorine also exist. EPA's Background Information Document (BID) identified facilities using the following "minor" chlorine production processes:

- Chloride production from hydrogen chloride: Electrolytic decomposition of aqueous hydrochloric acid is used to produce chlorine and hydrogen. The process is similar to the electrolytic processes described above with the exception that the input solution is hydrogen chloride (typically a 22 to 24 percent hydrogen chloride).

- Chlorine from sodium metal co-production with Downs cell: Molten salt consisting of sodium chloride, calcium chloride, and barium chloride is electrolytically broken down into sodium metal and chlorine gas using open top diaphragm cells. The Downs sodium cells require more maintenance (i.e., diaphragm replacement, purification) than the closed electrolytic chlor-alkali cells described earlier.

- Nitric acid salt process: One of the co-products during the electrolytic production of potassium hydroxide is chlorine. In this process, potassium chloride reacts with nitric acid and oxygen to form potassium nitrate, chlorine gas, and water. The potassium nitrate and water are drained form the reactor. Chlorine is liberated as a gas, along with nitrogen dioxide, and is liquified in refrigerated condensors.

- Co-production of magnesium and chlorine: Magnesium and chlorine are produced by fused salt electrolysis of magnesium dichloride. Chlorine is recycled through this process or it is sold commercially.

- Other production processes used to produce chlorine identified in the BID document include the nitrosyl chloride process, Kel-Chlor process, potash manufacture process, and sodium chloride/sulfuric acid process. However, no U.S. facilities were identified that use these processes.

2.1.1.3 Chlorine Purification

Regardless of the process, the chlorine stream leaving the synthesis stage is hot and saturated with water. Impurities in this chlorine stream include oxygen, nitrogen, carbon dioxide, carbon monoxide, hydrogen, and other contaminants produced through side reactions in the electrolytic process. To purify the chlorine, it is cooled, dried, and liquified. Chlorine gas is generally liquified for commercial use.

2.1.2 Forms of Output

2.1.2.1 Chlorine

Chlorine is a greenish-yellow gas belonging to the halogen family. It has a pungent odor and a density 2.5 times that of air. In liquid form, it is clear amber and solid chlorine forms pale yellow crystals. Chlorine is soluble in water and in salt solutions with solubility decreasing with salt strength and temperature. Chlorine is stored and transported as a liquefied gas. For shipping purposes, about 70 percent of chlorine is shipped by rail, 20 percent by pipeline, 7 percent by barges, and the remainder in cylinders (Kroschwitz, 1991).

2.1.2.2 Sodium Hydroxide

Sodium hydroxide, commonly referred to as caustic soda, is a brittle, white, translucent crystalline solid. Two types of sodium hydroxide are produced:

- diaphragm caustic (50 percent rayon grade): This type is suitable for most applications, and it accounts for approximately 85 percent of sodium hydroxide consumption.
- membrane and mercury caustic: This type of sodium hydroxide meets high purity requirements such as those required for rayon production. Membrane and mercury caustic are also produced in 73 percent caustic and anhydrous caustic forms.

2.1.3 Costs of Production

Energy and raw material costs represent the highest share of the chlor-alkali production costs. As shown in Table 2-1, these costs account for approximately 65 percent of total costs. The primary differences in operating costs between the three electrolysis processes (diaphragm, membrane, and mercury) result from variation in electricity requirements (Kroschwitz, 1991). Labor is another significant cost component, accounting for 21 percent of total production costs.

Total capital costs for a prototype 500 ton per day chlorine production plant are approximately $111 million (reported in 1990 dollars, the most recent year available). As shown in Table 2-2, the largest cost components are the electrolytic cells ($25.5 million) and the establishment of energy sources ($22.5 million). Although one company has recently converted a mercury process to a membrane process, conversion of mercury cells is generally considered a less attractive alternative to the construction of a new membrane plant. Cost estimates for this type of conversion range from $100,000 to $200,000 per ton per day. Electrolytic cells and membranes account for approximately 60 percent of the total investment (Kroschwitz, 1991).

Table 2-1. Costs of Production for the Chlor-Alkali Industry (SIC 2812; NAICS 325181): 1997

	Value (10^3)	Share of Total Costs	Share of Value of Shipments
Raw materials and supplies	$537,520	33%	22%
Fuels and electricity	$527,228	32%	21%
Labor	$339,677	21%	14%
Depreciation	$145,890	9%	6%
Purchased services	$62,293	4%	3%
Rental payments	$13,862	1%	1%
Total	$1,626,470	100%	66%
Value of shipments	$2,465,183	NA	100%

NA = not available

Source: U.S. Department of Commerce, Bureau of the Census. 1999. *1997 Economic Census—Manufacturing Industry Series: Alkalies and Chlorine Manufacturing.* EC97M-3251E. Washington, DC. [online]. <http://www.census.gov/prod/www/abs/97ecmani.html>.

2.2 Demand for Chlorine and Sodium Hydroxide

The previous section described supply side elements of the chlorine industry—how chlorine and its co-product, sodium hydroxide, are produced and what the costs of production are. This section addresses the demand side—the uses and consumers of chlorine and sodium hydroxide.

2.2.1 Chlorine Demand

Early uses of powdered and liquid chlorine included bleaching of textiles and paper, cleaning, and disinfecting (Gerhartz, 1992). Since 1950, chlorine has achieved increasing importance as a raw material in synthetic organic chemistry. Chlorine is an essential component of a multitude of end products that are used as materials for construction, solvents, and insecticides. In addition, chlorine is a component of intermediate goods used to make chlorine-free end products. These uses of chlorine generally influence chlorine production quantities in a given year.

Table 2-2. Capital Costs for 500 Ton per Day Chlorine Production Plant (10^6 \$1990)

	Average Total Cost[a]
Cells	\$25.5
Utilities and offsites	\$22.5
Overhead	\$11.7
Engineering	\$11.7
Caustic evaporation	\$8.3
Brine purification	\$7.5
Miscellaneous	\$6.7
Chlorine collection	\$6.5
Caustic storage	\$5.4
Rectifiers	\$3.4
Hydrogen collection	\$2.0
Total	\$111.0

[a] Capital costs for mercury cell plants were not available and are not included in the calculation of averages.

Source: Kroschwitz, Jacqueline. 1991. *Kirk-Othmer Encyclopedia of Chemical Technology*, 4th Ed. New York: John Wiley & Sons.

2.2.1.1 Chlorine Uses

Consumers use chlorine in three major categories:

- organic chemicals,
- inorganic chemicals, and
- direct applications.

Chlorine is used as a material input into the production of organic and inorganic chemicals, which in turn are used in other production processes and/or products. Organic chemicals (those containing carbon) are typically used either as chemical intermediates or end products. Inorganic chemicals are used in the production of a wide variety of products, including basic chemicals for industrial processes (i.e., acids, alkalies, salts, oxidizing agents, industrial gases, and halogens); chemical products to be used in the manufacturing products (i.e., pigments, dry colors, and alkali metals); and finished goods for ultimate consumption (i.e., mineral fertilizers, glass, and construction materials) (EPA, 1995). Chlorine is also used in several direct applications, including bleaching (pulp and paper), waste water treatment, and sanitizing and disinfecting (i.e., for municipal water supplies and swimming pools).

As shown in Table 2-3, the composition of chlorine demand is expected to remain fairly stable, with a slight decrease in the percentage of chlorine consumed in direct applications.

Table 2-3. U.S. Chlorine Consumption

Use	Percentage of Total Production		
	1995	**1998**	**2003**
Organic chemicals	**74%**	**76%**	**80%**
PVC	26%	30%	33%
Inorganic chemicals	**14%**	**14%**	**13%**
Direct applications	**12%**	**10%**	**7%**
Pulp and paper	6%	4%	1%
Water treatment	4%	4%	4%

Source: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide*. CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

2.2.1.2 Major Chlorine Consumers[3]

Industry accounts for most of the direct chlorine consumption in the United States. The chemical industry consumes chlorine as an intermediate good in the production of other chemicals, such as polyvinyl chloride (PVC) resin. The pulp and paper and waste treatment industries use chlorine in direct applications. Households consume chlorine indirectly, as a component of other products such as PVC pipe, clean water, or cleaning products. Consumers of chlorine in 1998 are presented in Figure 2-5 and summarized below (Berthiaume, Anderson, and Yoshida, 2000).

[3]The material in this section draws heavily from Kroschwitz (1991) and Gerhartz (1992). Any exceptions to this or specific references within these two sources are noted accordingly.

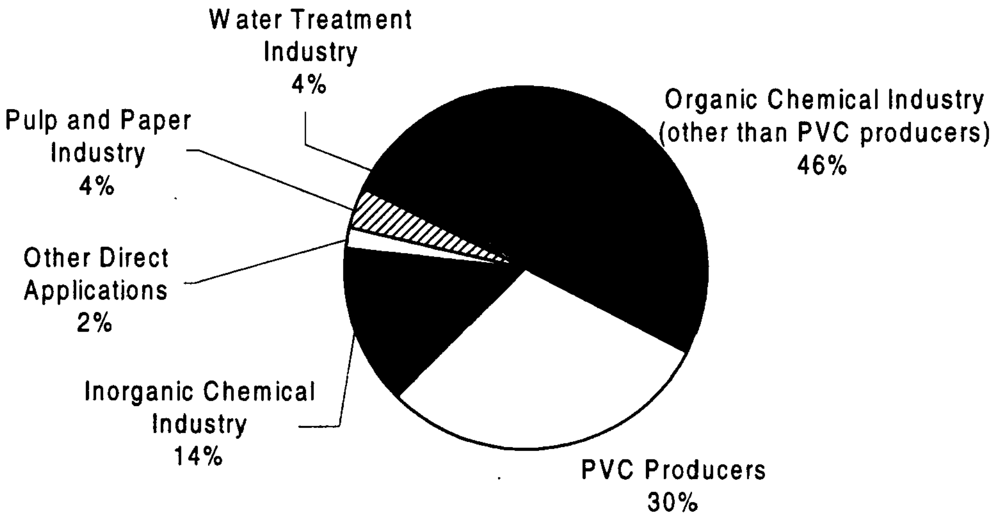


Figure 2-5. U.S. Chlorine Consumers, 1998

PVC Industry. In 1994, PVC accounted for approximately 34 percent of total chlorine demand. Chlorine is used primarily to manufacture ethylene dichloride, which is used in PVC production. More than 60 percent of PVC is used in building and infrastructure. Thus, construction and housing starts influence demand for chlorine. In developing countries, demand is particularly strong for pipes needed to upgrade areas to improve sanitation.

Propylene Oxide and Epichlorohydrin Industry. During the production of the organic chemical propylene oxide, chlorine reacts with propylene to make propylene chlorohydrin. After further processing, propylene oxide is made with other by-products (sodium or calcium chloride). Average annual growth of propylene oxide is between 1.5 and 2 percent per year and is based mostly on the growing demand for polyether polyol, a propylene oxide derivative used in urethane foam manufacturing. Epichlorohydrin, another organic chemical, is produced from dechlorinated allyl chloride and is primarily used to produce epoxy resins for the surface coating and composite industries. Chlorine consumption for epichlorohydrin is expected to grow between 2 and 2.5 percent annually and will be driven by the increased construction demand for epoxy resins.

Phosgene Industry. Phosgene, a chlorinated organic, is used primarily in polycarbonate production. Phosgene accounts for nearly 6 percent of chlorine consumption, and production is expected to grow around 3 percent annually. Polycarbonate resin is used for glazing and sheeting, polycarbonate composites, and alloys. Alloys are used to replace metal parts for the electronic and automobile industries.

C_1 Derivatives Industry. Industrial producers of carbon derivates (e.g., chlorinated methanes, chloroform, methylene chloride, and carbon tetrachloride) use chlorine as a material input during the production process. Aggregate growth in many of these organic compounds is expected to remain flat through the decade. Use of carbon tetrachloride in chlorofluorocarbon manufacture will be phased out because of its contribution to ozone depletion. Some positive growth is expected for the use of chloroform in alternative CFCs, which have not been linked with ozone depletion.

Titanium Tetrachloride Industry. A majority of titanium dioxide production uses the chloride process where chlorine reacts with titanium to produce titanium tetrachloride. Titanium tetrachloride, an inorganic chemical, is further processed to create titanium dioxide, which is used primarily as a filler in pulp and paper manufacture and as a pigment in paint and plastics manufacture.

The Pulp and Paper Industry. In 1994, the pulp and paper industry accounted for 9 percent of U.S. chlorine consumption. However, concerns over chlorine's potential to form toxic chlorinated organics has had a negative effect on the use of chlorine in this industry. Growth in chlorine use in the pulp and paper industry has been negative in the 1990s, and recent substitutions of oxygen, hydrogen peroxide, and particularly chlorine dioxide for chlorine indicate the decline will be significant (Kroschwitz, 1991).

The Water Treatment Industry. Chlorine is an excellent bacteriostat unsurpassed for use in residual water treatment. Because of efforts by municipal and industrial water treatment facilities to increase chemical efficiency and concerns over chlorine's involvement in the formation of undesirable organic compounds, little growth is projected for chlorine used in water treatment. Chlorine demand in 1994 for use in water treatment was 5 percent of all uses, and demand in the year 2010 is projected to remain at 5 percent.

2.2.1.3 Substitutes for Chlorine

Because environmental regulations in general, and the proposed NESHAP in particular, have the potential to raise the price (and/or alter the quality) of the regulated commodities, the economic impact of the regulations may depend on the extent to which users of the commodity can substitute other commodities for the regulated one. To the extent that chlorine is used as a chemical ingredient in the production of a particular product, substitution of other materials is limited. However, factors that raise the price of a given chemical ingredient can lead to chemical reformulations that substitute away from that ingredient either by reducing its use per unit of output or by completely switching to another ingredient.

For example, chlorine is widely used as a bleaching agent. However, the characteristics that make chlorine a superb cleaning/bleaching agent also contribute to its adverse impact on surrounding environments when released from the production process. This has been particularly pronounced in the use of chlorine in pulp and paper productions, which leads to water effluents containing dioxin, a highly toxic substance. A combination of regulatory and voluntary efforts has led the pulp and paper industry to substantially reduce its releases of chlorine derivatives, partly through waste stream treatment improvements and partly through reduced use of chlorine. In recent years, many pulp makers have switched to elemental chlorine-free (ECF) pulp, which uses chlorine dioxide rather than elemental chlorine because the former essentially avoids the release of dioxin as a pollutant (Alliance for Environmental Technology, 1996).

Sodium hypochlorite is also a substitute for chlorine in waste water treatment and drinking water disinfection applications. Sodium hypochlorite is easier to handle than gaseous chlorine or calcium hypochlorite. It is, however, very corrosive and must be stored with care and kept away from equipment that can be damaged by corrosion. Hypochlorite solutions also decompose and should not be stored for more than 1 month (Minnesota Rural Water Association [MRWA], 2000).

2.2.2 *Sodium Hydroxide Demand*[4]

Three forms of sodium hydroxide are produced to meet marketplace demands (Kroschwitz, 1991). These are purified diaphragm sodium hydroxide (50 percent) grade, 73 percent sodium hydroxide, and anhydrous sodium hydroxide. Fifty percent grade sodium hydroxide accounts for 85 percent of the sodium hydroxide consumed in the United States. Five percent of sodium hydroxide produced on a yearly basis is concentrated to 73 percent solutions for special usage in rayon, for example. Seventy-three percent sodium hydroxide is a derivative of 50 percent sodium hydroxide and is stored in liquid tanks. The remainder is used to produce anhydrous sodium hydroxide. Anhydrous sodium hydroxide is produced from either 50 or 73 percent sodium hydroxide.

2.2.2.1 Sodium Hydroxide Uses

Sodium hydroxide has a wide variety of industrial applications, including its use as a cleaning agent, catalyst, anticorrosive compound, and an agent for maintaining alkaline pH levels.

The majority of 73 percent sodium hydroxide and anhydrous sodium hydroxide is used to manufacture rayon and for the synthesis of alkyl aryl sulfates. The majority of sodium hydroxide uses refer to 50 percent sodium hydroxide (Kroschwitz, 1991).

2.2.2.2 Major Sodium Hydroxide Consumers

As Figure 2-6 shows, sodium hydroxide is consumed by many of the same industries that consume chlorine, but it is consumed by a larger variety of industries than chlorine. Table 2-4 shows that the composition of sodium hydroxide demand is expected to remain stable for the next 5 years. Households consume sodium hydroxide only indirectly, when it is a component of other goods. The major industrial consumers of sodium hydroxide are discussed below.

The Chemical Industry. Chemical manufacturing accounts for over half of all U.S. sodium hydroxide demand. It is used primarily for neutralization, in off gas scrubbing, and as a catalyst. A large part of this category is used in the manufacture of organic

---

[4]The material in this section draws heavily from Kroschwitz (1991) and Gerhartz (1992). Any exceptions to this or specific references within these two sources are noted accordingly.

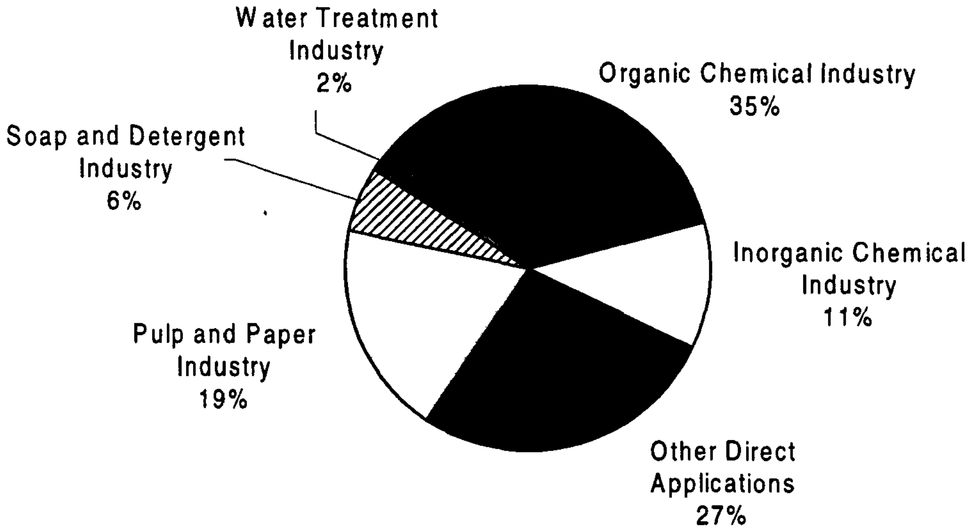


Figure 2-6. U.S. Sodium Hydroxide, 1998

Table 2-4. U.S. Sodium Hydroxide Consumption

	Percent of Total Production		
Use	**1995**	**1998**	**2003**
Organic chemicals	**36%**	**35%**	**35%**
Inorganic chemicals	**11%**	**11%**	**11%**
Direct applications	**53%**	**54%**	**54%**
Pulp and paper	19%	19%	16%
Soaps and detergents	6%	6%	6%
Water treatment	2%	2%	2%

Source: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide*. CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

intermediates, polymers, and end products. The majority of sodium hydroxide required here is for the production of propylene oxide, polycarbonate resin, epoxies, synthetic fibers, and surface-active agents.

The Pulp and Paper Industry. Pulp and paper manufacture accounts for about a quarter of total U.S. sodium hydroxide demand. The sodium hydroxide is used to pulp wood chips, to extract lignin during bleaching, and to neutralize acid waste streams. Changes in technologies aimed at decreasing chlorine use will also serve to decrease sodium hydroxide requirements. In addition, sodium hypochlorite, which requires sodium hydroxide in its manufacture, is under increased scrutiny in pulp and paper applications because of potential chloroform formation.

The Cleaning Product Industry. Sodium hydroxide is used in the production of a wide variety of cleaning products. This segment of the industry accounts for less than 10 percent of total consumption, but it is expected to continue growing by a small amount. Sodium hydroxide use in this segment goes into the production of soap and other detergent products, household bleaches, polishes, and cleaning goods.

Petroleum and Natural Gas. The sodium hydroxide used in the petroleum and natural gas industry is used to process oil and gas into marketable products, especially by removing acidic contaminants. The remainder is used primarily to decrease corrosion of drilling equipment and to increase the solubility of drilling mud components by maintaining an alkaline pH.

Cellulosics Producers. Rayon and other cellulose products such as cellophane and cellulose ethers also require sodium hydroxide. There are several very competitive substitute products and sodium hydroxide use in this area has decreased over the last 10 years.

2.2.2.3 Substitutes for Sodium Hydroxide

As discussed in Section 2.2.2.2, the NESHAP's effect on the price and quantity demanded of sodium hydroxide will be influenced by the availability of substitutes for sodium hydroxide. The more likely that sodium hydroxide consumers will substitute away from the product as its price rises, the more likely it is that the burden of regulatory costs will fall mostly on the producers of a commodity. Several close substitutes exist for sodium hydroxide, including other alkalies and, in particular, soda ash and lime. Sodium hydroxide has some attractive properties over substitute inputs for many uses, but it is usually more expensive. Many firms use sodium hydroxide until the price increases too much; then they switch to lower-priced substitutes (Berthiaume, Anderson, and Yoshida, 2000).

2.3 Organization of the Chlor-Alkali Industry

This section identifies the major sources of chlorine and sodium hydroxide production and describes how these suppliers are organized in the respective markets. Firm-level data for owners of the production facilities are presented, where available. Market structure issues are also discussed in the context of key estimates of industry concentration.

2.3.1 Market Structure

Market structure is of interest because it determines the behavior of producers and consumers in the industry. In perfectly competitive industries, no producer or consumer is able to influence the price of the product sold. In addition, producers are unable to affect the price of inputs purchased for use in their products. This condition most likely holds if the industry has a large number of buyers and sellers, the products sold and inputs used in production are homogeneous, and entry and exit of firms are unrestricted. Entry and exit of firms are unrestricted for most industries, except in cases where the government regulates who is able to produce output, where one firm holds a patent on a product, where one firm owns the entire stock of a critical input, or where a single firms is able to supply the entire market. In industries that are not perfectly competitive, producer and/or consumer behavior can have an effect on price.

Concentration ratios (CRs) and Herfindahl-Hirschmann indices (HHIs) can provide some insight into the competitiveness of an industry. The U.S. Department of Commerce reports these ratios and indices for the four-digit SIC code level for 1992, the most recent year available. Table 2-5 provides the value of shipments, the four- and eight-firm concentration ratios, and the HHI that have been calculated for the alkalies and chlorine industry (SIC 2812). It has been suggested that an industry be considered highly concentrated if the four-firm concentration ratio exceeds 50 percent, and in this industry, it far surpasses this threshold.

The criteria for evaluating the HHIs are based on the 1992 Department of Justice's Horizontal Merger Guidelines. According to these criteria, industries with HHIs below 1,000 are considered unconcentrated (i.e., more competitive), those with HHIs between 1,000 and 1,800 are considered moderately concentrated (i.e., moderately competitive), and those with HHIs above 1,800 are considered highly concentrated (i.e., less competitive). In general, firms in less concentrated industries are more likely to be price takers, while those in more

Table 2-5. Share of Value of Shipments by Number of Companies: Alkalies and Chlorine in 1992 (SIC 2812; NAICS 325181)

Companies (number)	Total Value of Shipments ($$10^6$)	Percentage Accounted for by CR4	Percentage Accounted for by CR8	HHI[a]
34	2,786.9	75	90	1,994

[a] Herfindahl-Hirschmann Index is for the 50 largest companies.

Source: U.S. Department of Commerce, Bureau of the Census. 1999. *Concentration Ratios in Manufacturing*. MC92-5-2. Washington, DC. <http://www.census.gov/mcd/mancen/ download/mc92cr.sum>. Last revised February 4, 1999.

concentrated industries have more ability to influence market prices. Based on these criteria, the alkalies and chlorine industry is considered highly concentrated. The HHI data support the conclusion drawn from the concentration ratio data.

Though the concentration ratios and HHI indicate a highly concentrated market, several factors may mitigate the market power of chlorine companies. For the baseline year of 1997, EPA classified the 43 facilities as producing for either the merchant or captive markets. Vertically integrated firms produce the vast majority of chlorine as an input for a variety of final products (referred to as "captive production"). Only 27 percent of chlorine is sold on the merchant market, although 75 percent of the facilities affected by the proposed regulation operate in the merchant market. The HHI for the 12 companies that participated in the merchant market in 1997 is 1,693—somewhat lower than the HHI for the industry as a whole, and no merchant firm commands more than 25 percent of the merchant market. Furthermore, demand for chlorine is projected to grow slowly and the trend in the industry is towards vertical integration (Dungan, 2000), again potentially limiting the market power of chlorine producers.

Unlike the chlorine market, several close substitutes for sodium hydroxide exist, in particular soda ash, and this limits the ability of sodium hydroxide producers to significantly raise prices. Because most chlorine is produced for captive use and it is difficult to store, demand for chlorine dominates production decisions (Berthiaume, Anderson, and Yoshida, 2000). Thus, despite the concentrated nature of production, the market for sodium hydroxide appears to be competitive.

2.3.2 Manufacturing Facilities

EPA identified 43 facilities in the United States engaged in chlorine production. The facilities are listed in Table 2-6 (EC/R Incorporated, 1996). As mentioned previously, the majority of chlorine production plants use the electrolyte processes (diaphragm, mercury, or membrane cells). These processes account for approximately 97 percent of chlorine production. Seven plants use a combination of two types of chlor-alkali cells. More specifically, diaphragm cells are used at 23 plants, mercury cells are used at 13 plants, and membrane cells are used at 8 plants. In addition, the HoltraChem facility in Acme, NC, facility recently converted from a mercury process to the diaphragm process. Figure 2-7 shows the distribution of chlorine production facilities across the United States. The facilities are concentrated in the Gulf Coast area because of the proximity of brine, a major input into chlorine production, and chemical companies that use chlorine as an input.

2.3.3 Industry Production and Capacity Utilization

Recent historical data on production capacity are presented in Tables 2-7 and 2-8 for chlorine and sodium hydroxide, respectively (Berthiaume, Anderson, and Yoshida, 2000; The Chlorine Institute, 2000). Because chlorine and sodium hydroxide are produced together and in fixed proportions, the capacity data possess very similar levels and trends.

Capacity increased slightly during the 1990s especially since 1995. Production levels rose steadily throughout the decade. Capacity utilization remained above 90 percent for most of the 1990s, reaching a peak in 1995. As a result, any future expansion in domestic output will likely need to come from new sources, either new plants or capacity expansion at existing plants.

2.3.4 Industry Employment

Table 2-9 lists data on employment and hours per worker for the chlor-alkali industry. Total and production-related employment both dropped between 1990 and 1997, following trends in the previous two decades. In 1997, there were roughly 4,900 total workers and 3,300 production workers engaged in chlor-alkali production.

Table 2-6. Summary of Chlorine Production Facilities by Location, Process, Age, and Type in 1997

Parent Company	Facility Location		Process	Year Built	Type[a]
ASHTA	Ashtabula	OH	Mercury	1963	Merchant
Bayer AG	Baytown	TX	HCL electrolysis	1987	Captive
Dow Chemical	Plaquemine	LA	Diaphragm	1958	Merchant
Dow Chemical	Freeport	TX	Diaphragm	1940	Merchant
Dupont Chemical	Niagra Falls	NY	Downs sodium	1898	Captive
Elf Aquitaine	Portland	OR	Diaphragm/membrane	1947	Merchant
Formosa Plastics	Baton Rouge	LA	Diaphragm	1937	Captive
Formosa Plastics	Point Comfort	TX	Membrane	1993	Captive
Fort James	Rincon	GA	Membrane	1990	Captive
Fort James	Muskogee	OK	Membrane	1980	Captive
Fort James	Green Bay	WI	Diaphragm	1968	Captive
General Electric	Burkville	AL	Diaphragm	1987	Captive
General Electric	Mt. Vernon	IN	Diaphragm	1976	Captive
Georgia Gulf	Plaquemine	LA	Diaphragm	1975	Captive
Georgia Pacific	Bellingham	WA	Mercury[b]	1965	Merchant
HoltraChem	Orrington	ME	Mercury	1967	Merchant
HoltraChem	Acme	NC	Mercury[c]	1963	Merchant
LaRoche Chemical	Grammercy	LA	Diaphragm	1958	Merchant
Magnesium Corporation	Rawley	UT	Magnesium production	NA	Captive
Occidental	Mobile	AL	Membrane	1964	Merchant
Occidental	Muscle Shoals	AL	Mercury	1952	Merchant
Occidental	Delaware City	DE	Mercury	1965	Merchant
Occidental	Convent	LA	Diaphragm	1981	Captive
Occidental	Taft	LA	Diaphragm/membrane	1966	Captive
Occidental	Niagra Falls	NY	Diaphragm	1898	Captive
Occidental	Ingleside	TX	Diaphragm	1974	Captive
Occidental	Laporte	TX	Diaphragm	1974	Merchant
Occidental	Deer Park	TX	Diaphragm/mercury	1938	Captive
Olin	McIntosh	AL	Diaphragm	1952	Merchant
Olin	Augusta	GA	Mercury	1965	Merchant
Olin	Niagra Falls	NY	Membrane	1987	Merchant
Olin	Charleston	TN	Mercury	1962	Merchant

(continued)

Table 2-6. Summary of Chlorine Production Facilities by Location, Process, Age, and Type in 1997 (continued)

Facility	Facility Location		Process	Year Built	Type[a]
Pioneer	St. Gabriel	LA	Mercury	1970	Merchant
Pioneer	Henderson	NV	Diaphragm	1942	Merchant
Pioneer	Tacoma	WA	Diaphragm/membrane	1929	Merchant
PPG	Lake Charles	LA	Diaphragm/mercury	1947	Captive
PPG	Natrium	WV	Diaphragm/mercury	1943	Merchant
Vicksburg Chemical	Vicksburg	NY	Nitric acid salt	1962	Merchant
Vulcan	Wichita	KS	Diaphragm/membrane	1952	Captive
Vulcan	Geismar	LA	Diaphragm	1976	Captive
Vulcan	Port Edwards	WI	Mercury	1967	Merchant
Westlake Monomers Corp	Calvert City	KY	Mercury	1966	Captive
Weyerhauser	Longview	WA	Diaphragm	1957	Captive

[a] Primary
[b] Closed 1999.
[c] Plant has recently converted to the process.

Sources: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide*. CEH Marketing Research Report. Chemical Economics Handbook—SRI International.
The Chlorine Institute. 2000. *Chlor-Alkali Industry Plants and Production Data Report*. Washington, DC.
EC/R Incorporated. September 12, 1996. *Background Information Document; Chlorine Production Summary Report*. Prepared for the U.S. Environmental Protection Agency. Durham, NC: EC/R Inc.

Taken together, Tables 2-7 through 2-9 indicate an increasing level of industry output being produced by a progressively smaller labor force. There are two reasons for this. First, annual hours worked per production employee have increased over time, and secondly, labor productivity per hour has risen steadily (see Figure 2-8).

2.3.5 Companies

Companies affected by the proposed NESHAP include entities that own and operate one or more chlor-alkali production plants that use the mercury cell process. The chain of ownership may be as simple as one plant owned by one company or as complex as multiple plants owned by subsidiary companies. The Agency identified 21 ultimate parent companies that own and operate 43 chlorine manufacturing facilities. Eight of these companies, or

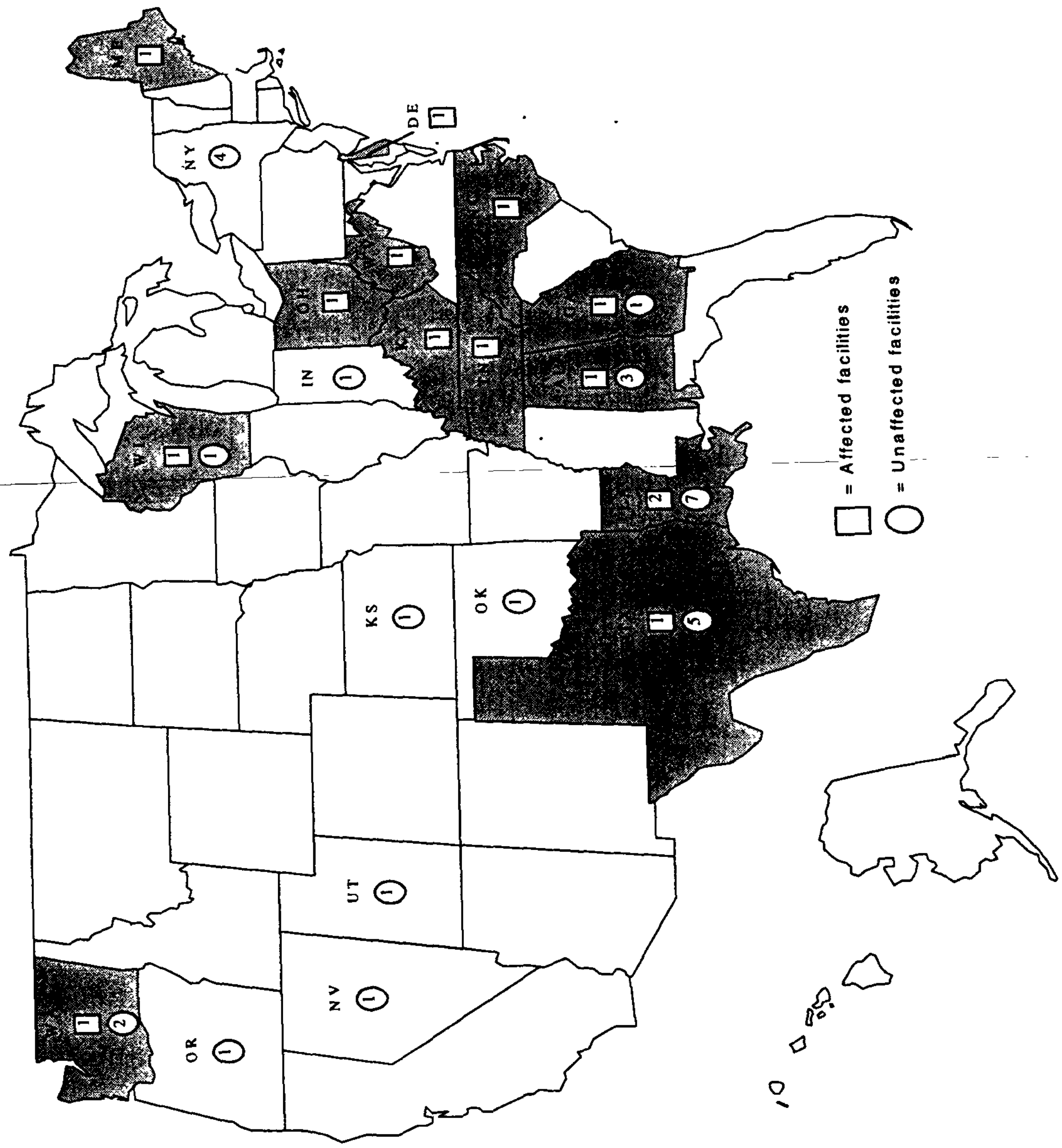


Figure 2-7. Distribution of Affected and Unaffected Chlorine Production Facilities by State

Note: The highlighted states contain affected facilities.

Table 2-7. U.S. Operating Rates for Chlorine (10^3 short tons)

Year	Capacity	Production	Capacity Utilization
1990	12,332	11,487	93.1%
1991	12,256	11,490	93.8%
1992	12,232	11,656	95.3%
1993	12,889	11,983	93.0%
1994	12,684	12,613	99.4%
1995	13,207	12,990	98.4%
1996	13,700	13,168	96.1%
1997	14,000	13,685	97.8%
1998	14,408	13,533	93.9%
1999	NA	13,807	NA

NA = not available

Sources: The Chlorine Institute. 2000. *Chlor-Alkali Industry Plants and Production Data Report.* Washington, DC.
Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide.* CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

38 percent, own plants that use the mercury cell process. For the economic analysis, EPA obtained company sales and employment data from one of the following sources:

- Gale Research, Inc. (1998),
- Hoover's Incorporated (2000),
- Information Access Corporation (2000), and
- Selected company 10-K reports.

Sales data were available for all 21 companies and employment data were available for 20 companies. All affected companies had sales and employment observations. Occidental (three facilities), Olin (two facilities), and PPG (two facilities) own approximately 60 percent of the mercury cell plants in the United States. Company size is likely to be a factor in the distribution of the regulation's financial impacts. Across all chlorine companies, the average

Table 2-8. U.S. Operating Rates for Sodium Hydroxide (10^3 short tons)

Year	Capacity	Production	Capacity Utilization
1990	13,091	12,459	95.2%
1991	13,273	12,151	91.5%
1992	13,442	12,336	91.8%
1993	14,147	12,623	89.2%
1994	13,771	13,293	96.5%
1995	13,771	13,688	99.4%
1996	14,285	13,857	97.0%
1997	14,598	14,328	98.2%
1998	15,585	14,183	91.0%

Source: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide*. CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

(median) annual sales were $12 billion ($2.4 billion). The average (median) employment is 44,000 (8,900) employees.

2.3.5.1 Small Business Identification

The proposed environmental regulation potentially affects large and small chlorine manufacturers using mercury cells, but small firms may encounter special problems with compliance. The Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement and Fairness Act of 1996 (SBREFA), requires EPA to consider the economic impacts of this regulatory action on these small entities. Companies operating chlorine manufacturing plants can be grouped into "large" and "small" categories using the Small Business Administration's (SBA) general size standard definitions (SBA, 2000). For this analysis, the SBA size standard for the chlor-alkali industry (SIC 2812; NAICS 325181) is 1,000 employees. Based on this standard, six firms can be classified as small. Three of these small firms own and operate facilities using the mercury cell process. As Table 2-10 shows, the six small firms' average (median) sales are $146 ($85) million; average (median)

Table 2-9. Employment in the Chlor-Alkali Industry (SIC 2812; NAICS 325181) (10^3): 1990–1997

Year	Total Employment	Production Workers	Annual Hours of Production Workers
1990	6.8	4.7	10,100
1991	7.5	5.2	11,000
1992	8.0	5.4	11,300
1993	7.7	5.3	11,100
1994	6.2	4.2	8,900
1995	6.1	4.2	8,400
1996	5.9	4.0	8,400
1997	4.9	3.3	7,085

Sources: U.S. Department of Commerce, Bureau of the Census. 1999. *1997 Economic Census—Manufacturing Industry Series: Alkalies and Chlorine Manufacturing.* EC97M-3251 E. Washington, DC. <http://www.census.gov/prod/www/abs/97ecmani.html>.
U.S. Department of Commerce, Bureau of the Census. 1996-1998. *Annual Survey of Manufactures: Statistics for Industry Groups and Industries.* <http://www.census.gov/prod/www/abs/industry.html>.
U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures Industry Series: Industrial Inorganic Chemicals.* MC92-I-28A. Washington, DC: [online]. <http://www.census.gov/prod/1/manmin/92mmi/mci28af.pdf>.

employment is 477 (435) employees. In contrast, the 15 large firms have average (median) sales of $17 ($8) billion, and average employment of 59,000 (34,000) employees.

2.4 Market Data and Industry Trends

This section presents historical market data, including foreign trade and market prices for chlorine by the major industry segments. Historical market data include U.S. production, foreign trade, and apparent consumption of chlorine across the industry segments for the years 1990 through 1997. The importance of foreign trade is measured by concentration ratios (i.e., the relation of exports to U.S. production and the relative importance of imports to U.S. apparent consumption). Furthermore, this section presents the quantities, values, and market prices of chlorine and sodium hydroxide in recent years.

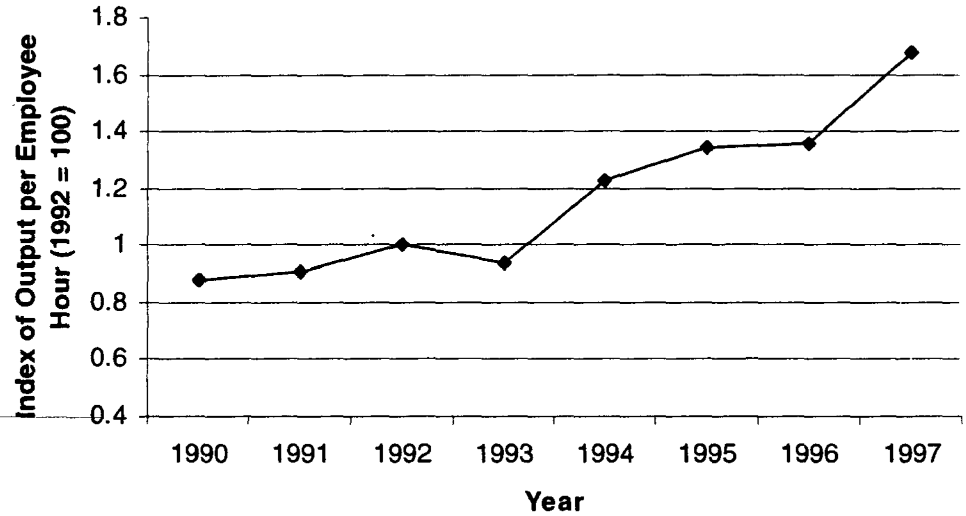


Figure 2-8. Labor Productivity Index for the Chlor-Alkali Industry: 1990-1997

Table 2-10. Summary Statistics for Chlorine Manufacturing Companies

	Annual Sales ($$10^6$)		Employment	
Companies	**Average**	**Median**	**Average**	**Median**
Small	$146	$85	477	435
Large	$16,857	$8,016	58,841	33,800
All	$12,082	$2,410	44,274	8,973

2.4.1 *Value of Shipments*

Table 2-11 lists recent historical data (1990-1997) on total value of shipments for the chlor-alkali industry. In real terms, the industry's value of shipments increased through 1992, then mostly followed a downward trend to reach approximately $2.5 million in 1997.

Table 2-11. Value of Shipments for the Chlor-Alkali Industry (SIC 2812; NAICS 325181) ($$10^6$): 1990-1997

Year	Value of Shipments
1990	$2,710
1991	$2,729
1992	$2,787
1993	$2,481
1994	$2,171
1995	$2,730
1996	$2,850
1997	$2,465

Sources: U.S. Department of Commerce, Bureau of the Census. 1999. *1997 Economic Census—Manufacturing Industry Series: Alkalies and Chlorine Manufacturing.* EC97M-3251 E. Washington, DC. <http://www.census.gov/prod/www/abs/97ecmani.html>.
U.S. Department of Commerce, Bureau of the Census. 1996-1998. *Annual Survey of Manufactures: Statistics for Industry Groups and Industries.* <http://www.census.gov/prod/www/abs/industry.html>.
U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures—Industry Series: Industrial Inorganic Chemicals.* MC92-I-28A. Washington, DC. <http://www.census.gov/prod/1/manmin/92mmi/mci28af.pdf>.

2.4.2 *U.S. Production and Apparent Consumption*

Tables 2-12 and 2-13 present historical data on the respective quantities of chlorine and sodium hydroxide produced, imported, exported, and (apparently) consumed. "Apparent" domestic consumption is not directly observed in the data; rather it is calculated as total domestic production less exports plus imports. For chlorine, domestic consumption has increased slightly more than domestic production since 1990, indicating a 16 percent

Table 2-12. Production, Imports, Exports, and Consumption of Chlorine (10^3 short tons)

Year	Production	Imports	Exports	Apparent Consumption
1990	11,487	357	69	11,775
1991	11,490	296	45	11,741
1992	11,656	275	38	11,893
1993	11,983	323	41	12,265
1994	12,613	394	30	12,977
1995	12,990	396	26	13,360
1996	13,168	419	19	13,568
1997	13,685	453	27	14,111
1998	13,533	413	25	13,921
Average Annual Growth Rate	2.1%	2.6%	–9.4%	2.1%

Source: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide.* CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

increased slightly more than domestic production since 1990, indicating a 16 percent increase in (net) imports of chlorine. Nonetheless, foreign trade plays a fairly minor role in chlorine trade, with net imports less than 3 percent of apparent consumption.

Foreign trade plays a larger role in the sodium hydroxide market, because the United States is a net exporter of this commodity. Gross exports accounted for 11.6 percent of U.S. production in 1998; net imports accounted for 5 percent of apparent consumption that year. However, the 1998 numbers mask the fact that exports (gross and net) had dropped rather dramatically from 1979 through 1994, with a rebound through 1998. Throughout the period observed, exports are highly variable in the sodium hydroxide market.

Table 2-13. Production, Imports, Exports, and Consumption of Sodium Hydroxide (10^3 short tons)

Year	Production	Imports	Exports	Apparent Consumption
1990	12,459	565	1,658	11,366
1991	12,151	474	1,555	11,070
1992	12,336	569	1,265	11,640
1993	12,623	502	965	12,160
1994	13,293	568	894	12,967
1995	13,688	553	1,697	12,544
1996	13,857	550	1,886	12,521
1997	14,328	560	1,481	13,407
1998	14,183	596	1,643	13,136
Average Annual Growth Rate	1.7%	1.3%	4.3%	1.9%

Source: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide*. CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

2.4.3 Market Prices

Price data for chlorine and sodium hydroxide are presented in Table 2-14. Unfortunately, these data are list prices and their lack of variation obscures the actual movement in transaction prices. Transactions prices are not readily available, so general inferences must be drawn from the list price data.

The data indicate a sharp decline in chlorine prices, yet a steady rise in sodium hydroxide prices in the early 1990s. The chlorine price rebounded in 1994, and the sodium hydroxide price continued ~~to rise,~~ declining slightly in 1997 and 1998.

2.4.4 Future Outlook

Global growth forecasts for chlorine range from 0.8–1.5 percent per year (Chemical Week, 1996). New demand is being driven by growth in PVC. PVC growth is projected at 4 to 5 percent per year, but declining use in pulp and paper, chlorofluorocarbons, and solvents will keep growth in check the next few years. The United States and the Mideast are widely viewed as the most attractive sites for new capacity because of low power rates and easy access to world markets. In 1995, operating rates continued to exceed 95 percent, which could lead to an increase in price if demand rises.

Table 2-14. U.S. List Prices for Chlorine and Sodium Hydroxide ($/short tons)

		Sodium Hydroxide	
Year	**Chlorine (Gas)**	**Solid**	**Liquid**
1990	$190-$200	$560	$290-$320
1991	$125-$200	$560	$300-$330
1992	$125-$200	$560	$300-$330
1993	$125-$200	$580	$300-$330
1994	$225-$255	$580	$300-$330
1995	$200	$600	$300-$330
1996	$155-$160	$600	$300-$330
1997	$245-$250	$595	$300-$330
1998	$245-255	$575	$300-$330

Source: Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 200. Chlorine/Sodium Hydroxide. CEH Marketing Research Report. Chemical Economics Handbook - SRI International.

SECTION 3

ENGINEERING COST ANALYSIS

Section 112 of the CAA requires the Agency to list and regulate categories of sources that account for 90 percent of the aggregate emissions of several pollutants, including mercury. This section presents the Agency's estimates of the national compliance costs associated with the regulation of mercury emissions from 12 mercury cell chlor-alkali manufacturing plants. A detailed discussion of the methodologies used to develop these estimates is provided in the Background Information Document (EC/R Incorporated, 1996).

3.1 National Control Cost Estimates

The Agency developed facility-specific estimates of total annual compliance costs associated with pollution control equipment or control system enhancements needed by the point sources to meet the MACT emission limits:

- Ten mercury cell chlor-alkali plants were assumed to add a new finishing device to one or more existing vent control systems. The devices included a nonregenerative carbon adsorber (with a specialty carbon medium for mercury removal) for the hydrogen by-product stream control system or mercury thermal recovery control system and a packed hypochlorite scrubber for the end-box ventilation control system.

- Five plants were assumed to require more frequent replacement of carbon media in existing carbon adsorbers.

The nationwide annual compliance cost estimate for these is estimated to be $1.46 million, or $0.91 per ton of chlorine (see Table 3-1). Note, however, that these cost estimates do not account for behavioral responses (i.e., changes in price and output rates). Instead these estimates are inputs to the economic model as described in Section 4.

Table 3-1. Emissions Control and Monitoring, Recordkeeping, and Recording Costs of the MACT for Mercury Cell Chlor-Alkali Plants

Facility	Emissions Control Costs				Monitoring, Recordkeeping, and Recording Costs				
	Total Capital Costs	Annualized Capital Costs	O&M Costs	Total Annual Control Costs	Total Capital Costs	Annualized Capital Costs	O&M Costs	Total Annual MRR Costs	Total Annual Costs
OxyChem— Muscle Shoals, AL	$166,272	$16,293	$104,046	$120,339	$33,937	$4,832	$47,042	$51,874	$172,213
HoltraChem— Orrington, ME	$0	$0	$0	$0	$33,937	$4,832	$47,042	$51,874	$51,874
OxyChem— Delaware City, DE	$16,897	$1,932	$28,187	$32,144	$84,841	$12,079	$54,811	$66,891	$97,010
Pioneer— St. Gabriel, LA	$94,761	$10,404	$30,467	$40,872	$33,937	$4,832	$47,042	$51,874	$92,746
Vulcan— Port Edwards, WI	$45,613	$5,884	$49,090	$54,974	$50,905	$7,248	$49,632	$56,880	$111,854
OxyChem— Deer Park, TX	$50,478	$5,767	$75,514	$81,282	$33,937	$4,832	$47,042	$51,874	$133,156
PPG— Lake Charles, LA	$94,761	$10,404	$30,467	$40,872	$50,905	$7,248	$49,632	$56,880	$97,751
Westlake— Calvert City, KY	$0	$0	$161,840	$161,840	$33,937	$4,832	$47,042	$51,874	$213,714
PPG— Natrium, WV	$58,560	$7,139	$46,039	$53,178	$33,937	$4,832	$47,042	$51,874	$105,052
Olin— Charleston, TN	$131,454	$13,113	$117,048	$130,162	$67,873	$9,664	$52,222	$61,885	$192,047
Olin— Augusta, GA	$14,537	$1,596	$24,708	$26,304	$33,937	$4,832	$47,042	$51,874	$78,178
ASHTA— Ashtabula, OH	$50,756	$5,589	$57,220	$62,809	$33,937	$4,832	$47,042	$51,874	$114,683
Total	$724,089	$78,121	$724,628	$802,749	$526,016	$74,893	$582,636	$657,529	$1,460,279

SECTION 4

ECONOMIC IMPACT ANALYSIS

The proposed NESHAP requires mercury cell chlor-alkali facilities to install additional control technologies to meet emission standards for releases of HAPs to the atmosphere. The additional costs imposed by the new control requirements will have financial implications for the affected producers and broader societal implications as these effects are transmitted through market relationships to other producers and consumers. The sections below describe the methodology and results for the EIA.

To measure the size and distribution of the economic impacts of the regulation, EPA compared baseline conditions of chlorine and sodium hydroxide markets in 1997 with those for the counterfactual or with-regulation conditions expected to result from implementing the regulation. The main elements of this analysis are

- economic characterization of the regulated facilities in terms of cost of production and whether they are a merchant or captive producer;
- characterization of baseline demand for chlorine and sodium hydroxide;
- development of economic models that evaluate behavioral responses to additional costs of the regulation in a market context; and
- presentation and interpretation of economic impact estimates generated by the models.

4.1 Economic Impact Methodology: Conceptual Approach

Regulatory costs increase the costs of production for the affected facilities. If the firms choose to continue to use the mercury production process, the marginal cost curves for these facilities will shift upwards by an amount determined by the variable costs of complying with the regulation. The firms may shift to an alternative production process; however, it is estimated that switching to an alternative production process (most likely membrane cells) would be more expensive than complying with the regulations, at least in the short run (Dungan, 2000).

The chlorine industry has a number of special characteristics that this analysis addresses. First, the chlorine market appears to be concentrated, although other features of the industry may mitigate the effects of concentration on firm behavior (see discussion of concentration in Section 2). Second, a majority of the processes for producing chlorine (including the mercury process, the target of the proposed regulation) result in the joint production of sodium hydroxide at a fixed rate. Finally, the merchant market for chlorine is small in size compared to production devoted to captive uses (internal uses by the producing firm), and 75 percent of the facilities affected by the proposed regulation operate primarily in the merchant market.

As discussed in Section 2, the chlorine industry appears to be concentrated, with 75 percent of production carried out by four firms and a high HHI (1,900). However, much of the production takes place in vertically integrated firms that use the chlorine internally. It is possible that the merchant market for chlorine is competitive, because many of the largest chlorine producers are vertically integrated and use most of the chlorine they produce to satisfy internal demand. The merchant market accounts for approximately 27 percent of total chlorine production, and the HHI for the participants in the merchant market is lower (1,693). Furthermore, the chlorine market is growing slowly, and the trend is toward vertical integration. To provide a range of alternatives, EPA calculated welfare losses two ways: under the assumption that the merchant market for chlorine is competitive and under the assumption that the merchant market for chlorine is concentrated.

For the concentrated model, EPA used a Cournot model to characterize the market. In the Cournot model, one of several models of monopolistic competition, firms are modeled as choosing production quantities. Unlike a competitive market, in which the market price equals the marginal cost of production and firms take the market price as given, the Cournot model reflects the fact that chlorine suppliers may have market power and can charge a price in excess of marginal cost by producing a quantity that is less than the competitive optimum.

Unlike the chlorine market, the market for sodium hydroxide appears to be competitive. Several close substitutes for sodium hydroxide prevent producers from raising prices. Much less sodium hydroxide is dedicated to captive uses, and the market for sodium hydroxide appears to move cyclically under the influence of demand for chlorine.

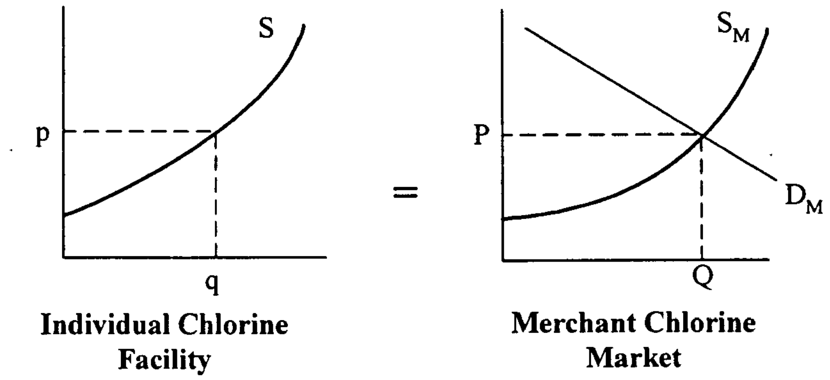
Chlorine and sodium hydroxide are joint products of a production process that starts with brine and separates it into these two chemicals. To address the issue of joint production, EPA modeled a joint marginal cost (supply) function for both chlorine and sodium hydroxide that interacts with separate demand curves. Because chlorine and sodium hydroxide are produced at a fixed ratio, sodium hydroxide can be expressed in chlorine units and the decision to produce chlorine with revenue streams from the two separate markets can be modeled.

Finally, for purposes of this analysis, EPA modeled the merchant and captive markets independently. Over the long run, if prices increase in the merchant market, one would expect to see firms engaged in captive production enter the merchant market. However, given the small size of the compliance costs it is unlikely that the proposed regulations will change the balance between the merchant and captive markets. Furthermore, the industry trend is towards vertical integration in chlorine production.

Given the capital in place, each chlorine facility will be assumed to face an upward-sloping marginal cost function. The facility owner is willing to supply chlorine and sodium hydroxide according to this schedule as long as the market prices of the two products are high enough to cover average variable costs. If revenue falls below average variable costs, then the firm's best response is to cease production because total revenue does not cover total variable costs of production. In this scenario, producers lose money on operations as well as capital. By shutting down, the firm avoids additional losses from operations. Demand is characterized by a downward-sloping demand curve, which implies that demand is low when prices are high and demand is high when prices are low.

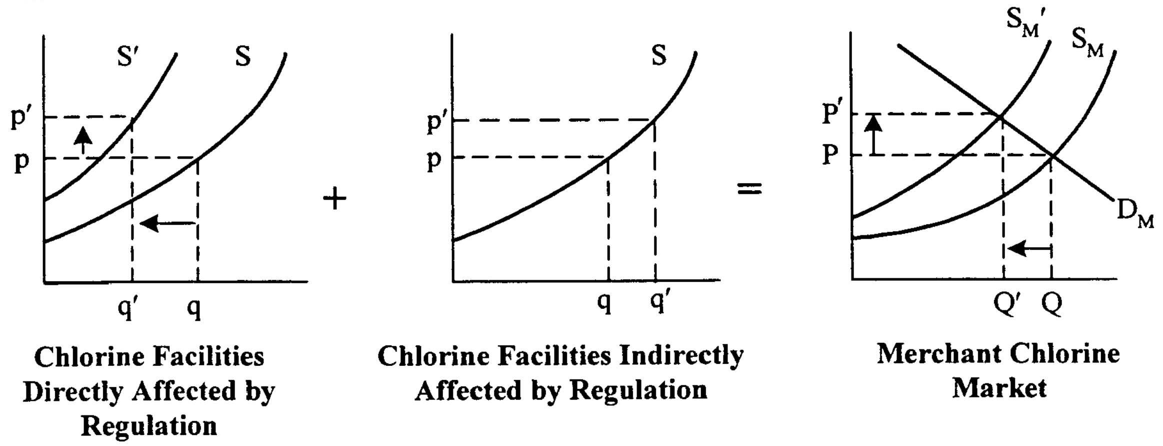
Figure 4-1(a) shows how the market prices and quantities of chlorine (or sodium hydroxide) are determined by the intersection of market supply and demand curves in a perfectly competitive market, but basic intuition is similar to the concentrated (not perfectly competitive) market model. The baseline consists of a market price and quantity (P, Q) that is determined by the downward-sloping market demand curve (D_M) and the upward-sloping market supply curve (S_M) that reflects the sum of the individual supply curves of chlorine facilities. Any individual supplier would produce amount q (at price p) and the facilities would collectively produce amount Q, which equals market demand.

Chlorine Market:



a) Baseline Equilibrium

Chlorine Market:



b) With-Regulation Equilibrium

Figure 4-1. Market Equilibrium Without and With Regulation

Now consider the effect of the regulatory control costs. Incorporating the regulatory control costs will involve shifting the supply curve upward for each regulated mercury cell chlor-alkali facility by the per-unit variable compliance cost. The supply curve of nonregulated facilities will remain unaffected.

The supply function of the affected facilities shifts upward from S to S′, causing the market supply curve to shift upward to S_M'. At the new equilibrium with the regulation, the market price increases from P to P′ and market output (as determined from the market demand curve, D_M) declines from Q to Q′ (see Figure 4-1[b]). This reduction in market output is the net result of output reductions at directly affected facilities and output increases at indirectly affected facilities. This illustrates the theory underlying estimation of the cost impacts of the MACT standards on the chlor-alkali facilities that use the mercury cell process.

4.2 Operational Model

The proposed regulation will increase the cost of production for existing mercury process chlor-alkali plants. The regulated facilities may alter their current levels of production or even close the facility in response to the increased costs. These responses will in turn determine the impact of the regulations on total market supply and ultimately on the equilibrium price and quantity. To determine the impact on equilibrium price and quantity, EPA

- characterized the merchant and captive supply of chlorine and sodium hydroxide at the facility and company level;
- characterized demand for chlorine and sodium hydroxide;
- developed the solution algorithm to determine the new with-regulation equilibrium; and
- computed the values for all the impact variables.

This section and the appendices describe how the Agency calculated market supply, market demand, and the impact of additional regulatory control costs on the market equilibrium. Supply is calculated for the merchant market for chlorine first under the assumption that the merchant chlorine market is competitive and next under the assumption that the merchant chlorine market is concentrated. The captive supply is calculated separately.

4.2.1 Market Supply

In each case, market supply calculations were conducted at the facility level and then summed to provide company and industry-level information. Based on the best available data, facilities were characterized as supplying to either the merchant or captive chlorine market.[1] This section and the appendices describe how the supply curve was constructed for each market.

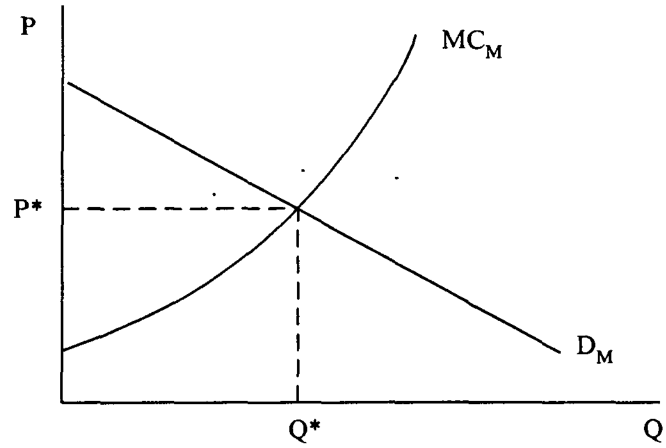
4.2.1.1 *Competitive Merchant Markets*

In the competitive market, firms are assumed to be price-takers—changes in the output of any one firm will not affect the market price. Furthermore, the market price equals the marginal cost of producing the last unit. Figure 4-2(a) depicts a perfectly competitive market. The Agency modeled the chlorine and sodium hydroxide markets at the facility level with upward-sloping supply curves, reflecting increasing marginal costs as output increases. Facility-level supply curves were estimated for both the firms directly affected by the regulation (the mercury cell chlor-alkali facilities) and those facilities that are indirectly affected by the regulation through changes in the amount supplied by the regulated firms. For this analysis, a Leontief specification was used to derive the supply curves for the individual facilities (see Appendix A for details about the calculation of the supply curves). The supply function parameters were calibrated using baseline 1997 production, capacity, and price data.

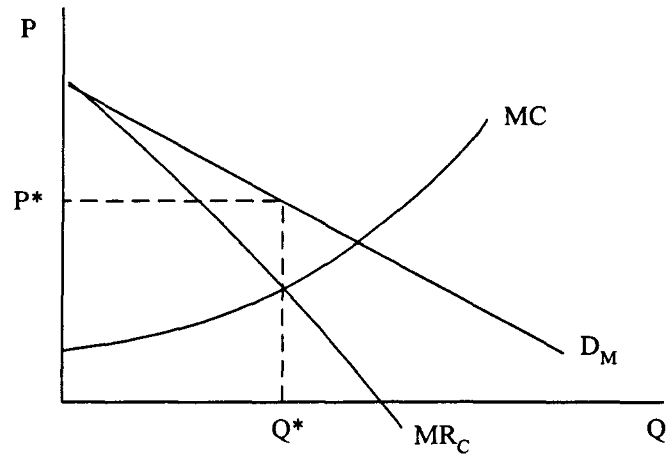
4.2.1.2 *Concentrated Merchant Market for Chlorine and Competitive Market for Sodium Hydroxide*

To model the merchant chlorine market as a concentrated market, the Agency used a Cournot model in which firms exercise some control over the price of chlorine. In these noncompetitive models, each supplier recognizes its influence over market price and chooses a level of output that maximizes its profits, given the output decisions of the others. Employing a Cournot model assumes that suppliers do not cooperate. Instead, each supplier evaluates the effect of its output choice on market price and does the best it can given the output decision of its competitors. Thus, given any output level chosen by other suppliers there will be a unique optimal output choice for a particular supplier.

[1]Facilities that produce for both the merchant and the captive markets were classified as wholly producing for which ever market received the majority of the supply based on EPA's interpretation of the best available data.



(a) Perfectly Competitive Market



(b) Imperfectly Competitive Market

Figure 4-2. Perfectly Competitive and Imperfectly Competitive Markets

The basic oligopoly model considered is the "many firm Cournot equilibrium" model, described in Varian (1993). As is the case in all imperfectly competitive models of profit-maximizing behavior, each oligopolist chooses an output level where marginal revenue equals marginal cost (total marginal cost is the sum of the preregulation marginal cost per unit plus the per-unit compliance costs). For the monopolist, marginal revenue is simply a function of the demand elasticity. In the Cournot model, marginal revenue is a fraction, Z_i, of the market price: $Z_i = (1 - s_i/\varepsilon_d)$, where $s_i = q_i/Q$. Equilibrium is defined by q_i*, such that marginal revenue = marginal cost (see Figure 4-2[b]). Because the quantity produced for each facility depends on the market share of the parent company, production from the directly and indirectly affected suppliers was summed to determine the company's market share. Appendix B provides the details on calculating marginal cost and supply.

The Agency assumed a competitive sodium hydroxide market in both scenarios.

4.2.2 Captive Market for Chlorine and Competitive Market for Sodium Hydroxide

Three of the affected facilities produce chlorine used by the parent companies internally to produce other downstream products (captive chlorine producers). For these facilities, the engineering compliance costs will equal the welfare costs to society. The chlorine produced at these facilities is used to make a large variety of downstream products, and good data are lacking on the specific downstream products produced, the amount of chlorine devoted to specific downstream products, and the markets for these products. If these downstream product markets are competitive, it will be very difficult for the three affected facilities to pass on the higher cost of chlorine to consumers of the downstream products. Instead, EPA assumed that the very small compliance costs will not alter the production decisions of captive producers of chlorine, and the firm will simply receive a lower producer surplus for the final, downstream products.

4.2.3 Market Demand

The Agency modeled separate demand curves for chlorine and sodium hydroxide. The two products are jointly produced under the same marginal cost structure, but the demand curves for chlorine and sodium hydroxide are different. EPA modeled one aggregate consumer with a downward-sloping demand curve for chlorine and one aggregate consumer for sodium hydroxide in the merchant market that are consistent with the theory of demand (i.e., consumption of the commodity is high at low prices and low at high prices, reflecting the opportunity costs of purchasing these products). The Agency developed these curves using the same equation and baseline quantity, price data, and assumptions about the responsiveness to changes in price (demand elasticity). Appendix C presents the details for calculating the demand curves. For domestic demand, a demand elasticity of –1.0 was used (i.e., a 1 percent increase in the price of the commodity would result in a 1 percent decrease in quantity demanded, and vice versa), although sensitivity analysis was conducted to determine the impact of this assumption on the model results.

4.2.4 Control Costs and With-Regulation Equilibrium for Merchant Market

Facility responses and market adjustments can be conceptualized as an interactive feedback process. Facilities face increased production costs due to compliance, which causes facility-specific production responses (i.e., output reduction). The cumulative effect of these responses leads to an increase in the market price that all producers (directly affected and indirectly affected) and consumers face. This increase leads to further responses by all producers and consumers and, thus, new market prices. The new with-regulation equilibrium is the result of a series of these iterations between producer and consumer responses and market adjustments until a stable market price equilibrium in which total market supply equals total market demand (i.e., $Q_s = Q_d$). Appendix D details how the Agency modeled the change in market equilibrium to produce estimates of the economic impacts described below.

4.3 Economic Impact Results

The theory presented above suggests that producers attempt to mitigate the impacts of higher-cost production by shifting the burden onto other economic agents to the extent the market conditions allow. Because of the small control costs, the model projects little upward pressure on prices in the merchant market because producers reduce output rates only slightly in response to higher costs. Higher prices reduce quantity demanded and output for the commodity, leading to changes in economic surplus to consumers and profitability of firms. These market adjustments determine the social costs of the regulation and its distribution across stakeholders (producers and consumers). (As stated above, in the captive market the Agency assumes that producers will not pass on the higher costs of chlorine to consumers of the final end market products, so the change in welfare is the reduction in producer surplus.) In this case, based on the Agency's characterization of the market, the directly affected producers bear the brunt of the cost changes. This section reports impact results under both the perfect competition and imperfect competition behavioral assumptions.

4.3.1 Market-Level Results

The increased cost of production due to the regulation is expected to slightly increase the price of chlorine and sodium hydroxide and only marginally reduce production and consumption from baseline levels. As shown in Table 4-1, price is projected to only increase less than 0.01 percent for both chlor-alkali products. The price impacts are attenuated by the existence of unaffected producers (domestic and foreign). Only marginal changes in chlorine output occur with the regulation. Domestic chlorine output is projected to decline by 24.9 tons, while foreign imports are projected to increase by 2.5 tons resulting in a net decline of 22.4 tons. Domestic sodium hydroxide output is projected to decline by 12.7 tons, while foreign imports are projected to increase by 0.5 tons resulting in a net decline of 12.3 tons.

These small changes are the result of small per-unit compliance costs and their distribution across merchant chlorine facilities. The per-unit compliance costs are small relative to the market price of chlorine for all affected producers (less than 0.01 percent). Additionally, the majority of market share is produced by facilities not subject to regulation (i.e., domestic producers using the diaphragm or membrane process and foreign producers). In the chlorine market and sodium hydroxide market, these producers account for over 75 percent of output. Thus, they limit the ability of directly affected producers to increase prices in these markets.

There are only marginal differences in the market-level impacts between the two behavioral assumptions (perfect competition and concentrated models). As discussed above, the small size of the control costs and distribution of these costs contributes to this result. In addition, although the domestic merchant chlorine market is concentrated, no affected company accounts for more than 25 percent of total market production.

4.3.2 Industry-Level Results

Industry revenues, costs, and profitability change as chlor-alkali prices and production levels adjust to with-regulation conditions. The projected change in operating profits is the net result of changes for directly and indirectly affected companies that own merchant facilities plus changes for directly affected companies that own captive facilities. Table 4-2 reports the projected changes in revenue and costs for the directly and indirectly affected companies operating in the merchant market. After accounting for market adjustments under perfect

Table 4-1. Market-Level Impacts of the Mercury Cell Chlor-Alkali NESHAP: 1997

		Perfect Competition		Concentrated Market	
		Change		Change	
	Baseline	Absolute	Relative	Absolute	Relative
Chlorine					
Price ($/ton)	$233.75	$0.0013	0.001%	$0.0013	0.001%
Quantity (tons/yr)	4,009,309	–22.4	–0.001%	–22.4	–0.001%
Domestic production	3,556,309	–24.9	–0.001%	–24.9	–0.001%
Directly affected producers[a]	1,131,109	–25.0	–0.002%	–25.0	–0.002%
Indirectly affected producers	2,425,200	0.1	0.000%	0.1	0.000%
Imports	453,000	2.5	0.001%	2.5	0.001%
Sodium Hydroxide					
Price ($/ton)	240.75	$0.0002	0.000%	$0.0002	0.000%
Quantity (tons/yr)	14,888,000	–12.3	0.000%	–12.3	0.000%
Domestic production	14,328,000	–12.7	0.000%	–12.7	0.000%
Directly affected producers[a]	1,191,948	–21.5	–0.002%	–21.5	–0.002%
Indirectly affected producers	13,136,052	8.7	0.000%	8.7	0.000%
Imports	560,000	0.5	0.000%	0.5	0.000%

[a] Reflects the aggregate production volumes from the nine merchant mercury cell facilities affected by the proposed MACT.

competition and imperfect competition, the directly affected merchant producers are expected to incur $1 million annually in regulatory compliance costs. As shown in Table 4-2, based on projected individual and market responses, the economic analysis estimates the net effect of revenue and cost changes for these producers to result in a decline in operating profits of $1 million per year. This reduction in profits is less than the regulatory costs they incur because these producers reduce their production, resulting in higher market chlor-alkali prices, which effectively shifts a very small portion of the regulatory burden onto consumers. The

Table 4-2. National-Level Industry Impacts of the Mercury Cell Chlor-Alkali NESHAP: 1997[a]

		Perfect Competition		Concentrated Market	
		Change		Change	
	Baseline	Absolute	Relative	Absolute	Relative
Chlorine Companies (Directly Affected)[b]					
Revenue ($\$10^6$)	$1,468.4	–$0.007	0.000%	–$0.007	0.000%
Costs ($\$10^6$)	$644.0	$1.005	0.156%	$1.006	0.156%
Control	$0.0	$1.016	NA	$1.016	NA
Production	$644.0	–$0.011	–0.002%	–$0.009	–0.001%
Operating profits ($\$10^6$)	$824.4	–$1.011	–0.123%	–$1.013	–0.123%
Companies (#)	7	0	0.000%	0	0.000%
Facilities (#)	9	0	0.000%	0	0.000%
Employment (FTEs)	1,055	0	0.000%	0	0.000%
Chlorine Companies (Indirectly Affected)					
Revenue ($\$10^6$)	$304.7	$0.001	0.000%	$0.001	0.000%
Costs ($\$10^6$)	$120.6	$0.000	0.000%	$0.000	0.000%
Control	$0.0	$0.000	NA	$0.000	NA
Production	$120.6	$0.000	0.000%	$0.000	0.000%
Operating profits ($\$10^6$)	$184.1	$0.001	0.001%	$0.001	0.001%
Companies (#)	4	0	0.000%	0	0.000%
Facilities (#)	12	0	0.000%	0	0.000%
Employment (FTEs)	218	0	0.000%	0	0.000%

NA = Not available
FTEs = Full-time equivalents

[a] Merchant operations only.
[b] Includes the companies that own the 12 mercury cell facilities affected by the proposed MACT.

unaffected merchant producers slightly increase their production in response to the higher market prices and, thereby, experience gains a marginal increase in operating profits (0.001 percent). Lastly, by assumption the Agency projects directly affected captive facilities to incur a loss in operating profits of $0.445 million annually, which is assumed to be equal to the aggregate engineering estimate of compliance costs. For these producers, the Agency did not predict higher prices for their end products and, thus, captive producers bear the full costs of compliance.

As a result of these changes, the regulation is projected to decrease industry operating profits by $1.45 million (see Table 4-2).[2] *No facilities* are projected to close with the rule, and *no losses* in employment are attributable to the rule. This section discusses these industry-level impacts in detail with additional emphasis on the rule's distributional impacts.

Additional distributional impacts of the rule within the directly affected merchant producers are not apparent from the reported decline in their aggregate operating profits. The regulation creates both gainers and losers within the merchant segment. As Table 4-3 indicates, 12 merchant facilities are projected to experience marginal profit increases under the recommended alternative. None of these 12 facilities are directly affected by the regulation. The nine facilities predicted to experience profit losses are the directly affected merchant facilities. No facility is projected to cease operations and forego baseline operating profits. The merchant facilities with profit gains tend to have higher chlorine output rates (average of 202,100 tons per facility per year) and no per-unit compliance costs. Facilities that experience profit losses are generally lower-volume facilities (average of 125,676 tons per facility per year) and positive per-unit compliance costs ($0.90 per pound).

The Agency projects only small changes in output in response to the regulation. Therefore, it is unlikely that there will be significant changes in employment levels. Although captive producers incur compliance costs that would potentially influence levels of employment, EPA did not attempt to project changes in employment for these facilities.

---

[2] The total change in operating profits is calculated by summing the loss in operating profits for the directly affected merchant facilities and the gain in operating profits for the indirectly affected facilities (reported in Table 4-2) plus the loss in operating profits for the directly affected captive producers of $0.445 million (not reported in Table 4-2).

Table 4-3. **Distributional Impacts of the Mercury Cell Chlor-Alkali NESHAP Across Merchant Chlorine Facilities: 1997**

	Perfect Competition				Concentrated Market			
	With-Profit Gain	With-Profit Loss	Closure	Total	With-Profit Gain	With-Profit Loss	Closure	Total
Facilities (#)	12	9	0	21	12	9	0	21
Chlorine production								
Total (tons/yr)	2,425,200	1,131,084	0	3,556,284	2,425,200	1,131,084	0	3,556,284
Average (tons/facility)	202,100	125,676	NA	169,347	202,100	125,676	NA	169,347
Control costs								
Total ($$10^6$)	$0.00	$1.02	$0.00	$1.02	$0.00	$1.02	$0.00	$1.02
Average ($/ton)	NA	$0.90	NA	$0.29	NA	$0.90	NA	$0.29
Change in operating profits ($$10^6$)	$0.00	–$1.01	$0.00	–$1.01	$0.00	–$1.02	$0.00	–$1.01
Change in employment (FTEs)	0	0	0	0	0	0	0	0

With-profit gain = Facilities become more profitable with-regulation.
With-profit loss = Facilities become less profitable with-regulation.
NA = Not available
FTEs = Full-time equivalents

Table 4-4. Distribution of the Social Costs Associated with the Mercury Cell Chlor-Alkali NESHAP: 1997

	Perfect Competition Value (10^6)	Concentrated Market Value (10^6)
Change in Consumer Surplus	–$0.008	–$0.008
Chlorine	–$0.005	–$0.005
Domestic	–$0.005	–$0.005
Foreign	$0.000	$0.000
Sodium hydroxide	–$0.003	–$0.003
Domestic	–$0.003	–$0.003
Foreign	$0.000	$0.000
Change in Producer Surplus	–$1.452	–$1.454
Domestic producers	–$1.453	–$1.454
Mercury cell facilities	–$1.459	–$1.460
Merchant	–$1.014	–$1.016
Captive	–$0.445	–$0.445
Other domestic producers	$0.006	$0.006
Foreign producers	$0.001	$0.001
Total Social Cost	–$1.460	–$1.462

4.3.3 Social Costs of Regulations

The value of a regulatory action is traditionally measured by the change in economic welfare that it generates. Welfare impacts, or the social costs required to achieve the environmental improvements, resulting from this regulatory action will extend to the many consumers and producers of chlor-alkali products. Consumers will experience welfare impacts due to changes in market prices and consumption levels associated with imposition of the regulation. Producers will experience welfare impacts resulting from changes in their revenues associated with imposition of the regulation and the corresponding changes in production and market prices. However, it is important to emphasize that this measure does not include benefits that occur outside the market, that is, the value of reduced levels of air pollution with the regulation.

For this analysis, based on applied welfare economics principles, social costs as described above are measured as the sum of the expected changes in consumer and producer surplus (see Appendix E for a discussion of the calculation of social costs). Consumers experience reductions in consumer surplus because of increased market prices. Producers may experience either increases or decreases in producer surplus (i.e., profits) as a result of increased market prices and changes in production and compliance costs.

The national estimate of compliance costs is often used as an approximation of the social cost of the rule. The engineering analysis estimated annual costs of $1.460 million. However, this estimate does not account for behavioral responses by producers or consumers to imposition of the regulation (e.g., shifting costs to other economic agents, shutting down product lines or facilities). Accounting for these responses results in a social cost estimate that differs from the engineering estimate as well as provides insights on how the regulatory burden is distributed across society (i.e., the many consumers and producers of chlor-alkali products). As described earlier in this section, the economic impacts are projected to be small. Therefore, there is only a slight difference between the engineering cost estimate and social cost estimate based on the market analysis described above. The annual social costs of the recommended controls are projected to be approximately $1.460 million under the competitive model (slightly lower than the baseline control cost estimates when rounded to more digits) and $1.462 under the concentrated model (slightly higher than the baseline control cost estimates, see Table 4-4).[3]

[3]Under a perfectly competitive model, the social costs estimates ($1,460,261) are slightly smaller than the engineering cost estimate ($1,460,275). However, under a concentrated model, the social cost estimate ($1,461,926) is larger than the engineering cost estimate because the regulation exacerbates the pre-existing social inefficiency.

More importantly, the economic analysis reveals how the burden of the social costs is divided between consumers and producers once behavioral changes are modeled.[4] Table 4-4 provides the social costs and their distribution across stakeholders under competitive and concentrated market models. This distribution of social costs depends critically on the relationship between the responsiveness of consumers and producers to prices changes (i.e., supply/demand elasticities). Generally, the stakeholder with the less-elastic response (in absolute value) will bear a higher share of the costs associated with the regulation. The economic analysis of the chlor-alkali industry suggests that chlorine producers have limited ability to pass on the regulatory costs to consumers. The Agency estimates a loss in directly affected producer surplus of $1.46 million annually. Although indirectly affected producers potentially would benefit from higher prices without additional control costs, these benefits are expected to be extremely small (less than $50,000). Thus, the net change in producer surplus is projected to be $1.46 million. The Agency estimates minimal impacts for consumers (less than $10,000 annually). Note, however, an important model parameter affecting the estimated consumer surplus losses is the elasticity of demand for the chlor-alkali products. Sensitivity analysis revealed that in this case even very small demand elasticities do not result in significantly greater losses to consumers.

---

[4]In the long run, it is expected that all costs of the rule would be passed on to consumers in the form of higher product prices. This is because investors will not invest in new plants and equipment unless they expect to cover all their costs of production and earn a return on investment appropriate for the risk they are incurring. However, currently fixed assets specific to chlor-alkali production are the result of past investment decisions that cannot be reversed today. Thus, over the next 10 to 20 years owners of these facilities will have to decide how best to use these resources.

SECTION 5

SMALL BUSINESS IMPACTS

The proposed NESHAP protects air quality and promotes public health by reducing the current levels of HAP emissions generated by mercury cell chlor-alkali manufacturers. However, this regulatory action will also affect the economic welfare of owners of the chlor-alkali facilities that use the mercury cell process. These individuals may be owners/operators who directly conduct the business of the firm (i.e., "mom and pop shops" or partnerships) or, more commonly, investors or stockholders who employ others to conduct the business of the firm on their behalf (i.e., privately held or publicly traded corporations). Although environmental regulations like this rule potentially affect all businesses, large and small, small businesses may have special problems in complying with such regulations.

The Regulatory Flexibility Act (RFA) of 1980 requires that special consideration be given to small entities affected by federal regulation. The RFA was amended in 1996 by the Small Business Regulatory Enforcement Fairness Act (SBREFA) to strengthen the RFA's analytical and procedural requirements. Under SBREFA, the Agency implements the RFA as written with a regulatory flexibility analysis required only for rules that will have a *significant* impact on a *substantial* number of small entities. This section identifies the businesses that this proposed rule will affect and provides a preliminary screening-level analysis to assist in determining whether this rule is likely to impose such an impact within this industry. The screening-level financial analysis employed here is a "sales test," which computes the annualized compliance costs as a share of sales for each company. In addition, the economic analysis provides information about the impacts on merchant small businesses after accounting for producer responses to the regulation and the resulting changes in market prices and output for chlor-alkali products.

5.1 Identifying Small Businesses

As described in Section 2 of this report, the Agency identified six small businesses that manufacture chlorine, or 30 percent of the total. However, only three of these firms are subject to the proposed rule—ASHTA, Holtrachem Mfg Co., and Pioneer Chlor-Alkali Co.—because they own and operate facilities using the mercury cell process.

5.2 Screening-Level Analysis

For the purposes of assessing the potential impact of this rule on small businesses, the Agency calculated the share of annual compliance cost relative to baseline sales for each company (CSR). When a company owns more than one affected facility, the costs for each facility it owns were summed to develop the numerator of the test ratio. For this screening-level analysis, annual compliance costs were defined as the engineering control costs imposed on these companies; thus, they do not reflect the changes in production expected to occur in response to imposing these costs and the resulting market adjustments. The engineering analysis estimates the aggregate compliance costs for small businesses total $0.259 million, or 18 percent of the total industry costs of $1.460 million. As shown in Table 5-1, the average CSR is 0.05 percent for small businesses and 0.01 percent for large businesses. Thus, the analysis shows that *no company* (small or large) is expected to incur costs greater than 1 percent of their sales.

Table 5-1. Summary Statistics for SBREFA Screening Analysis

	Small	Large	Total
Total companies (#)	6	15	21
Annual compliance costs ($$10^6$)	$0.259	$1.201	$1.460
Companies with sales data (#)	6	15	21
Affected <1%	6	15	21
Affected ≥1%	0	0	0
Affected ≥3%	0	0	0
Cost-to-sales ratios			
Average	0.05%	0.01%	0.02%
Median	0.02%	0.00%	0.00%
Minimum	0.00%	0.00%	0.00%
Maximum	0.22%	0.11%	0.22%

Data on industry-wide profitability ratios were not available from Dun & Bradstreet or other secondary data sources. Only one of the three small firms subject to the regulation (Pioneer Chlor-Alkali Co.) reported profitability data publicly in company 10-K reports. The operating income[1] for this company equaled 7.7 percent of sales in 1997. However, this ratio declined to –13.1 percent in 1999. The company's net income measures that account for interest and tax expenses ranged from –$24.5 million in 1997 to –$50.4 million in 1999.

5.3 Economic Analysis

The Agency also analyzed the economic impacts on *merchant*[2] small businesses (five total) under with-regulation conditions expected to result from implementing the MACT (see Table 5-2). Unlike the screening-level analysis described above, this approach examined small business impacts in light of the expected behavioral responses of producers and consumers to the regulation. After accounting for market adjustments, the operating profits for three directly affected small firms are projected to decline by $0.258 million under both perfectly competitive and oligopoly scenarios, only slightly smaller than the engineering cost estimates of $0.259 million. Although, the other small merchant companies would potentially benefit from increased prices without additional control costs, price increases are projected to be very small. Therefore, with-regulation profitability for these firms is expected to be nearly identical to baseline conditions.

5.4 Assessment

This analysis suggests the proposed rule *will not* have a significant impact on a substantial number of small entities. The screening analysis shows that no company (small or large) is expected to incur costs greater than 1 percent of their sales. The economic analysis, which includes market responses to the regulation, shows operating profits for small companies will decline by $0.258 million. EPA continues to be interested in the potential impacts of the propose rule on small entities and welcomes comments on issues related to such impacts.

---

[1]Operating income = sales less cost of goods sold, selling, general, and administrative expenses, and unusual charges.

[2]The remaining small firm does not use the mercury cell process and is assumed to perform captive operations for this analysis.

Table 5-2. Small Business Impacts of the Mercury Cell Chlor-Alkali Production NESHAP: 1997[a]

		Perfect Competition		Concentrated Market	
		Change		Change	
	Baseline	Absolute	Relative	Absolute	Relative
Small Chlorine Companies (Directly Affected)[b]					
Revenue ($\$10^6$)	\$402.7	–\$0.002	0.000%	–\$0.002	0.000%
Costs ($\$10^6$)	\$173.0	\$0.256	0.148%	\$0.257	0.148%
Control	\$0.0	\$0.259	NA	\$0.259	NA
Production	\$173.0	–\$0.003	–0.002%	–\$0.003	–0.002%
Operating profits ($\$10^6$)	\$229.7	–\$0.258	–0.112%	–\$0.258	–0.112%
Companies (#)	4	0	0.000%	0	0.000%
Facilities (#)	6	0	0.000%	0	0.000%
Employment (FTEs)	289	0	0.000%	0	0.000%
Other Small Chlorine Companies (Indirectly Affected)					
Revenue ($\$10^6$)	\$137.9	\$0.000	0.000%	\$0.000	0.000%
Costs ($\$10^6$)	\$61.4	\$0.000	0.000%	\$0.000	0.000%
Control	\$0.0	\$0.000	NA	\$0.000	NA
Production	\$61.4	\$0.000	0.000%	\$0.000	0.000%
Operating profits ($\$10^6$)	\$76.4	\$0.000	0.001%	\$0.000	0.001%
Companies (#)	2	0	0.000%	0	0.000%
Facilities (#)	2	0	0.000%	0	0.000%
Employment (FTEs)	99	0	0.000%	0	0.000%

NA = Not available
FTEs = Full-time equivalents

[a] Merchant operations only.
[b] Includes the small companies that own mercury cell facilities affected by the proposed MACT.

REFERENCES

Alliance for Environmental Technology, Press release, April 15, 1996.

Berthiaume, Sylvie, Eric Anderson, and Yuka Yoshida. 2000. *Chlorine/Sodium Hydroxide.* CEH Marketing Research Report. Chemical Economics Handbook—SRI International.

Chemical Week. 1996. <http://www.chemweek.com/marketplace/product_focus/1996 chlorine.html>

The Chlorine Institute. 2000. *Chlor-Alkali Industry Plants and Production Data Report.* Washington, DC: The Chlorine Institute.

Dungan, Arthur, The Chlorine Institute. June 2, 2000. Personal communication with Carol Mansfield, Research Triangle Institute. Chlorine discussion.

EC/R Incorporated. September 12, 1996. *Background Information Document: Chlorine Production Summary Report.* Prepared for the U.S. Environmental Protection Agency. Durham, NC: EC/R Inc.

"Facts and Figures for the Chemical Industry." *Chemical and Engineering News.* June 24, 1996.

Gale Research. 1998. *Ward's Business Directory of U.S. Private and Public Companies.* Detroit, MI: Gale Research.

Hoover's Incorporated. 2000. Hoover's Company Profiles. Austin, TX: Hoover's Incorporated. <http://www.hoovers.com/>.

Information Access Corporation. 2000. Business & Company ProFile [computer file]. Foster City, CA: Information Access Corporation.

Kroschwitz, Jacqueline. 1991. *Kirk-Othmer Encyclopedia of Chemical Technology,* 4th Ed. New York: John Wiley & Sons.

Shakhahiri, B.Z. 2000. Chemical of the Week: Sulfuric Acid. <http://www.scifun.chem.wisc.edu/CHEMWEEK/sulf&top/Sulf&top.html>. Obtained June 6, 2000.

Selected company 10-K reports.

Ullman's Encyclopedia of Industrial Chemistry. 1992.

U.S. Small Business Administration (SBA). 2000. Size Standards by SIC Industry. <http://www.sba.gov/regulations/sicodes/siccodes.htm>.

U.S. Department of Commerce, Bureau of the Census. 1999. Concentration Ratios in Manufacturing. MC92-5-2. Washington, DC. <http://www.census.gov/mcd/mancen/download/mc92cr.sum>. Last revised February 4, 1999.

U.S. Department of Commerce. Current Industrial Reports, Series MA-28A. Washington, DC, U.S. Department of Commerce, Bureau of the Census.

U.S. Department of Commerce, Bureau of the Census. 1996. *1992 Census of Manufactures Industry Series: Industrial Inorganic Chemicals.* MC92-I-28A. Washington, DC: [online]. <http://www.census.gov/prod/1/manmin/92mmi/mci28af.pdf>.

U.S. Department of Commerce, Bureau of the Census. 1999. *1997 Economic Census—Manufacturing Industry Series: Alkalies and Chlorine Manufacturing.* EC97M-3251E. Washington, DC: [online]. <http://www.census.gov/prod/www/abs/97ecmani.html>.

U.S. Department of Commerce, Bureau of the Census. 1993-1996. *Annual Survey of Manufactures: Statistics for Industry Groups and Industries.* <http://www.census.gov/prod/www/abs/industry.html>.

U.S. Department of Commerce, Bureau of the Census. 1996-1998. *Annual Survey of Manufactures: Statistics for Industry Groups and Industries.* Washington, DC: Government Printing Office.

U.S. Department of Energy, Energy Information Administration. 1998. *Electric Power Annual 1997, Volume 1.* Washington, DC: U.S. Department of Energy. <http://www.eia.doe.gov/cneaf/electricity/epav1/html/contents.htm> . Last updated July 30, 1998.

U.S. Environmental Protection Agency (EPA). 1995. *Inorganic Chemicals Sector Notebook.* Washington, DC. U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency (EPA). 1996. *Economic Analysis of Pollution Regulations: Pharmaceutical Industry.* Research Triangle Park, NC: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency (EPA). 1999. *OAQPS Economic Analysis Resource Document.* Research Triangle Park, NC: EPA, Innovative Strategies and Economics Group.

Varian, Hal. 1993. *Microeconomic Analysis*, 3rd Edition. New York: W.W. Norton & Company.

Appendix A

Supply of Chlorine and Sodium Hydroxide to the Merchant Market Assuming Competitive Merchant Markets for Chlorine and Sodium Hydroxide

Production of chlorine (or sodium hydroxide) can be expressed as the amount produced for sale on the domestic merchant market and foreign supply (or imports), that is,

$$Q_s = q_m + q_i \tag{A.1}$$

where Q_s is the total supply of chlorine to the merchant market, q_m is the amount produced for sale on the domestic merchant market, and q_i is the foreign supply (or imports). Because of the fixed production relationship between chlorine and sodium hydroxide, we can express sodium hydroxide in units of chlorine (1 ton of chlorine = 1.1 tons of sodium hydroxide). Throughout this description, we refer to the production of "chlorine" and express sodium hydroxide in units of chlorine. Conceptually, the firm will make a decision about the amount of chlorine produced, which also determines the amount of sodium hydroxide produced. The decision will be based on the joint cost function and revenue from the sale of both products. The analysis was conducted at the facility level and then the results were summed across facilities to get company and market-level results.

A.1 Directly Affected Facilities

Producers of chlorine products have some ability to vary output in the face of production cost changes. Production cost curves, coupled with market price, can be used to determine the facility's optimal production rate, including zero (shutdown). For this analysis, the generalized Leontief profit function was used to derive the supply curve for chlorine products at each facility (see Chambers [1988] p. 172, for a description of the generalized Leontief). By applying Hotelling's lemma to the generalized Leontief profit function, the following general form of the supply functions for each chlorine product is obtained:

$$q_j = \gamma_j + \frac{\beta_j}{2}\left[\frac{1}{p_c + (1.1)(p_{cs}) - c_j}\right]^{\frac{1}{2}} \tag{A.2}$$

where p_c is the market price for chlorine, p_{cs} is the market price for sodium hydroxide, c_j is the cost of complying with the regulations ($c_j = 0$ in the pre-regulation baseline), β_j and γ_j are model parameters, and j indexes producers (i.e., individual chlorine facilities). The theoretical restrictions on the model parameters that ensure upward-sloping supply curves are $\gamma_j > 0$ and $\beta_j < 0$. We can calculate γ_j using data on production capacities at the affected facilities. From this, we can calculate a firm-specific β_j calibrated to the 1997 baseline data using Eq. (A.2).

Figure A-1 illustrates the theoretical supply function from Eq. (A.2). As shown, the upward-sloping supply curve is specified over a productive range with a lower bound of zero that corresponds with a shutdown price, p_s, equal to $\frac{\beta_j^2}{4\gamma_j^2}$ and an upper bound given by the productive capacity of $\overline{q}_j$ that is approximated by the supply parameter. The curvature of the supply function is determined by the parameter β_j.

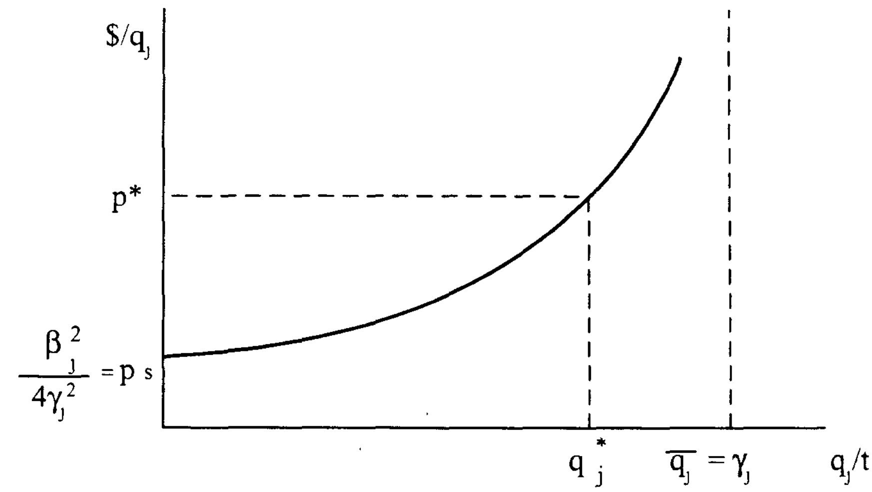


Figure A-1. Theoretical Supply Function for Chlorine and Sodium Hydroxide Facilities

A.2 Adjustment of Product-Specific Minimum Prices and Quantities at Facility

The area under the product supply curve at the facility represents the facility's total variable costs of producing that product, represented by the shaded areas in Figure A-2. This area can be expressed where VC_j is the total variable cost of production at facility j, q_j^* is the level of production at the facility, $f_j(q_j)$ is the inverse supply function, and q_j^m is the minimum economically feasible production level at the facility, which corresponds to the price p_j^m.

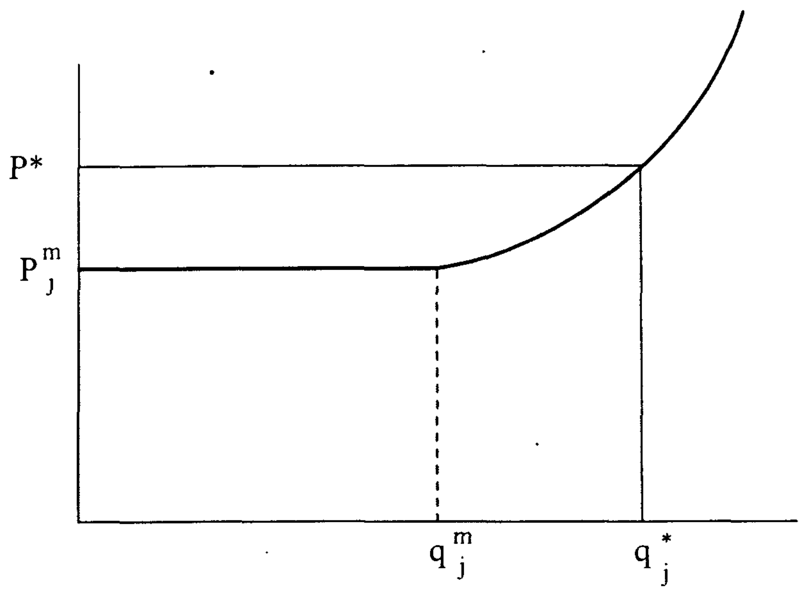


Figure A-2. Model TVC Equal to Reported Value

$$VC_j = f_j(q_j^m)\, q_j^m + \int_{q_j^m}^{q_j^*} f_j(q_j)\, dq_j \qquad \text{(A.3)}$$

The variable q_j^m is unobserved but may be chosen to calibrate the shutdown points for those facilities with estimated production cost data.[1] By integrating under the generalized Leontief supply function,[2] given the above relationships, we can express a facility's total variable costs of production as a function of q_j^* and q_j^m:

$$VC_j = \frac{\beta^2}{4}\left[\frac{q_j^m}{(q_j^m - \gamma_j)^2} + \frac{1}{(q_j^m - \gamma_j)} - \frac{1}{(q_j^* - \gamma_j)}\right] \qquad \text{(A.4)}$$

[1]Variable cost data were estimated for each facility using data on electricity requirements per ton of chlorine (Kroschwitz, 1991), state-level electricity costs (U.S. DOE, 1998), and industry-level variable cost share data (Berthiaume, Anderson, and Yoshida, 2000).

[2]See Eq. (A.2).

where q_j^* is known, while q_j^m is unknown.

The problem can be reduced further if we assume that q_j^m is proportional to base year output, q_j^*, by a factor k, so that

$$q_j^m = k\, q_j^* \qquad \text{(A.5)}$$

Thus, the facility's total variable costs can be expressed as

$$VC_j = \frac{\beta^2}{4}\left[\frac{kq_j^*}{(kq_j^* - \gamma_j)^2} + \frac{1}{(kq_j^* - \gamma_j)} - \frac{1}{(q_j^* - \gamma_j)}\right] \qquad \text{(A.6)}$$

Facility-specific q_j^m and p_j^m may be derived by solving Eq. (A.6) for the unknown variable k and then backsolving through Eq. (A.4) to solve for q_j^m and using that result with the inverse supply function to solve for p_j^m.

Applying this technique for each facility resulted in the outcome summarized in Figure A-2. First, as shown in Figure A-2, the value for k is determined to be greater than zero and less than one (i.e., $0 < k < 1$) so that q_j^m is less than q_j^*.[3] Thus, the total variable costs as measured by the area under the facility's product supply function matches the estimated value for that facility.

A.3 Regulation-Induced Shift in Supply Functions

The regulation-induced control costs enter each affected facility's supply equation as a net price change ($c_j > 0$ in Eq. [A.2]).

A.4 Facility Closure Decision

A chlorine production facility may shut down because it is no longer profitable. The sufficient condition for production at each facility is nonnegative profits (π):

$$\pi = TR - TC \geq 0 \qquad \text{(A.7)}$$

[3]For one facility, k > 1, which implies an erroneous baseline closure of this facility (i.e. current output level is less than the shutdown level), as well as the selection of some arbitrary value for k that will be instrumental in determining facility closures. For this facility, we assumed the minimum economically achievable output level was equal to baseline output level (i.e. zero profit condition).

where TR is the total revenue earned from the sale of chlorine and sodium hydroxide and TC is the sum of the variable production costs (production and compliance) and total avoidable fixed costs (annualized expenditure for compliance capital).

A.5 Indirectly Affected Merchant Suppliers

The indirectly affected facilities do not face additional costs of production with the regulation. However, their output decisions are affected by price changes expected to result from the regulation. The indirectly affected facilities were also modeled at the facility-level using Eq. (A.2) to compute supply curves. While data on the capacity of the unaffected facilities exist, data on actual 1997 production levels does not. Facility-specific estimates were computed as follows:

1. Compute aggregate chlorine production level for indirectly affected merchant producers using the following equation:

$$Q_{IA} = \alpha Q_S - Q_{DA} \tag{A.8}$$

   where

   α = estimated merchant share of chlorine production (27 percent),

   Q_S = total chlorine production (captive and merchant) in 1997 (13.7 million tons), and

   Q_{DA} = total directly affected merchant production (1.1 million tons).

2. Distribute Q_{IA} across indirectly affected facilities using secondary data of facility-specific merchant chlorine capacity.

Appendix B

Supply of Chlorine and Sodium Hydroxide to the Merchant Market Assuming a Concentrated Merchant Market for Chlorine and a Competitive Merchant Market for Sodium Hydroxide

Much of the analysis is the same as in the competitive case. The Agency used the same equation for marginal cost (although the parameter values differ). Below is a discussion of the model's two components that differ from the competitive model—the supply of chlorine from the directly affected suppliers and indirectly affected suppliers.

B.1 Directly Affected Merchant Facilities

To model chlorine as a concentrated market, the Agency used a Cournot model in which firms exercise some control over the price of chlorine. In these noncompetitive models, each supplier recognizes its influence over market price and chooses a level of output that maximizes its profits, given the output decisions of the others. Employing a Cournot model assumes that suppliers do not cooperate. Instead, each supplier evaluates the effect of its output choice on market price and does the best it can, given the output decision of its competitors. Thus, given any output level chosen by other suppliers there will be a unique optimal output choice for a particular supplier.

The basic oligopoly model considered is the "many firm Cournot equilibrium" described in Varian (1993). As the case with all imperfectly competitive models of profit-maximizing behavior, each oligopolist chooses an output level where marginal revenue equals marginal cost (where marginal cost is the sum of the preregulation marginal cost per unit plus the per-unit compliance costs). For the monopolist, marginal revenue is simply a function of the demand elasticity. In the Cournot model, marginal revenue is a fraction, Z_i, of the market price: $Z_i = (1 - s_i/|\epsilon_d|)$, where $s_i = q_i/Q$ and i indexes the parent company of facility j. Equilibrium is defined by q_j^*, such that marginal revenue = marginal cost:

$$P(Q) \cdot (1 - s_i/|\epsilon_d|) = MC(q_j^*) + c_j \qquad \text{(B.1)}$$

In the baseline, $c_j = 0$. EPA has data on the merchant price of chlorine (P(Q)), estimates of the total quantity produced for the merchant market (Q), and estimates of the market share of the parent company in the merchant market (s_i), the amount produced by the facility (q_j^*), and the price elasticity of demand (ϵ_d). Under this formula, MC will be equalized across facilities with the same parent company. Because compliance costs are so small, EPA assumed that the market share for each firm will not change as a result of the regulation.

EPA assumed the same generalized Leontief marginal cost function as in the competitive model, Eq. (A.2). However the parameter values are different, specifically β_j. In this study's data, the Agency observed a single market price and quantity (p^*, q^*). In the competitive market, EPA assumed this price and quantity correspond to the point where the marginal cost curve (or aggregate industry supply curve) crosses the demand curve, so the competitive equilibrium price, p^*, equals the marginal cost (see Figure 4-2[a] in Section 4). In the Cournot model, each firm chooses a level of output consistent with marginal cost equal to a fraction of marginal revenue, MR_c (see Figure 4-2[b] in Section 4). Given that the demand curve is the same in both the competitive and Cournot models, this implies that the marginal cost curves must be different. EPA calculated β_j using Eq. (B.1) where s_i is the share of the merchant market for the parent company of each facility, so facilities with the same parent company will have the same market share. Lacking data from the literature, EPA assumed that the price elasticity of demand is 1.

B.2 Indirectly Affected Merchant Suppliers

The indirectly affected facilities do not face additional costs of production with the regulation. However, their output decisions are affected by price changes expected to result from the regulation. In the Cournot model, firms with different market shares will react differently to changes in the output decisions of other suppliers. Because EPA has some facility-level data, the Agency modeled the indirectly affected merchant chlorine suppliers at the facility level, but market shares were calculated at the company level. Marginal cost curves were constructed using Eq. (A.2) and data on production capacities at the facility level. Marginal revenue was calculated using the left-hand side of Eq. (B.1). The 1997 production data were only provided for the directly affected facilities. Production at the indirectly affected facilities was estimated in the same manner as described for the competitive model in Appendix A.

Appendix C

Demand for Chlorine and Sodium Hydroxide

EPA modeled separate markets for chlorine and sodium hydroxide. The two products are jointly produced under the same marginal cost structure, but the demand curves for chlorine and sodium hydroxide are different. The following equations outline the Agency's method for calculating the demand for chlorine, and the same equations were used to calculate the demand for sodium hydroxide.

Market demand for chlorine (Q_d) can be expressed as the sum of domestic and foreign demand (similarly for sodium hydroxide):

$$Q_d = q_d + q_x \tag{C.1}$$

where q_d is the domestic demand and q_x is the foreign demand (or exports), as described below.

C.1 Domestic Merchant Demand

Domestic merchant demand for chlorine (or sodium hydroxide) can be expressed by the following general formula:

$$q_d = B_d[p]^{\eta d} \tag{C.2}$$

where p is the market price of chlorine (or sodium hydroxide), η^d is the domestic demand elasticity (assumed value), and B_d is a multiplicative demand parameter that calibrates the demand equation for chlorine, given data on price and the domestic demand elasticity to replicate the observed baseline year 1997 level of domestic consumption. This quantity is estimated as follows:

$$q_d = Q_s - q_x \tag{C.3}$$

where Q_s is the sum of domestic production and imports and q_x is exports.

C.2 Foreign Demand (Exports)

Foreign demand, or exports, for chlorine (or sodium hydroxide) can be expressed by the following general formula:

$$q_x = B_x[p]^{\eta x} \tag{C.4}$$

where p is the market price of chlorine, η^d is the assumed export demand elasticity (assumed to be more elastic than domestic demand), and B_x is a multiplicative demand parameter that calibrates the foreign demand equation, given data on price and the foreign demand elasticity to replicate the observed baseline year level of exports.

Appendix D

With-Regulation Market Equilibrium for Chlorine and Sodium Hydroxide Markets

The process for determining equilibrium price (and output) with the increased production cost was modeled as a Walrasian auctioneer. The auctioneer calls out a market price for each product (chlorine and sodium hydroxide) and evaluates the reactions by all participants (producers and consumers in both markets), comparing total quantities supplied and demanded to determine the next price that will guide the market closer to equilibrium (i.e., where market supply equals market demand). Decision rules are established to ensure that the process will converge to an equilibrium, in addition to specifying the conditions for equilibrium. The result of this approach is prices with the proposed regulation that equilibrate supply and demand for each product.

The algorithm for deriving the post-compliance equilibria in all markets can be generalized to five recursive steps:

1. Impose the control costs on each directly affected facility, thereby affecting their supply decisions for chlorine and sodium hydroxide.

2. Recalculate the market supply for both chlorine and sodium hydroxide.

3. Determine the new prices in both markets via the price revision rule.

4. Recalculate the supply functions of all suppliers with the new prices in both markets, resulting in a new market supply of chlorine and sodium hydroxide. Evaluate market demand at the new prices in both markets.

5. Compare market supply and market demand in both markets. If different, return to Step #3, resulting in new prices for chlorine and sodium hydroxide. Repeat until equilibrium conditions are satisfied (i.e., the difference between supply and demand is arbitrarily small in both markets).

D.1 Concentrated Chlorine Market and Competitive Sodium hydroxide Market

Similar to the competitive case, facility responses and market adjustments can be conceptualized as an interactive feedback process. Facilities face increased production costs due to compliance, which causes facility-specific production responses (i.e., output reduction). The cumulative effect of these responses leads to an increase in the market price that all producers (directly affected and indirectly affected) and consumers face. This increase leads to further responses by all producers and consumers and, thus, new market prices. The new with-regulation equilibrium is the result of a series of these iterations between producer and consumer responses and market adjustments until a stable market price equilibrium is reached in which total market supply equals total market demand (i.e., $Q_s = Q_d$).

The process for determining equilibrium price (and output) with the increased production cost is modeled somewhat differently. The algorithm for deriving the post-compliance equilibria in all markets can be generalized to five recursive steps:

1. Choose a level of aggregate demand in the chlorine market that is smaller than current aggregate demand.

2. Use the demand curve to calculate the associated price of chlorine; use the price revision rule to calculate a new price for sodium hydroxide.

3. For each firm, use the market price of chlorine and aggregate demand quantity for chlorine to determine marginal revenue according to Eq. (B.1). Set marginal cost (including compliance costs) equal to marginal revenue for chlorine to compute a firm-specific quantity of chlorine and sodium hydroxide.

4. Sum the firm-specific quantities to compute aggregate supply of chlorine and sodium hydroxide.

5. Compare aggregate supply of chlorine to aggregate demand for chlorine; compare the aggregate supply of sodium hydroxide to aggregate demand for sodium hydroxide at that price; if either is unequal repeat the process starting in Step 1 by revising aggregate demand for chlorine.

Appendix E

Estimating Changes in Economic Welfare with Regulation

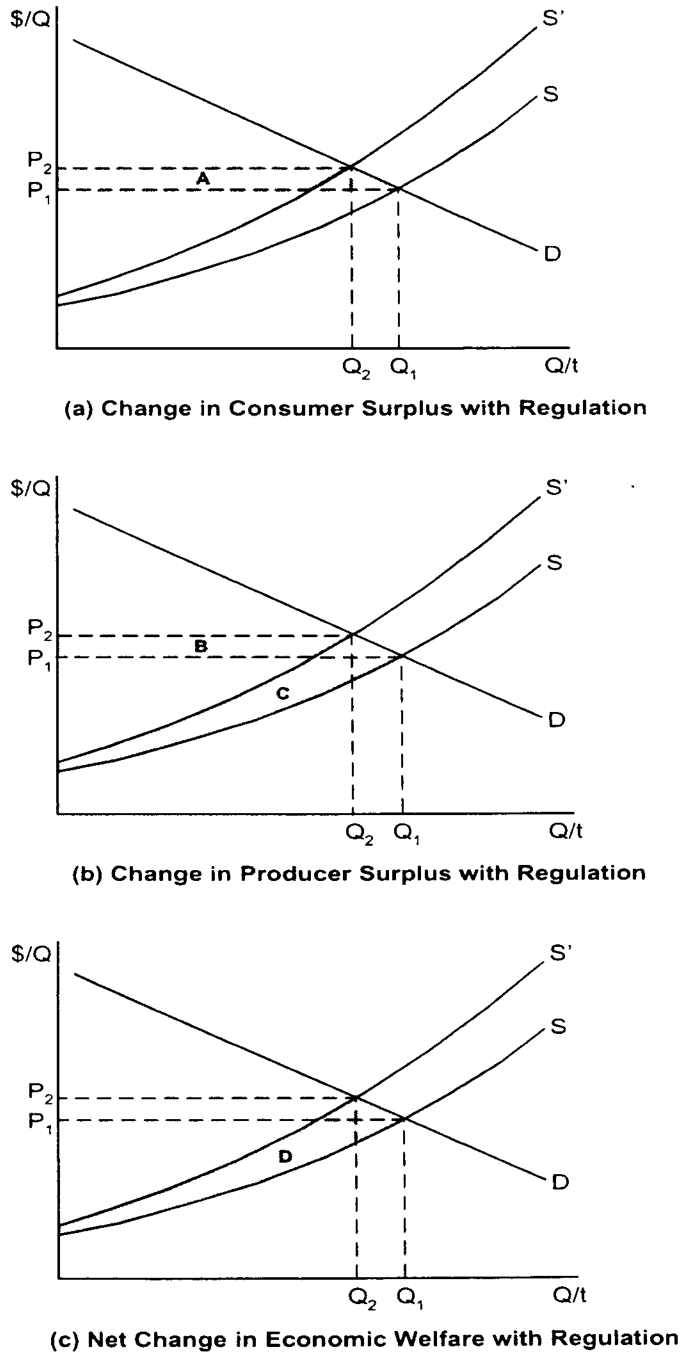
E.1 Social Cost Effects Under Perfect Competition

The economic welfare implications of the market price and output changes with the regulation can be examined using two slightly different tactics, each giving a somewhat different insight but the same implications: (1) changes in the net benefits of consumers and producers based on the price changes and (2) changes in the total benefits and costs of these products based on the quantity changes. This analysis focuses on the first measure—the changes in the net benefits of consumers and producers. Figure E-1 depicts the change in economic welfare in a competitive market by first measuring the change in consumer surplus and then the change in producer surplus. In essence, the demand and supply curves previously used as predictive devices are now being used as a valuation tool.

This method of estimating the change in economic welfare with the regulation divides society into consumers and producers. In a market environment, consumers and producers of the good or service derive welfare from a market transaction. The difference between the maximum price consumers are willing to pay for a good and the price they actually pay is referred to as "consumer surplus." Consumer surplus is measured as the area under the demand curve and above the price of the product. Similarly, the difference between the minimum price producers are willing to accept for a good and the price they actually receive is referred to as "producer surplus" or profits. Producer surplus is measured as the area above the supply curve and below the price of the product. These areas can be thought of as consumers' net benefits of consumption and producers' net benefits of production, respectively.

In Figure E-1, baseline equilibrium in the competitive market occurs at the intersection of the demand curve, D, and supply curve, S. Price is P_1 with quantity Q_1. The increased cost of production with the regulation will cause the market supply curve to shift upward to S′. The new equilibrium price of the product is P_2. With a higher price for the product, there is less consumer welfare, all else being unchanged as real incomes are reduced. In Figure E-1(a), area A represents the dollar value of the annual net loss in consumers' benefits with the increased price. The rectangular portion represents the loss in consumer surplus on the quantity still consumed, Q_2, while the triangular area represents the foregone surplus resulting from the reduced quantity consumed, Q_1–Q_2.

In addition to the changes in consumer welfare, producer welfare also changes with the regulation. With the increase in market price, producers receive higher revenues on the quantity still



(a) Change in Consumer Surplus with Regulation

(b) Change in Producer Surplus with Regulation

(c) Net Change in Economic Welfare with Regulation

Figure E-1. Economic Welfare Changes with Regulation: Perfect Competition

purchased, Q_2. In Figure E-1(b), area B represents the increase in revenues due to this increase in price. The difference in the area under the supply curve up to the original market price, area C, measures the loss in producer surplus, which includes the loss associated with the quantity no longer produced. The net change in producer welfare is represented by area B–C.

The change in economic welfare attributable to the compliance costs of the regulation is the sum of consumer and producer surplus changes, that is, – (A) + (B–C). Figure E-1(c) shows the net (negative) change in economic welfare associated with the regulation as area D. However, this analysis does not include the benefits that occur outside the market (i.e., the value of the reduced levels of air pollution with the regulation). Including this benefit will reduce the net cost of the regulation, and may result in overall net positive benefits to society.

E.2 Social Cost Effects Under a Imperfect Competition[1]

The conceptual framework for evaluating social costs and distributive impacts in a concentrated market model is illustrated in Figure E-2. The baseline equilibrium is given by the price, P_0, and the quantity, Q_0. In a pure monopoly situation, the baseline equilibrium is determined by the intersection of the marginal revenue curve (MR) and the MC curve. In imperfect competition, such as in the Cournot model used in this analysis, the baseline equilibrium is determined by the intersection of MC with some fraction of MR. Without the regulation, the total benefits of consuming the chlorine product is given by the area under the demand curve up to Q_0. This equals the area filled by the letters ABCDEFGHIJ. The total variable cost to society of producing Q_0 equals the area under the original MC function, given by IJ. Thus, the total social surplus to society from the production and consumption of output level Q_0 equals the total benefits minus the total costs, or the area filled by the letters ABCDEFGH.

The total social surplus value can be divided into producer surplus and consumer surplus. Producer surplus accrues to the suppliers of the product and reflects the value they receive in the market for the Q_0 units of output less what it costs to produce this amount. The market value of the product is given by the area DEFGHIJ in Figure E-2. Since production

[1]The Agency has developed this conceptual approach in a previous economic analysis of regulations affecting the pharmaceutical industry (EPA, 1996).

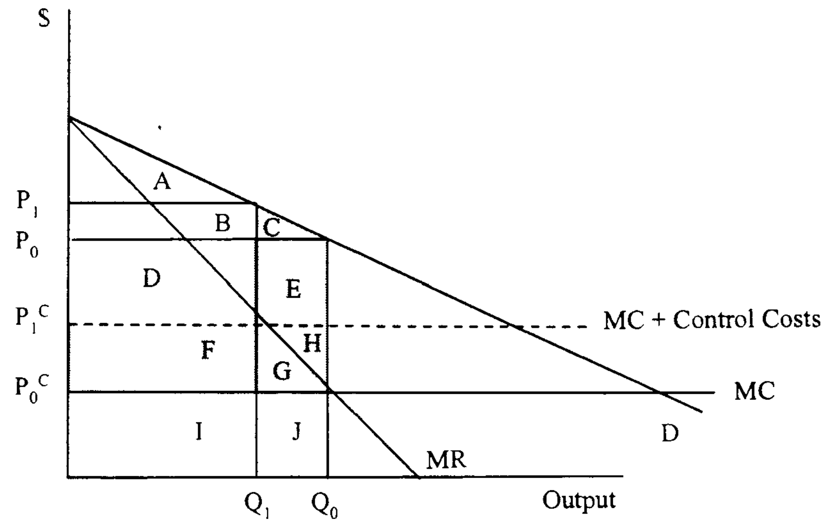


Figure E-2. Economic Welfare Changes with Regulation: Imperfect Competition

costs IJ, producer surplus is given by area DEFGH. Consumer surplus accrues to the consumers of the product and reflects the value they place on consumption (the total benefits of consumption) less what they must pay on the market. Consumer surplus is thereby given by the area ABC.

The with-regulation equilibrium is P_1, Q_1. Total benefits of consumption are ABDFI and the total variable costs of production are FI, yielding a with-regulation social surplus of ABD.[2] Area BD represents the new producer surplus and A is the new consumer surplus. The social cost of the regulation equals the total change in social surplus caused by the regulation. Thus, the social cost is represented by the area FGHEC in Figure E-2.

The distributive effects are estimated by separating the social cost into producer surplus and consumer surplus losses. First, the change in producer surplus is given by

$$\Delta PS = B - F - (G+H+E) \qquad (E.1)$$

[2]Fixed control costs are ignored in this example but are included in the analysis.

Producers gain B from the increase in price, but lose F from the increase in production costs due to regulatory control costs. Furthermore, the contraction of output leads to foregone baseline profits of G+H+E.

The change in consumer surplus is

$$\Delta CS = -(B + C) \tag{E.2}$$

This reflects the fact that consumer surplus shrinks from the without-regulation value of ABC to the with-regulation value of A.

The social cost or total change in social surplus shown earlier can then be derived simply by adding the changes in producer and consumer surplus together

$$\Delta SC = \Delta PS + \Delta CS = -(F + G + H + E + C) \tag{E.3}$$

E.3 Comparison of Social Cost with Control Cost

It is important to compare this estimate of social costs to the initial estimate of baseline control costs and explain the difference between the two numbers. The baseline control cost estimate is given by the area FGH, which is simply the constant cost per unit times the baseline output level. In the case of imperfect competition, the social cost estimate exceeds the baseline control cost estimate by the area EC. In other words, the baseline control cost estimate understates the social costs of the regulation. A comparison with the outcome under perfect competition helps illustrate the relationship between control cost and total social cost.

Suppose that the MR curve in Figure E-2 were the demand function for a competitive market, rather than the marginal revenue function for a monopolistic producer. Similarly, let the MC function be the aggregate supply function for all producers in the market. The market equilibrium is still determined at the intersection of MC and MR, but given our revised interpretation of MR as the competitive demand function, the without-regulation (competitive) market price, P_0^C, equals MC and Q_0 is now interpreted as the competitive level of product demand. In this type of market structure, all social surplus goes to the consumer. This is because producers receive a price that just covers their costs of production.

In the with-regulation perfectly competitive equilibrium, price would rise by the per-unit control cost amount to P_1^c. Now the social cost of the regulation is given entirely by the loss in consumer surplus, area FG. As this is compared to the initial estimate of regulatory control costs, FGH, the control cost estimate overstates the social cost of the regulation. The overstatement is due to the fact that the baseline control cost estimates are calibrated to baseline output levels. With regulation, output is projected at Q_1, so that control costs are given by area F. Area G represents a monetary value from lost consumer utility due to the reduced consumption, also referred to as deadweight loss (analogous to area C under the monopolistic competition scenario).

Social cost effects are larger with monopolistic market structures because the regulation already exacerbates a social inefficiency (Baumol and Oates, 1988). The inefficiency relates to the fact that the market produces too little output from a social welfare perspective. In the monopolistic equilibrium, the marginal value society (consumers) places on the product, the market price, exceeds the marginal cost to society (producers) of producing the product. Thus, social welfare would be improved by increasing the quantity of the good provided. However, the producer has no incentive to do this because the marginal revenue effects of lowering the price and increasing quantity demanded is lower than the marginal cost of the extra units. The Office of Management and Budget (OMB) explicitly mentions the need to consider these market power-related welfare costs in evaluating regulations under Executive Order 12866 (Executive Office of the President, 1996).

E.4 Total Social Costs in the Chlorine and Sodium Hydroxide Markets

In the chlorine and sodium hydroxide markets the Agency calculated total social costs as the sum of the social costs in the merchant chlorine market, the captive chlorine market, and the merchant sodium hydroxide market. Social costs were calculated under the assumption of both a perfectly competitive merchant chlorine and an imperfectly competitive chlorine market.

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1 REPORT NO EPA-452/R-01-002	2	3 RECIPIENT'S ACCESSION NO

4 TITLE AND SUBTITLE
Economic Impact Analysis for the Proposed Mercury Cell Chlor-Alkali Production NESHAP

5 REPORT DATE
December 2000

6 PERFORMING ORGANIZATION CODE

7 AUTHOR(S)

8 PERFORMING ORGANIZATION REPORT NO.

9 PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Strategies and Standards Division
Research Triangle Park, NC 27711

10 PROGRAM ELEMENT NO

11. CONTRACT/GRANT NO.
None

12 SPONSORING AGENCY NAME AND ADDRESS
Director
Office of Air Quality Planning and Standards
Office of Air and Radiation
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

13 TYPE OF REPORT AND PERIOD COVERED
Proposed Regulation

14 SPONSORING AGENCY CODE
EPA/200/04

15 SUPPLEMENTARY NOTES

16 ABSTRACT
Pursuant to Section 112 of the Clean Air Act, the U.S. Environmental Protection Agency (EPA) is developing a National Emissions Standard for Hazardous Air Pollutants (NESHAP) to control emissions released from chlorine production at mercury cell chlor-alkali facilities. Of the 43 facilities EPA identified as engaging in the production of chlorine, there are 12 facilities that use the mercury cell process. Eleven of these 12 mercury cell process facilities face positive costs of complying with this regulation.

The total annual costs of meeting the MACT standards for these facilities is $1.46 million. The economic impacts of this regulation were examined using two models: a competitive market model and an oligopoly market model. The price of chlorine and its co-product sodium hydroxide is expected to increase by less than 0.01% using either market model. Impacts on quantity produced of both chlorine and sodium hydroxide are of similar magnitude.

The 43 chlorine manufacturing facilities are owned by 21 companies, six of which are considered small based on the Small Business Administration's definitions for small businesses. A small business screening level analysis was conducted to determine if this regulation would have a significant impact on a substantial number of small businesses. An examination of the compliance costs-to-sales ratios of 21 companies shows that costs are expected to be less than 1 percent of company revenues, thus this regulation is not anticipated to have a significant economic impact on companies owing mercury cell chlor-alkali production plants.

17 KEY WORDS AND DOCUMENT ANALYSIS

a DESCRIPTORS	b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
	Air Pollution control, environmental regulation, economic impact analysis, chlor-alkali, chlorine, sodium hydroxide, mercury cell	

18 DISTRIBUTION STATEMENT	19. SECURITY CLASS *(Report)*	21 NO OF PAGES
Release Unlimited	Unclassified	92
	20 SECURITY CLASS *(Page)* Unclassified	22 PRICE